

Francisco Rebelo  
Marcelo M. Soares *Editors*

# Advances in Ergonomics in Design

Proceedings of the AHFE 2019 International  
Conference on Ergonomics in Design,  
July 24–28, 2019, Washington D.C., USA

# **Advances in Intelligent Systems and Computing**

Volume 955

## **Series Editor**

Janusz Kacprzyk, Systems Research Institute, Polish Academy of Sciences,  
Warsaw, Poland

## **Advisory Editors**

Nikhil R. Pal, Indian Statistical Institute, Kolkata, India

Rafael Bello Perez, Faculty of Mathematics, Physics and Computing,  
Universidad Central de Las Villas, Santa Clara, Cuba

Emilio S. Corchado, University of Salamanca, Salamanca, Spain

Hani Hagras, School of Computer Science & Electronic Engineering,  
University of Essex, Colchester, UK

László T. Kóczy, Department of Automation, Széchenyi István University,  
Gyor, Hungary

Vladik Kreinovich, Department of Computer Science, University of Texas  
at El Paso, El Paso, TX, USA

Chin-Teng Lin, Department of Electrical Engineering, National Chiao  
Tung University, Hsinchu, Taiwan

Jie Lu, Faculty of Engineering and Information Technology,  
University of Technology Sydney, Sydney, NSW, Australia

Patricia Melin, Graduate Program of Computer Science, Tijuana Institute  
of Technology, Tijuana, Mexico

Nadia Nedjah, Department of Electronics Engineering, University of Rio de Janeiro,  
Rio de Janeiro, Brazil

Ngoc Thanh Nguyen, Faculty of Computer Science and Management,  
Wrocław University of Technology, Wrocław, Poland

Jun Wang, Department of Mechanical and Automation Engineering,  
The Chinese University of Hong Kong, Shatin, Hong Kong



The series “Advances in Intelligent Systems and Computing” contains publications on theory, applications, and design methods of Intelligent Systems and Intelligent Computing. Virtually all disciplines such as engineering, natural sciences, computer and information science, ICT, economics, business, e-commerce, environment, healthcare, life science are covered. The list of topics spans all the areas of modern intelligent systems and computing such as: computational intelligence, soft computing including neural networks, fuzzy systems, evolutionary computing and the fusion of these paradigms, social intelligence, ambient intelligence, computational neuroscience, artificial life, virtual worlds and society, cognitive science and systems, Perception and Vision, DNA and immune based systems, self-organizing and adaptive systems, e-Learning and teaching, human-centered and human-centric computing, recommender systems, intelligent control, robotics and mechatronics including human-machine teaming, knowledge-based paradigms, learning paradigms, machine ethics, intelligent data analysis, knowledge management, intelligent agents, intelligent decision making and support, intelligent network security, trust management, interactive entertainment, Web intelligence and multimedia.

The publications within “Advances in Intelligent Systems and Computing” are primarily proceedings of important conferences, symposia and congresses. They cover significant recent developments in the field, both of a foundational and applicable character. An important characteristic feature of the series is the short publication time and world-wide distribution. This permits a rapid and broad dissemination of research results.

**\*\* Indexing: The books of this series are submitted to ISI Proceedings, EI-Compendex, DBLP, SCOPUS, Google Scholar and Springerlink \*\***

More information about this series at <http://www.springer.com/series/11156>

Francisco Rebelo · Marcelo M. Soares  
Editors

# Advances in Ergonomics in Design

Proceedings of the AHFE 2019 International  
Conference on Ergonomics in Design,  
July 24–28, 2019, Washington D.C., USA

*Editors*

Francisco Rebelo  
Faculdade de Arquitetura  
Universidade de Lisboa  
Lisbon, Portugal

Marcelo M. Soares  
School of Design  
Hunan University  
Changsha, Hunan, China

ISSN 2194-5357

ISSN 2194-5365 (electronic)

Advances in Intelligent Systems and Computing

ISBN 978-3-030-20226-2

ISBN 978-3-030-20227-9 (eBook)

<https://doi.org/10.1007/978-3-030-20227-9>

© Springer Nature Switzerland AG 2020

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG  
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

# Advances in Human Factors and Ergonomics 2019

AHFE 2019 Series Editors

Tareq Ahram, Florida, USA

Waldemar Karwowski, Florida, USA



10th International Conference on Applied Human Factors and Ergonomics and the  
Affiliated Conferences

Proceedings of the AHFE 2019 International Conference on Ergonomics in Design,  
held on July 24–28, 2019, in Washington D.C., USA

Advances in Affective and Pleasurable Design	Shuichi Fukuda
Advances in Neuroergonomics and Cognitive Engineering	Hasan Ayaz
Advances in Design for Inclusion	Giuseppe Di Bucchianico
Advances in Ergonomics in Design	Francisco Rebelo and Marcelo M. Soares
Advances in Human Error, Reliability, Resilience, and Performance	Ronald L. Boring
Advances in Human Factors and Ergonomics in Healthcare and Medical Devices	Nancy J. Lightner and Jay Kalra
Advances in Human Factors and Simulation	Daniel N. Cassenti
Advances in Human Factors and Systems Interaction	Isabel L. Nunes
Advances in Human Factors in Cybersecurity	Tareq Ahram and Waldemar Karwowski
Advances in Human Factors, Business Management and Leadership	Jussi Ilari Kantola and Salman Nazir
Advances in Human Factors in Robots and Unmanned Systems	Jessie Chen
Advances in Human Factors in Training, Education, and Learning Sciences	Waldemar Karwowski, Tareq Ahram and Salman Nazir
Advances in Human Factors of Transportation	Neville Stanton

(continued)

(continued)

Advances in Artificial Intelligence, Software and Systems Engineering	Tareq Ahram
Advances in Human Factors in Architecture, Sustainable Urban Planning and Infrastructure	Jerzy Charytonowicz and Christianne Falcão
Advances in Physical Ergonomics and Human Factors	Ravindra S. Goonetilleke and Waldemar Karwowski
Advances in Interdisciplinary Practice in Industrial Design	Cliff Sungsoo Shin
Advances in Safety Management and Human Factors	Pedro M. Arezes
Advances in Social and Occupational Ergonomics	Richard H. M. Goossens and Atsuo Murata
Advances in Manufacturing, Production Management and Process Control	Waldemar Karwowski, Stefan Trzcielinski and Beata Mrugalska
Advances in Usability and User Experience	Tareq Ahram and Christianne Falcão
Advances in Human Factors in Wearable Technologies and Game Design	Tareq Ahram
Advances in Human Factors in Communication of Design	Amic G. Ho
Advances in Additive Manufacturing, Modeling Systems and 3D Prototyping	Massimo Di Nicolantonio, Emilio Rossi and Thomas Alexander

# Preface

Successful interaction with products, tools and technologies depends on usable designs and accommodating the needs of potential users without requiring costly training. In this context, this book is concerned with emerging ergonomics in design concepts, theories and applications of human factors knowledge focusing on the discovery, design and understanding of human interaction and usability issues with products and systems for their improvement.

This book will be of special value to a large variety of professionals, researchers and students in the broad field of human modeling and performance who are interested in feedback of devices' interfaces (visual and haptic), virtual reality, user-centered design, design for special populations, particularly the elderly and assistive technology. We hope this book is informative, but even more that it is thought provoking. We hope it inspires, leading the reader to contemplate other questions, applications and potential solutions in creating good designs for all.

The book is organized into seven sections focusing on the following subject matters: *design methods, user interfaces and interaction design, information, design and visualization virtual reality and digital environments in design, cultural aspects in design and city planning*

In the sections that cover design methods, user interfaces and interaction design, the focus goes to the limits and capabilities. Generally, the effect of changes in force and kinematics, physiology, cognitive performance, design of consumer products, tools and workplaces is discussed. The sections that cover virtual reality and digital environment, product and design evaluation and sustainable design employ a variety of research methods and user-centered evaluation approaches, for developing products that can improve safety and human performance and at the same time the efficiency of the system. Usability evaluations are reported for different kinds of products and technologies.

*Section 1 Design methods, user interfaces and interaction design*

*Section 2 Design and user involvement*

*Section 3 Information, design and visualization*

*Section 4 Virtual reality*

*Section 5 Product and system design*

*Section 6 Cultural aspects in design and city planning*

*Section 7 Design applications*

This book will be of special value to a large variety of professionals, researchers and students in the broad field of human performance who are interested in feedback of devices' interfaces (visual and haptic), user-centered design and design for special populations, particularly the elderly. We hope this book is informative, but even more that it is thought provoking. We hope it inspires, leading the reader to contemplate other questions, applications and potential solutions in creating good designs for all.

We would like to thank Editorial Board Members for their contributions.

Pedro Arezes, Portugal  
Amilton Arruda, Brazil  
Erminia Attaianese, Italy  
Eric Brangier, France  
Ralph Bruder, Germany  
Marcelo Cairrão, Brazil  
José Juan Canãs, Spain  
Miguel Carvalho, Portugal  
F. M. da Silva, Portugal  
J. C. P. da Silva, Brazil  
Emilia Duarte, Portugal  
José Pinto Duarte, Portugal  
E. Filgueiras, Portugal  
M. Goebel, South Africa  
Sougata Karmakar, India  
L. B. Macedo, Brazil  
Daniel Raposo Martins, Portugal  
Beata Mrugalska, Poland  
Mitsuo Nagamachi, Japan  
Andre Neves, Brazil  
P. Noriega, Portugal  
M. L. L. R. Okimoto, Brazil  
L. Paschoarelli, Brazil  
L. Prado, Mexico  
Pradip Kumar Ray, India  
Sarbjit Singh, India  
Peeyush Soni, Thailand  
Steve Summerskill, UK  
Ming Sun, USA

Patel Thaneswer, India  
Bruce Thomas, the Netherlands  
Steve Ward, Australia  
T. Yamaoka, Japan

July 2019

Francisco Rebelo  
Marcelo M. Soares



# Contents

<b>Design Methods, User Interfaces and Interaction Design</b>	
<b>The Role of Design in Technology Driven Ergonomics Product Development . . . . .</b>	<b>3</b>
Byungsoo Kim and Sharon Joines	
<b>Teenagers Postural Effects Through Videogames Therapeutic Approach . . . . .</b>	<b>15</b>
Ernesto Filgueiras, Gustavo Desouzart, and Ana Silva	
<b>Eye-Tracking Examination of the Anthropological Race, Gender and Verbal-Pictorial Relative Positions on Ergonomics of Visual Information Presentation . . . . .</b>	<b>23</b>
Rafał Michalski and Joanna Koszela-Kulińska	
<b>How to Read Red: Red in Western Culture (Part II) . . . . .</b>	<b>35</b>
Leonor Ferrão	
<b>Contribution of Visual Ergonomics to a Holistic View of the Symbols Applied in Touristic and Cultural Signage: The Portuguese Case . . . . .</b>	<b>48</b>
João Neves, Fernando Moreira da Silva, Daniel Raposo, and José Silva	
<b>Design, Objects and Memory: A Sustainability-Oriented Project Itinerary . . . . .</b>	<b>57</b>
Myrla Lopes Torres, Paulo Maldonado, and Leonor Ferrão	
<b>Effectiveness of Coach Marks or Instructional Overlay in Smartphone Apps Interfaces . . . . .</b>	<b>68</b>
Paulo Noriega, Diana Carvalho, Igor Correia, Jose Luís Alves, Tiago Oliveira, and Francisco Rebelo	
<b>Communication Design as Tool for Social Transformation: A Co-design Project with the Residents of the Rego Neighborhood, in Lisbon . . . . .</b>	<b>79</b>
Teresa Olazabal Cabral and Inês Farmhouse Coimbra	

<b>The Brand Mark Competitors Map as Visual Research Tool. Using Graphic and Symbolic Data in the Brand Visual Identity Project . . . . .</b>	<b>91</b>
Daniel Raposo, Rogério Ribeiro, Mariana Amaral, Fernando Moreira da Silva, and Juan Ramón Martín Sanromán	
<b>Boundary Dimension Design of Graphical Symbols Based on User Preference . . . . .</b>	<b>103</b>
Zhongting Wang, Ling Luo, Linghua Ran, and Liang Zhang	
<b>An Ergonomic Assessment on the Detectability Design of the New Generation Currency (NGC) Coin Series and Bangko Sentral ng Pilipinas (BSP) Coin Series . . . . .</b>	<b>110</b>
Diane Denise Francisco, Patricia Michaela C. Gregorio, Ninna Ysabel G. Layug, and Nikole Andrei B. Mallare	
<b>Research on Optimization of Information Coding for Car Dashboard Based on Eye Movement Analysis . . . . .</b>	<b>122</b>
Guilei Sun, Qin Li, Yanhua Meng, and Linghua Ran	
<b>Brand Identity in Motion. Structural Models of Brand Identity on TV Opening Credits . . . . .</b>	<b>136</b>
João Brandão, Ricardo Maia Pestana, and Daniel Raposo	
<b>Human Factors Engineering Research on Folding Umbrellas Design . . .</b>	<b>147</b>
Xiaohan Zhou and Xiaoping Hu	
<b>Effects of Screen Brightness on Visual Performance Under Different Environments . . . . .</b>	<b>155</b>
Qi Tian, Linghua Ran, Cancan Zhao, Zihan Zhou, and Haimei Wu	
<b>Study on the Effect of Key-to-Key Distance on Touch-Sensitive Key Operation . . . . .</b>	<b>164</b>
Xiaoli Fan, Huimin Hu, Chaoyi Zhao, and Wei Zhang	
<b>Research on Standardization of Public Information Guidance Systems for Railway Stations . . . . .</b>	<b>177</b>
Chuan-yu Zou, Yongquan Chen, and Ziding Chen	
<b>Methodology of Analysis of Brand Visual Identity of Food Products: Comprehension and Valuation of Graphic Signs . . . . .</b>	<b>188</b>
Daniel Raposo, Catarina Laginha, João Neves, José Silva, and Fernando Moreira da Silva	
<b>Design and User Involvement</b>	
<b>Evaluation of the Concept of a Smart City Gamification from a User Centered Design Perspective . . . . .</b>	<b>207</b>
Francisco Rebelo, Paulo Noriega, and Tiago Oliveira	

<b>Natural Human-Computer Interfaces’ Paradigm and Cognitive Ergonomics</b> .....	220
Victor M. Almeida, Sónia Rafael, and Marco Neves	
<b>Grains of Memory: User Experience in the SandBox Interactive Installation</b> .....	228
Adriana Moreno, Arminda Guerra Lopes, and Mónica Mendes	
<b>Measure of the Lived and Functional Effects of Gamification: An Experimental Study in a Professional Context</b> .....	242
Eric Brangier and Cathie Marache-Francisco	
<b>Comparative Analysis of Body Measurement and Morphology Between Subjects with Different Body Mass Index</b> .....	254
Caelen Teger da Silva, Maria Lúcia Leite Ribeiro Okimoto, Dominique Leite Adam, and Kelli C. A. S. Smythe	
<b>A New Tool for Cognitive Workload Assessment in System Design Prototypes</b> .....	263
Pedro Mendonça and Manuel Adler Abreu	
<b>Research on Human-Computer Interaction Design of Bed Rehabilitation Equipment for the Elderly</b> .....	275
Zhijuan Zhu, Wenzhen Pan, Xin Ai, and Renjun Zhen	
<b>Visual Storytelling - Creative Strategy of Visual Clues Promoted by Archetypal Images</b> .....	287
Jose Silva, Daniel Raposo, João Neves, and Fernando Moreira da Silva	
<b>Review of the Research on Car Seating Comfort</b> .....	296
Xiaoli Fan, Chaoyi Zhao, Xuemei Chen, Yuwei Jiang, Yongjia Shen, and Tong Shen	
<b>Ergonomics Assessment Criteria as a Way to Improve the Quality and Safety of People’s Transport in Underground Coal Mines</b> .....	305
Jarosław Tokarczyk, Dariusz Michalak, Magdalena Rozmus, Kamil Szewerda, Leszek Żyrek, and Gregor Źeleznik	
<b>Development of an Ergonomically Designed Backpacks for Junior High School Students</b> .....	318
Emmanuel Oliver D. C. Porciuncula, Leonard T. Aquino, Daniel G. Araneta, Jeremiah V. Austria, Briant Angelo M. Censon, John Michael A. Cruz, Patrick Henry S. Fernandez, Kent Xaivery L. Moreno, Joshua M. Ng, Genhino Glenn D. C. Reyes, Aroma M. Santillan, and Wendel Jimver De Guia	

**A Study on the Correlation of Head and Face Data of Chinese Adults** . . . . . 325  
Linghua Ran, Chaoyi Zhao, Hong Luo, Xin Zhang, Taijie Liu, Huimin Hu, Zhongting Wang, Nicole Sator, Erika Siebert-Cole, and Peter Straßer

**Directions Towards Sustainability Through Higher Education** . . . . . 334  
Theresa Lobo

**Information, Design and Visualization**

**Water Museums and Digital Media: Two Case Studies on Digital Media in Water Museums** . . . . . 349  
Joana Lessa

**A Human-Computer Interaction Framework for Interface Analysis and Design** . . . . . 359  
Sónia Rafael, Victor M. Almeida, and Marco Neves

**Collaboration: Critical Roles of Academia-Business Partnerships and Challenges the Workforce Must Face** . . . . . 370  
Sara Antunes and Rita Almendra

**The ‘Place’ that Shows the Title of a TV Series: What to Name It and How It Has Evolved** . . . . . 383  
Ricardo Maia Pestana and João Brandão

**Communication Design and Medical Procedures: Inform Citizens to Act in Emergency Situations** . . . . . 394  
Marco Neves and Ana Rafaela Poças

**Color and Interaction in Journalistic Infographics: The Case of Online Portuguese Media** . . . . . 404  
Salomé Esteves and Marco Neves

**Information Design in Presentation, Interpretation and Dissemination of Natural and Cultural Heritage** . . . . . 413  
Cristina Santos, Maria João Pereira Neto, and Marco Neves

**Virtual Reality**

**Evaluation of Behavioral Compliance with Safety Warnings at Different Levels of Cognitive Load in Warehouses** . . . . . 427  
Ana Almeida, Francisco Rebelo, and Paulo Noriega

**Locomotion-in-Place and Teleport: Which Is the Best Technique to Be Used in Human Behavior Research Using Virtual Reality?** . . . . . 436  
Inês Galrão, Francisco Rebelo, and Paulo Noriega

<b>Openness Feeling on Height Direction in High Ceiling Room and Bending Pattern of Leading Passage . . . . .</b>	<b>446</b>
Takuya Sugiyama and Yohsuke Yoshioka	
<b>Exploratory Study to Investigate the Influence of a Third Person on an Individual Emergency Wayfinding Decision . . . . .</b>	<b>452</b>
Elisângela Vilar, Paulo Noriega, Francisco Rebelo, Inês Galvão, Daniel Semedo, and Nuno Graça	
<b>How Deep Is a Virtual Reality Experience? Virtual Environments, Emotions and Physiological Measures . . . . .</b>	<b>462</b>
Tiago Oliveira, Paulo Noriega, José Carvalhais, Francisco Rebelo, and Vanessa Lameira	
<b>Emotion Through Narrative: Validation for User Engagement in Game Context . . . . .</b>	<b>472</b>
Yanick Trindade, Francisco Rebelo, and Paulo Noriega	
<b>Product and System Design</b>	
<b>The Importance of Ergonomics in the Development of Sustainable Materials Applied to Footwear Design . . . . .</b>	<b>485</b>
Ana Margarida Fernandes	
<b>Effect of Body Weight of Wheelchair Care Recipient on Physical Activity Intensity of Assistant Person . . . . .</b>	<b>494</b>
Haruka Sugiyama, Yohsuke Yoshioka, Masaki Takahashi, Cheng Jiayu, Mitsunaki Shiraishi, Fumitake Hakozaiki, Satoshi Kamenon, Yoshihide Tokuda, and Ken Nunota	
<b>Research on Body Pressure Distribution of Mattress for Different Genders . . . . .</b>	<b>502</b>
Huimin Hu, Mengjing Cai, Pu Hong, Yinxia Li, Ling Luo, and Haimei Wu	
<b>Universal Design for Enhancing Accessibility of the Visually Impaired in Touristic Environments . . . . .</b>	<b>514</b>
Carlos Arce-Lopera, Juan Jimenez Garcia, Camilo Montoya, and Jose Giraldo	
<b>Toothbrush Innovation Design Based on Man-Machine Engineering Research . . . . .</b>	<b>522</b>
Peng Han	
<b>Study on the Influence of BMI Difference on Pressure Distribution of Mattress . . . . .</b>	<b>531</b>
Huimin Hu, Pu Hong, Mengjing Cai, Yinxia Li, Hong Luo, and Haimei Wu	

**A JACK-Based Ergonomic Analysis and Design of the Cockpit of Agricultural Material Handling Vehicle . . . . . 538**  
Sen Gu, Sheng Su, Cheng Huang, Zhiqiang Song, and Shasha Yuan

**Research on Comfort of Mattresses with Different Hardness Based on Body Pressure Distribution . . . . . 551**  
Huimin Hu, Pu Hong, Mengjing Cai, Hong Luo, and Haimei Wu

**Cultural Aspects in Design and City Planning**

**Built Environment Preservation: A Process of Ergonomic Design . . . . . 563**  
Conceição Trigueiros and Mario Saleiro Filho

**Lighting Design at Workplaces: What Should Be the Concerns for an Architect? . . . . . 571**  
Sandra Preto

**Design for the Model of Shared Office Space Based on the Logic of Behavior: A Case Study of Chinese Users . . . . . 584**  
Zhang Ping, Yang Simeng, Liu Tingyu, and Zhang Liang

**The Italic Style: Understanding the Shape Through History . . . . . 597**  
João Aranda Brandão and Catarina Machado Almeida

**Graphic Design and Cinema: Portuguese Movie Posters from the Nouvelle Vague Period . . . . . 609**  
Elisabete Rolo and Maria do Carmo Kattau Lopes

**At Hand, the Brain of Men . . . . . 621**  
Luis Miguel Ginja

**Exploring Design Requirements of Outdoor Fitness Equipment for Young People . . . . . 628**  
Aylin Karadeniz, Melis Dursun, and Gülşen Töre-Yargın

**Design Ergonomics for Human Beings and Wild Animals in Densely Populated Cities: A Design Case in Hong Kong Country Parks. . . . . 640**  
Kin Wai Michael Siu, Yi Lin Wong, and Chi Hang Lo

**Research on Guiding Sign Ergonomic Setting Based on Visual Sensitivity in Long and Narrow Passageway . . . . . 648**  
Ling Luo, Zhongting Wang, Linghua Ran, Chuanyu Zou, and Haimei Wu

**The Application of Ergonomics of the Built Environment in Architectural Projects as a Benefit for the Hearing Impaired . . . . . 656**  
Aline da Silva Oliveira, Renata de Assunção Neves, and Marcelo M. Soares

## Design Applications

<b>A Synthesis of Sociotechnical Principles for System Design</b> . . . . .	665
Amangul A. Imanghaliyeva, Pauline Thompson, Paul Salmon, and Neville A. Stanton	
<b>Cut Me Off: An Exploratory Study About How the User Perceives the Information of Clothes Textile Labels</b> . . . . .	677
Maria Aurileide Ferreira Alves and Gonalo Falco	
<b>Ergonomic Research in Civil Aircraft External Service Design</b> . . . . .	683
Yu Chen	
<b>Design for Children - Ergonomics in a Ceramic Tile’s Project</b> . . . . .	692
Cristina Salvador	
<b>Graphic-Semantic Expressions Map: A New Tool on Design Teaching</b> . . . . .	700
Ctia Rijo	
<b>Research on Ergonomic Design and Evaluation of Office Backrest Curve</b> . . . . .	711
Yumeng Zhang, Ling Luo, Jie Wang, Huimin Hu, and Chaoyi Zhao	
<b>Assessment of Portuguese Firefighters’ Needs: Preliminary Results of a Pilot Study</b> . . . . .	721
Anna S. P. Moraes, Miguel A. F. Carvalho, Rachel S. Boldt, Fernando B. N. Ferreira, Linsey Griffin, and Susan P. Ashdown	
<b>“Possible But Improbable Spaces”: From Interior Design Experience to Jewellery Creation</b> . . . . .	733
Mnica Romozinho	
<b>Service Mapping: Case Study of University Waste Management System</b> . . . . .	742
Flvia Azevedo and Luciana Cruz	
<b>Current Theoretical Developments and Applications of Fitts’ Law: A Literature Review</b> . . . . .	753
Rong Jiang and Zhenyu Gu	
<b>On Girls Bra Design for the Demand of User</b> . . . . .	761
Ding-Bang Luh and Yu-Lin Zhao	
<b>Effects of Playing Surface on Physiological Responses and Performance Variables of Hockey Players</b> . . . . .	769
Ajita D. Singh and Ajay Deswal	
<b>Role of Postural Control Exercises and Pelvic Floor Strengthening Exercises on Chronic Low Back Pain of Women with Sitting Jobs</b> . . . .	775
Ajita Dsingh and Amanpreet Kaur	

<b>The Role of Organizational Factors in Development and Progression of Wrist Disorders: Psychosocial Aspects . . . . .</b>	<b>783</b>
Arunita Paul and Urmi R. Salve	
<b>Developing a Framework that Can Assist Designers to Identify and Incorporate Notable Cultural Elements into Products Designed for Tourists . . . . .</b>	<b>794</b>
Wanrisa Bok Kharkongor and Debkumar Chakrabarti	
<b>Design Interventions of an Exergame for Fall Problem in Indian Older Adults. . . . .</b>	<b>805</b>
Nilakshi Yein and Swati Pal	
<b>A Re-look into the Information in Multimedia Design and Animation Theme Presentation . . . . .</b>	<b>816</b>
Manoj Majhi and Debkumar Chakrabarti	
<b>Author Index. . . . .</b>	<b>823</b>



# **Design Methods, User Interfaces and Interaction Design**



# The Role of Design in Technology Driven Ergonomics Product Development

Byungsoo Kim and Sharon Joines<sup>(✉)</sup>

NC State University, 50 Pullen Road, Raleigh, NC 27695, USA  
{bkim18, sharon\_joiner}@ncsu.edu

**Abstract.** Human Factors and Ergonomics (HFE) have been considered in New Product Development (NPD) to develop solutions that are useable and useful while maintaining productivity. The importance of technology and design has increased at the intersection between NPD and HFE. Developing a new product driven by technology is known as a technology driven approach which can be infused into existing ergonomic product development processes and may result in the development of effective, new and innovative products. The purpose of this study is to instigate design methods and tools that can be applicable to the technology driven NPD process. The literature regarding existing design methods and tools used and potentially utilized in technology driven NPD process has been reviewed in this study. Also, the role of HFE experts in a technology driven NPD process is addressed in the discussion section. In addition, when to use the design methods and tools found in the literature in the front end of the technology driven NPD process is suggested in this paper to help develop new and innovative products.

**Keywords:** New product development · Design thinking methods · Design thinking tools · Technology-driven approach · Innovation · Ergonomic products

## 1 Introduction

Human Factors and Ergonomics (HFE) are traditionally considered in New Product Development (NPD) to anticipate users' activities in order to develop solutions that are useable and useful while maintaining productivity [1]. For instance, ergonomics has been closely related to a User-Centered Design process (UCD) [2] while the UCD approach has been helping to develop new products that have high customer value [3–6]. At the intersection between NPD and HFE, the importance of technology and design has increased [7]. For instance, new or emerging technologies, such as using wearable computer system for users, opened the possibility of improving users' work postures [8]. In addition, adopting advanced technology helped reducing the perceived physical workload in bricklaying [9]. Also, the decreases in the cost of technologies enable the design and development of affordable, ergonomic consumer products such as height adjustable desks. Developing a new product driven by technology is called technology driven approach [6]. Since the technology driven approach is associated with developing discontinuous (innovative) products [10], a technology driven approach infused into

product development processes coupled with ergonomics may result in the development of effective, new and innovative products.

The technology development process and the application of technology in NPD are two different concept [11]. While technology development focuses on developing state of the art technology, the application of technology into the NPD process focuses on developing a competitive and innovative product [11]. The transition from technology to product development is known as technology transfer which happens at the front end of the NPD process [11]. Since innovation grows from technology and related technological research that forms the basis of product evolution [12], successful technology transfer would help developing competitive and innovative products. Since design thinking plays an important role during the early phase of NPD [7], design thinking may be able to aid in technology transfer. While there are many methods and tools to support the customer driven approach to NPD [6], there are relatively few studies regarding methods and tools to support the technology driven NPD process and to aid technology transfer.

The purpose of this study is to investigate design methods and tools that may be applicable to the technology driven NPD process. This paper includes a review of literature across three areas: studies using established design methods and tools; studies documenting the development of methods and tools; and studies documenting the evaluation of methods and tools (in the NPD process or an educational setting). Finally, this paper suggests possible design methods and tools for the technology driven NPD process to help develop new and innovative ergonomic products.

## 2 Methodology

A systematic literature review [13] was conducted to answer the following research questions: (1) what is the role of design in technology driven NPD? and (2) what are the existing the design methods and tools used at the front end of technology-driven NPD process?

To find the literature that is relative, recent, and valid, the inclusion criteria was set prior to conducting the search (see Table 1).

**Table 1.** Criteria for literature inclusion

Type	Inclusion criteria
Topic	Literature must relate directly to one of the research questions
Recency	Literature should have been published between 1998 to 2019
Study target	Literature should relate to higher educational settings (university students) or in practice (professional designers and other experts (e.g. engineers) involved in technology driven NPD process)

(continued)

**Table 1.** (continued)

Type	Inclusion criteria
Research base	<p>Literature must be based on:</p> <ul style="list-style-type: none"> <li>• Empirical research (findings based on actual experience, either qualitative or quantitative) about the existing methods and tools</li> </ul> <p>or</p> <ul style="list-style-type: none"> <li>• Suggestions of methods and tools including: <ul style="list-style-type: none"> <li>– Case study</li> <li>– Theoretical research</li> <li>– Literature review</li> </ul> </li> </ul>
Transparency	The study methodology should be well defined (e.g. procedure, sample sizes, instruments, and analysis)
Reliability/validity	The findings from the literature must be valid and reliable (e.g. the finding and conclusion should be based on the results of the study, cases, and/or other related literature)

Initially online databases were used to find relevant literature in key journals related to design, technology, education. A second phase of the literature review consisted of reviewing the initial articles references, author searches based on the initial journals' author list, and informal searching of internet by topic. The second phase revealed additional related journal articles, conference proceedings and book chapters. The types of literature and sources searched are summarized in Table 2 while search terms are presented in Table 3.

**Table 2.** Types of literature and sources searched.

Type of literature	Source searched or search tool
Key journal articles	<p>Online databases:</p> <ul style="list-style-type: none"> <li>• Web of Science</li> <li>• Science Direct</li> </ul> <p>Scanning the contents of key journals:</p> <ul style="list-style-type: none"> <li>• Ergonomics</li> <li>• Design studies</li> <li>• International Journal of Technology and Design Education</li> <li>• Design and Technology Education</li> <li>• International Journal of Design</li> <li>• Thinking Skills and Creativity</li> </ul>
Additional journal articles, conference proceedings, and book chapters	<ul style="list-style-type: none"> <li>• Google Scholar</li> <li>• Google</li> <li>• Researchgate</li> </ul>

**Table 3.** Search terms

Terms	
Included	Technology driven new product development design; technology forces; technology centric; technology transfer; technology; technology adoption; design process; user centered design; customer experience; tools; methods; higher education; capstone; creativity; innovation skills; innovation; product innovation; breakthrough innovation; radical innovations; front-end innovation; technology integration; inspiration tool; project based curriculum; brainstorming; fuzzy front end; engineering; engineers; new product development; capstone; innovation skills
Excluded	Children; middle school; primary school; elementary school; high school; educational technology; technology education; mathematics; driver

### 3 Findings

Approximately a thousand journal articles between 1998–2019 were found using the aforementioned search terms. After reviewing the ~1000 journal papers based on the inclusion criteria (described in Table 1), only 25 journal articles were found to be related to the research questions. The second phase of the literature review produced 2 conference proceedings, and 2 book chapter. The relevant literature included 22 empirical studies, 6 literature reviews and a case studies for developing framework, methods, and tools. The empirical studies documented several different research methods including: (1) testing the existing methods and tools using surveys and interviews of students during and/or after coursework or workshops, (2) observing the methods and tools being utilized over a long period of time in companies, (3) interviews with domain experts, such as experienced designers and engineers. The literature review (including case studies) covered previous studies or cases which emphasized the role of design and design methods and tools in technology driven NPD. From this, conceptual frameworks were developed while methods and tools to aid or possibly to be utilized to aid technology driven NPD were identified.

The 25 studies were categorized into the following themes: (1) the role of design in technology driven new product development and innovation, (2) the methods and tools to support user involvement at the front end of technology driven new product development, and (3) the methods and tools for innovative idea generation from technology.

#### 3.1 The Role of Design in Technology Driven New Product Development and Innovation

Design helps companies differentiates their products from competitors’ products by improving performance and attractiveness during product development [14].

Technological advances and design have been key enablers for electronic product development [15]. Recent technology based service projects, which includes tangible artifacts, have an emphasis on design [14]. The designer’s role in a technology driven NPD process is to design product features and systems to enhance the user experience of a product, to facilitate discussions regarding how to rapidly generate ideas for

solutions, and to develop the form of the products considering aesthetics and ergonomics [16–19]. Industrial designers interact with engineers to implement the developed design concept into feasible products [20].

Design has supported product innovation in recent years [21]. Design has aided new technology development [21] and product development [22] to achieve product innovation [23, 24]. Open innovation, sharing information in a creative environment with user involvement, has been receiving attention in industry [12]. Designers, with a human centered design emphasis, are well suited to the open innovation approach because of their focus on understanding users/customers' needs; the connection between customers and the design process has been highlighted in the study of innovation [12].

### **3.2 Methods and Tools to Support User Involvement at the Front End of Technology Driven NPD**

Customer involvement in NPD process has been a helpful approach to obtain information from users [3, 4, 22, 25]. Inadequate understanding of customer needs results in the misperception of “engineers' wishes” as “customers' needs” when applying technology in to the front end of product development; this has been revealed as a major factor in the failure of innovations [26]. The strong engagement of customers in the early stages of NPD has been emphasized in order to capture the customers' knowledge and to understand user needs [22].

Philips' approach to NPD emphasizes user involvement across three different aspects of product development including Technology Objectives (TO), Design Objectives (DO) and Strategic Marketing Objectives (SO) [5]. Philips developed their TO: DO: SO approach which includes core tools, such as personas, Experience Targets and Slice of Life Experience Prototypes [5].

While there were no studies in the found journals articles regarding design methods and tools to involve customers at the front end of technology driven NPD, there are methods and tools that enable customer involvement in the early phase of NPD. User-centered design methods and tools help develop end-user centered products which have high customer value [3–5, 9]. Focus groups [4, 22], interviews [22, 27, 28], cognitive walkthroughs [4, 22], think-aloud protocols [4, 22], and observation [4, 28, 29] have been used to understand the customers' needs. Since companies prefer less-time-consuming approaches during the early stages of NPD [30], focusing on interacting with open-minded users, lead users who represent the target group, and/or care givers (instead of the elderly) allow for effective, efficient understanding of the customers' needs [4, 22]. Web-based visual customer communication [3] and co-creation (customer involvement in NPD) [3] methods have been utilized to connect designers, engineers, and marketers to customer knowledge. The use of user personas [31] during user/developer workshops [28] have been noted to aid empathy in design education [4]. Attribute listing and story boarding have supported user involvement during brainstorming [22]. User-feedback [5], focus group sessions [22], express processing (receiving frequent feedback from customers) [3], storytelling [29], and constructive interaction (interaction between two people with the product and capturing the communication between them) [22] have been suggested to optimize and to improve a second round of ideas from a set of initially generated ideas which involves the users.

### 3.3 The Methods and Tools for Innovative Idea Generation from Technology

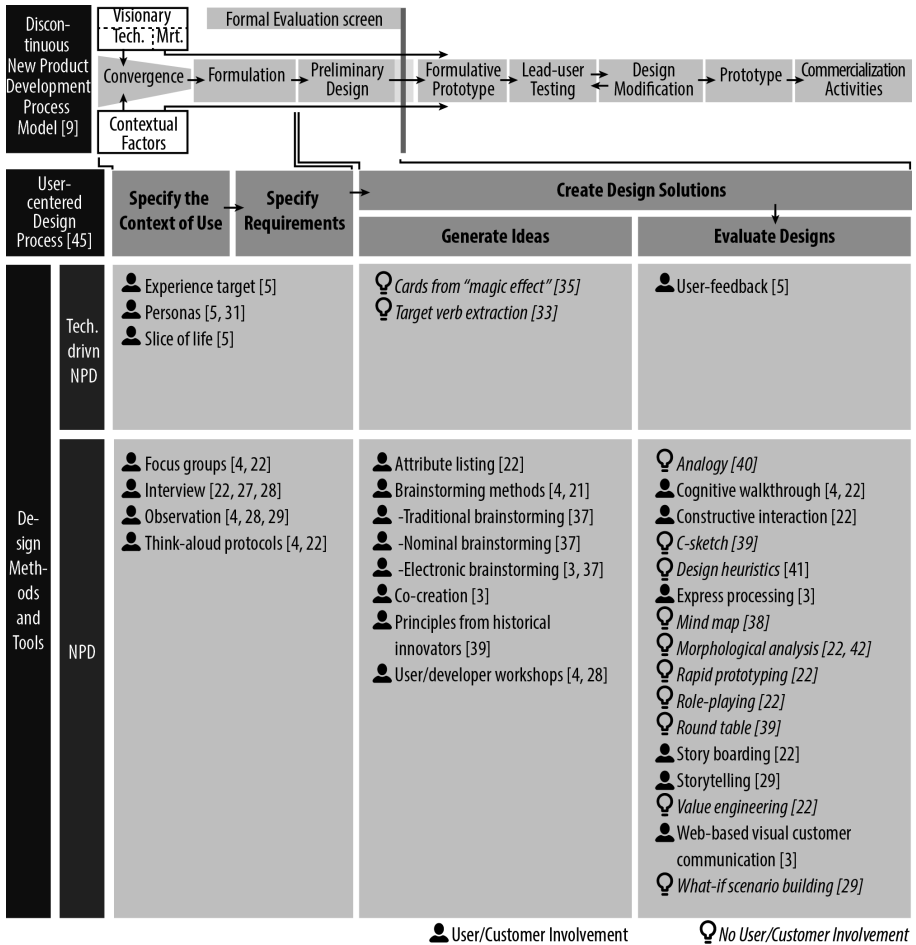
To aid technology transfer in the early phase of NPD, there are methods and tools to generate innovative ideas inspired by technology. Considering technology as a design material helps designers to focus on generating conceptual ideas [32]. The verbal knowledge from patent analysis for design inspiration was investigated [33]. Use of “Target verb extraction” and “related verb mining” from related product patents to inspire innovative ideas had positive effects for university students for idea generation [33]. Tangible tools, such as card format, to focus on the potential of touch-points in innovation has been addressed in a previous study [34]. One recent study developed cards as inspiration tools for innovative ideas that provide a “magic effect” to encapsulate technical information for novice designers [35].

While relatively small number of studies were found which explicitly described methods and tools aiding the technology driven NPD process, there were many studies using well-established methods which are potentially applicable for innovative idea generation in the context of technology driven NPD. Different brainstorming methods have been widely used in the creative idea generation phase [4, 21]. The goal of brainstorming is to generate as many ideas as possible [36]. Three different types of brainstorming have been used in idea generation: (1) traditional brainstorming (engagement in dialogue and idea sharing), (2) nominal brainstorming (idea generation individually without communicating with others), and (3) electronic brainstorming (use of online resources to facilitate idea generation) [37]. Mind maps, analogies, and round table discussions have been effectively used for in person (classroom) discussions for idea generation [38]. C-Sketch (adding ideas to the ideas generated by others in round table format) [39], Principles from Historical Innovators (capturing the principles of previously designed innovative products and apply these principles to the concept generation process) [39], and analogy [40] have been utilized for idea generation methods with design students [35]. Design Heuristics, a tool to help generate more ideas, was suggested to be used after exhausting the initial idea generation phase [41]. The additional ideas generated, after the initial idea generation phase, were rated as higher in novelty, specificity and relevance [41]. Morphological analysis (exploration of possible solutions using matrix model) [22, 42], value engineering (an function examination to improve the value of products) [22], rapid prototyping [22], use cases and pluralistic walkthrough (idea development with a demonstration of prototype based on user action sequence) [22], role-playing [22], and what-if scenario building [29] have been suggested to optimize and to improve a second round of ideas from a set of initially generated ideas.

## 4 Results

The discontinuous (innovative) NPD Process Model, which shows technology driven approach [10], and the HCD process model, which is closely related to ergonomics [43], are presented adjacent to each other to suggest how the HCD process model may help the front end of technology driven NPD process in Fig. 1. Figure 1 also captures the methods and tools documented in the literature. The visualization of the methods and tools found in

the literature adjacent to the NPD and HCD process models suggests where they may be useful in the front end of the technology driven NPD process. The methods and tools can be separated into two categories: (1) directly aiding the technology driven NPD or (2) potentially helpful to aid technology driven NPD. These categories are identified as “Tech. driven NPD” and “NPD” in Fig. 1. Within Fig. 1, two distinctive icons were used to differentiate whether or not the methods and tools support user/customer involvement.



**Fig. 1.** A matrix of methods and tools to support a technology driven NPD process.

## 5 Discussion

In addition to the methods and tools, the literature reviewed for this paper addresses topics relevant to the technology driven NPD process which should be brought into this discussion. Technology is noted as being one of the three main levers (form, mode of use,



and technology) of the design-driven NPD process [44]. Technical research along with observational research and interviews is central to develop innovative products [28]. Due to designer's lack of technological knowledge, conceptual functions suggested by designers may not be possible or feasible to develop [35]. This lack of feasibility often results in engineers, who are less concerned with user experience during product development, being in charge of product conceptual development and designers being in charge of products appearance [35]. Thus the importance of improving technology literacy for designers is underscored [15]. Some of the methods and tools documented in the literature that aid idea generation from technology may help designers improve their technology literacy.

Since HFE experts are capable of modelling new user needs and usages, the involvement of HFE experts in the front end of NPD helps define market opportunity [27] and guide the application of technology in products in order to fulfill user's needs. Closing the gap between the HFE research findings and the application of the findings in design process is critical [45]. Qualitative research results meaningfully address design issues and are easily understood by designers. However, quantitative research results need to further decoupled from the data for designers to more effectively infuse HFE research results into the design process [45].

Previous studies noted challenges when teaching novice designers, engineers and students to apply design methods and tools in a technology driven NPD and NPD process [16, 46]. First, human centered design methods used in the Fuzzy Front-End are difficult to teach in education settings due to the short time lines and lack of prior experience of the students [29]. Second, it is difficult for students to transfer the user-centered research results to design inspiration [29]. Third, while students think design methods are useful for innovative product development, they tend not to use design methods because of the effort required to understand how and when to implement design methods within a given time frame [16]. Finally, applying design thinking, a complex and holistic approach, to technology driven NPD is difficult to implement in traditional education lectures or seminars [47]. Studies suggest situating students in a practice-based studio learning environment (such as, capstone model), allowing them to work with design experts and working on complex, real-world problems will enhance students' understanding of the design methods and tools [16, 46, 47]. This approach may help students learn how and when to use the methods and tools during the technology transfer at the front fuzzy end of technology driven NPD. Thus, effective design methods, tools and education programs need to be more accessible and structured for novice designers and engineers. Future studies need to investigate how design methods and tools can be effectively taught to design students enabling their active engagement in technology driven NPD once they graduate and are in practice.

Also, papers mentioned that the additional help and education will be needed for practitioners including designers and engineers [3]. Studies addressed that there will be friction within companies while embedding design in NPD [21] because of the difference in perspectives between experts (e.g. technologists and designers) [15]. In other words, it takes some time for design to be able to fully and effectively contribute when developing innovative products [21] in technology driven NPD. Over reliance on customer involvement results in merely incremental innovation [3, 48, 49]; thus the tools and methods integrating customer input in NPD need to balance customer

perspectives with technological possibilities [3]. Since new ideas occur spontaneously outside of a development process [50], the over use of design methods and tools in technology driven NPD would have a negative effect on product innovation. Since the front end of NPD needs to be fast for companies to remain competitive, the methods and tools to be used in the early phase of NPD need to be updated to be effective in a limited time frame. While there are many studies regarding utilizing design methods and tools used in NPD process in engineering and design management, there are few publications documenting the assessment of design methods and tools in the design field. Additional design research investigations are necessary for design researchers who are updating methods and tools to effectively aid designers in the technology driven NPD.

There are limitations regarding this systematic literature review. The journals reviewed were focused; key journals from related fields could also be reviewed in future studies. Since the review was focused on peer reviewed papers and their associated citations, conference proceedings and book chapters from related fields also need to be identified and synthesized. The usefulness and effectiveness of the methods and the tools were not evaluated in this study. Future studies are needed to evaluate the usefulness and effectiveness of the methods and tools used in the front end of technology driven NPD process.

## 6 Conclusions and Recommendations

This systematic literature review presents the documented design methods and tools that have been developed and used in technology driven NPD process. The findings are categorized into the following themes: (1) the role of design in technology driven new product development and innovation; (2) the methods and tools to support user involvement at the front end of technology driven NPD; and (3) the methods and tools for innovative idea generation from technology. Figure 1 presents when each method and tool can be used in the technology driven NPD process. Design researchers and HFE experts can use these empirically tested methods and tools to specify the context of use and requirements, to generate innovative ideas, and evaluate designs in the front end of technology driven NPD process. These design methods, tools and education programs needed to be updated and new ones developed to be effective, accessible and structured for both designers and engineers involved in the technology driven NPD process.

## References

1. Stanton, N.A., Young, M.S.: Giving ergonomics away? The application of ergonomics methods by novices. *Appl. Ergon.* **34**(5), 479–490 (2003)
2. The importance of ergonomics. <https://www.nibusinessinfo.co.uk/content/importance-ergonomics>
3. Yoon, B.S., Jetter, A.J.: Connecting customers with engineers for the successful fuzzy front end: requirements of tools. In: *Management of Engineering and Technology*, Portland, pp. 1585–1595 (2015)

4. Galway, L., O'Neill, S., Donnelly, M., Nugent, C., McClean, S., Scotney, B.: Stakeholder involvement guidelines to improve the design process of assistive technology: lesson from the development of the MPVS system. *Health Technol.* **3**(2), 119–127 (2013)
5. Gardien, P., Kyffin, S.: Navigating the innovation matrix: an approach to design-led innovation. *Int. J. Des.* **3**(1), 57–69 (2009)
6. Technology-driven Definition in the Cambridge English Dictionary. <https://dictionary.cambridge.org/us/dictionary/english/technology-driven>
7. Norros, L.: Developing human factors/ergonomics as a design discipline. *Appl. Ergon.* **45**(1), 61–71 (2014)
8. Baber, C., Haniff, D., Cooper, L., Knight, J., Mellor, B.: Preliminary investigations into the use of wearable computers. In: Johnson, H., Nigay, L., Roast, C. (eds.) *People and Computers XIII*, pp. 313–325. Springer, London (1998)
9. De Jong, A.M., Vink, P., De Kroon, J.C.A.: Reasons for adopting technological innovations reducing physical workload in bricklaying. *Ergonomics* **46**(11), 1091–1108 (2003)
10. Verzyer Jr., R.W.: Discontinuous innovation and the new product development process. *J. Prod. Innov. Manag.* **15**(4), 304–321 (1998)
11. De Keersmaecker, A., Jacoby, A., Baelus, C.: Technology-driven Innovation: applying the technology to product tool in an educational settings. In: *14th International Conference on Engineering & Product Design Education (E&PDE 2012) Design Education for Future Wellbeing*, Antwerp, pp. 1–6 (2012)
12. Eroğlu, I., Ekmekçioglu, D.: Exploring the relation between students' research behaviours in project courses and open innovation. *Des. Technol. Educ.* **23**(3), 46–61 (2018)
13. Gough, D., Oliver, S., Thomas, J.: *An Introduction to Systematic Reviews*. SAGE Publications, Thousand Oaks (2017)
14. Candi, M.: The role of design in the development of technology-based services. *Des. Stud.* **28**(6), 559–583 (2007)
15. Blanco, T., Casas, R., Manchado-Pérez, E., Asensio, Á., López-Pérez, J.M.: From the islands of knowledge to a shared understanding: interdisciplinarity and technology literacy for innovation in smart electronic product design. *Int. J. Technol. Des. Educ.* **27**(2), 329–362 (2017)
16. Miller, W.S., Summers, J.D.: Investigating the use of design methods by capstone design students at Clemson University. *Int. J. Technol. Des. Educ.* **23**(4), 1079–1091 (2013)
17. Ulrich, K.T., Eppinger, S.D.: *Product Design and Development*. McGraw-Hill/Irwin, New York (2004)
18. Eder, W.E.: Engineering design vs. artistic design: some educational consequences. *US-China Educ. Rev.* **3**(4), 259–280 (2013)
19. Pahl, G., Beitz, W., Feldhusen, J., Grote, K.H.: *Engineering Design: A Systematic Approach*. Springer, London (2007)
20. Persson, S., Warell, A.: Relational modes between industrial design and engineering design – a conceptual model for interdisciplinary design work. In: *Proceedings of the 6th Asian Design International Conference*, Kuching (2003)
21. Malmberg, L., Holmlid, S.: Embedding design capacity in research driven innovation teams. In: *Tsinghua International Design Management Symposium: Design-Driven Business Innovation*, Shenzhen, pp. 236–241. IEEE (2013)
22. van Schie, T.N., Schot, M., Schoone-Harmsen, M., Desmet, P.M.A., Rövekamp, A.J.M., Van Dijk, M.B.: User-centered design of tele-homecare products. In: Yogesani, K., Bos, L., Brett, P., Gibbons, M.C. (eds.) *Handbook of Digital Homecare*, pp. 221–242. Springer, Berlin (2009)
23. Verganti, R.: *Design-Driven Innovation: Changing the Rules of Competition by Radically Innovating What Things Mean*. Harvard Bus. Press, Boston (2009)

24. Kleinsmann, M., Valkenburg, R., Sluijs, J.: Capturing the value of design thinking in different innovation practices. *Int. J. Des.* **11**(2), 25–40 (2017)
25. François, M., Osiurak, F., Fort, A., Crave, P., Navarro, J.: Automotive HMI design and participatory user involvement: review and perspectives. *Ergonomics* **60**(4), 541–552 (2017)
26. van der Panne, G., van Beers, C., Kleinknecht, A.: Success and failure of innovation: a literature review. *Int. J. Innov. Manag.* **07**(03), 309–338 (2003)
27. Xu, W.: Enhanced ergonomics approaches for product design: a user experience ecosystem perspective and case studies. *Ergonomics* **57**(1), 34–51 (2014)
28. Albayrak, A., Wauben, L.S.G.L., Goossens, R.H.M.: Ergonomics in the operating room: design framework. In: Brinkerhoff, B.N. (ed.) *Ergonomics: Design, Integration and Implementation*, pp. 147–177. Nova Science Publishers, Inc., New York (2009)
29. Liem, A., Sanders, E.B.N.: Human-centered design workshops in collaborative strategic design projects: an educational and professional comparison. *Des. Technol. Educ. Int. J.* **18**(1), 72–86 (2013)
30. Casner, D., Houssin, R., Renaud, J., Knittel, D.: Optimization as an innovative design approach to improve the performances and the functionalities of mechatronic devices. *Procedia Eng.* **131**, 941–950 (2015)
31. Haag, M., Marsden, N.: Exploring personas as a method to foster empathy in student IT design teams. *Int. J. Technol. Des. Educ.* **29**, 565–582 (2018)
32. Nordby, K.: Conceptual designing and technology: short-range RFID as design material. *Int. J. Des.* **4**(1), 29–44 (2010)
33. Ji, Y., Qiu, Q., Feng, P., Wu, J.: Empirical study on the impact of knowledge in international patent classification on design inspiration of undergraduate students. *Int. J. Technol. Des. Educ.* **28**(94) (2018)
34. Clatworthy, S.: Service innovation through touch-points: development of an innovation toolkit for the first stages of new service development. *Int. J. Des.* **5**(2), 15–28 (2011)
35. Haritaipan, L., Saijo, M., Mougenot, C.: Impact of technical information in magic-based inspiration tools on novice designers. *Int. J. Technol. Des. Educ.* (2018). No. 0123456789
36. Wilson, C.: *Brainstorming and Beyond: A User-Centered Design Method*. Morgan Kaufmann Publishers Inc., San Francisco (2013)
37. Al-Samarraie, H., Hurmuzan, S.: A review of brainstorming techniques in higher education. *Think. Ski. Creat.* **27**, 78–91 (2018)
38. Chua, K.J., Yang, W.M., Leo, H.L.: Enhanced and conventional project-based learning in an engineering design module. *Int. J. Technol. Des. Educ.* **24**(4), 437–458 (2014)
39. White, C., Wood, K.L., Jensen, D.D.: From Brainstorming to C-sketch to principles of historical innovators: ideation techniques to enhance student creativity. *J. STEM Educ.* **13**(3), 12–25 (2012)
40. Goel, A.K., Bhatta, S.R.: Use of design patterns in analogy-based design. *Adv. Eng. Inform.* **18**(2), 85–94 (2004)
41. Gray, C.M., McKilligan, S., Daly, S.R., Seifert, C.M., Gonzalez, R.: Using creative exhaustion to foster idea generation. *Int. J. Technol. Des. Educ.* **29**(1), 177–195 (2017)
42. Allen, M.S.: *Morphological Creativity: The Miracle of Your Hidden Brain Power; a Practical Guide to the Utilization of Your Creative Potential*. PrenticeHall, Englewood Cliffs (1962)
43. User-Centered Design Basics. <https://www.usability.gov/what-and-why/user-centered-design.html>
44. Rampino, L.: The innovation pyramid: a categorization of the innovation phenomenon in the product - design. *Int. J. Des.* **5**(1), 3–16 (2011)
45. Dekker, S.W.A., Nyce, J.M.: How can ergonomics influence design? Moving from research findings to future systems. *Ergonomics* **47**(15), 1624–1639 (2004)

46. Novoa, M.: Industrial design education as innovation broker through making, pivot thinking, autopoiesis and expansive learning. *Des. Technol. Educ.* **23**(3), 119–152 (2018)
47. Pavel, N., Berg, A.: Complexity in design-driven innovation: a case study of knowledge transfer flow in subsea seismic sensor technology and design education. *Des. Technol. Educ.* **20**(1), 59–67 (2015)
48. Kim, K.M., Lee, K.-p.: Collaborative product design processes of industrial design and engineering design in consumer product companies. *Des. Stud.* **46**, 226–260 (2016)
49. Norman, D., Verganti, R.: Incremental and radical innovation: design research vs. technology and meaning change. *Des. Issues* **30**(1), 78–96 (2013)
50. Hakansson, H., Ford, D.: How should companies interact in business networks? *J. Bus. Res.* **55**(2), 133–139 (2002)



# Teenagers Postural Effects Through Videogames Therapeutic Approach

Ernesto Filgueiras<sup>1,2(✉)</sup>, Gustavo Desouzart<sup>3,4</sup>, and Ana Silva<sup>4</sup>

<sup>1</sup> CIAUD - Research Centre for Architecture, Urbanism and Design, FA,  
ULisboa, Lisbon, Portugal  
ernestovf@gmail.com

<sup>2</sup> University of Beira Interior, Covilha, Portugal

<sup>3</sup> RECI – Piaget Institute of Viseu, Lordosa, Portugal

<sup>4</sup> Health School Jean Piaget, Piaget Institute, Viseu, Portugal

**Abstract.** Over the school year, children tend to get poor posture, which will gradually be manifesting through malaise, pain and the risk behaviors, even dysfunctions of musculoskeletal component causing affection muscle groups and overload in structures. This study aimed to implement an exercise program using videogames through the Wii Fit platform, in order to verify if the intervention is effective in the postural alterations of 54 children and adolescents, in relation to the posture, flexibility and decreased back pain. After 8 weeks of intervention, significant results were obtained in the reduction of complaints of back pain ( $p = 0.040$ ) and pain while in video game activity ( $p = 0.033$ ), and improvements in posture and flexibility, but without significant difference. This study demonstrated that the exercise plan in the Wii platform allows positive effects on the variables and allows a greater incentive to the participants, the awakening for its future application.

**Keywords:** Teenagers postural changes · Postural intervention · Wii Fit · Back pain

## 1 Introduction

At present, there is greater concern and striving to risk painful and restrictive processes in school children and youngsters, a period for which it is regarded as the precursor phase for the development of musculoskeletal disorders. The high ratio should be the continuation of inappropriate postures in the school environment and the other intrinsic and extrinsic factors [1].

With the accommodation of structures due to growth there is a predisposition to postural deviations when associated with risk factors, such as inappropriate postures adopted during classes, incorrect use of the backpack, inadequate footwear, ergonomics, sedentary lifestyle and obesity [2].

Therefore, these inappropriate patterns can cause long-term, acute or chronic-degenerative injuries, which may lead to a predisposition for exacerbations of the spine at a later stage, manifested by painful conditions and likely visible deformations. So in short this whole compilation results in a modification of the function of movement and body support [3].

The occurrence of musculoskeletal pain in the vertebral column is very frequent in schoolchildren, and can reach a prevalence of over 60%, a phenomenon described in several countries. Typically the regions with the most painful complaints are the lumbar, cervical and dorsal regions. We have the child example when for an extended time remains in the sitting position in a chair, positioned in the wrong way can occur the pain of the lumbar region. Low back pain is also related to the weight of school backpacks and how this weight is distributed over the back and shoulders [4].

The school is the space responsible for the formalization of education and the teaching and learning process, and it is in the first years of school life, when the child is still in the growth phase, the best moment to begin the postural education work with a view to decrease musculoskeletal problems, increasing functional efficiency [5].

According to Verderi [6], it is not uncommon for children to develop their own daily-life activities without receiving proper recommendations on how to avoid bad postural behaviors, by their Physical Education teachers.

In order to avoid musculoskeletal disorders, European Community prioritize preventive measures development among adults and children. This measures, based upon user's daily-life risks, are focused on aspects where Burton et al. [7] highlight lifestyle (which may include nutrition, work, physical activity and obesity), physical related (like mobility, flexibility and muscle strength), school environment related (which include backpack transportation and school furniture) and finally psychological related that according to them, after modified may reduce the occurrence of musculoskeletal problems among the general population.

There are a large number of children who only perform physical activity, whether in physical education classes or when they play with their classmates. After that they return to the sedentary base of the study, use of computer, watch television or play video games [8].

In order to keep a healthy and free of pain body, especially when it comes to spine area, it is important to maintain an ideal posture alongside with regular physical activity practice. On the opposite side of the spectrum, a bad posture, sleep disturbances and stress are the main risk factors that contribute to pain episodes [9].

The technological advance contributed significantly to the development of virtual games destined to the practice of physical activity, developed to employ human movement as input element, with the purpose of increasing caloric expenditure and interactivity. [10]

This study focused on the use of video games through the Wii console, with the application of activities on the Wii Fit platform, to prove benefits in the postural changes of the children, in order to demonstrate their importance and their effectiveness in postural habits.

In order to elaborate this project, a literature review was carried out where each topic will be approached, for a better knowledge and exploration of the study, being these (children's growth and development, posture, habits and postural alterations, musculoskeletal pain in the spine in children, intervention of physical therapy in postural changes and use of the Wii console and Wii Fit platform in the posture).

In the methodology section, the general and specific objectives and their hypotheses will be addressed, as well as the methods and materials will describe the type of study, the instruments used, the characterization of the sample and the exclusion and inclusion criteria.

The results will present the results of the intervention plan and will be compared to previous studies of similar studies. It follows the conclusion where one will reflect on the objectives and results achieved in the study.

## 2 Methodology

The benefits of using the Wii console in Physical Therapy as a therapeutic tool in the literature, improving balance, postural control, increased locomotion capacity, range of motion of the upper and lower limbs, and patient motivation [11].

This study aimed to verify the effectiveness of postural intervention through video games in children and teenagers in posture, flexibility and musculoskeletal back pain.

Dating from March to June 2018, there were 230 students enrolled in the school, which attending the 2<sup>nd</sup> and 3<sup>rd</sup> Basic Education Cycle, of whom 125 were in the 7<sup>th</sup> and 9<sup>th</sup> grade (50 and 75, respectively).

Children and adolescents aged between 9 and 16 years who attended the 2nd and 3rd cycles of elementary school education in the city of Viseu, Portugal, were chosen for the sample of the present study.

For the collection of data will be used an elaborate questionnaire containing posture habits, information on health problems and sociodemographic data of the participants and the image capture of the static posture and that will be done in two parts.

This study have taken three month from participant selection process, personal identification questionnaire fill, which included 13 questions related to socio-demographic analysis (gender, age, weight, height and participant identification number), the occurrence, intensity and location of musculoskeletal pain assessment according to Corporal Discomfort Scale [12] in order to verify and categorize the pain felt (where 0 corresponded to no pain and 5 to the full amount of pain felt by the subject), and its duration (acute pain – under one month, subacute – from 1 to 3 months, and finally, chronic pain – over a 3 month period) and postural habits according to the Posture Habits Assessment Questionnaire and with consent by the caregivers.

After initial evaluation, the participants were randomly assigned and for convenience in two groups, one control and one experimental. The control group served as a comparison model and did not participate in the exercise plan while the experimental group performed an exercise protocol through video games on the Wii Fit platform to improve posture flexibility.

For the study, 54 participants were selected, 27 males and 25 females belonging to the 7th and 9th grades due to colliding with growth stages. The beginning and end of the 3rd cycle were then chosen randomly. In the 7th year the group was divided in half, with 12 participants as experimental group and 12 as control group, while in the 9th year, group A served as an experimental group and group B as a control group.

The exercises were applied twice a week (40 min each session), lasting 8 weeks.

In order to assess postural changes, an informal questionnaire was conducted, based on the work made by Carmo and Ferreira [13] and Rebolho [14], it pointed out pain body placement while in a seated, upstanding and backpack and weight carrying.

SPSS, 24.0 version was used in order to treat all the statistical data, for normality verification Kolmogorov-Smirnov test was applied before a descriptive analysis. This



last, was calculated based upon standard methods. In order to analyze any characteristic difference between both groups, the nonparametric test of U of Mann Whitney was applied. The statistically level of significance was established in  $p \leq 0.05$ .

### 3 Results and Discussion

A sample of 54 subjects, with  $13,76 \pm 1,971$  years old, 50% male and 50% female, 55,6% in the 9<sup>th</sup> grade and 44,4% in the 7<sup>th</sup> grade, with Body Mass Index (BMI)  $21,15 \pm 3,376$ .

Body Discomfort Scale allowed us to find that, between a 0 (no pain) and a 5 (maximum pain) episode among the 54 subjects, there was a mean of  $2,40 \pm 0.893$  that correspond to a moderate episode.

When it comes to pain episodes duration compared with their own intensity, our study allowed to find that with episodes duration increments comes intensity increments as well, as we may see by the 37.8% of the subjects that claim to suffer from chronic pain ( $2.54 \pm 0.73$ ) and  $2.00 \pm 0.00$  and  $2.39 \pm 1.08$  corresponding to subacute and acute episodes, respectively.

When it comes to musculoskeletal pain occurrence, 68.5% of the subjects claim to have experienced some episode, in at least one body area. From these, 43.5% claim to have experienced pain in two distinctive body areas while 11,1% claim to have felt it in three or more of this region.

Considering its placement, 66.1% (81) point out the spine region, 25.3% the head, 2.5% lower limbs, and finally, 5.1% upper limbs as the main problematic areas of pain occurrence.

Considering the aim of this particular paper, musculoskeletal pain occurrence between the 7<sup>th</sup> school grade students with an average intensity of pain  $2.53 \pm 0.89$  (as it may be seen in Table 1). When it comes to its duration, 31.4% of the subjects claim to have experienced chronic episodes. On the other hand, when it comes to 9<sup>th</sup> grade school age children (3<sup>rd</sup> Basic Education Cycle ending) the amount that claim to have experienced some kind of pain occurrence decreased (65%), but the average pain intensity ( $2.28 \pm 0.89$ ) and its duration (43.6% chronic episodes) increased, as we may see in Fig. 1.

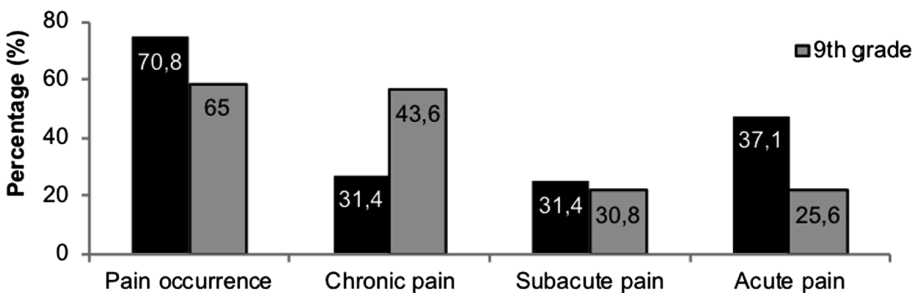


Fig. 1. 7<sup>th</sup> and 9<sup>th</sup> grade episodes duration of pain comparison

In the evaluation are presented the statistical data regarding the experimental group and the control group before and after the application of the practical intervention with videogames in the Wii Fit platform. The variables selected for the study were flexibility, amount of pain, duration of pain, pain during video game activity and total ideal posture.

According to the reassessment of the experimental group, overall, all participants in the experimental group showed an improvement in the various parameters mentioned. There were no significant changes in the control group.

Then the normality test of Kolmogorov-Smirnov, in which it was verified that the normality was zero, then the nonparametric test of U of Mann Whitney was realized.

According to the variable flexibility, the data demonstrate an improvement in flexibility between the 1st and 2nd phase of the experimental group. Regarding the first phase, the group obtained a mean of 81.80 (+14.40) and in the second phase obtained a mean of 85.31 (+13.43), with  $p = 0.627$ , whereas the control group had an average 74, 16 (+11.73) with  $p = 1,000$  in both phases without improvement.

Regarding the amount of pain, it is verified that the data show a decrease between the 1st and 2nd phase of the experimental group. In relation to the first phase, the group obtained a mean of 2.15 ( $\pm 1.32$ ) and in the second phase obtained a mean of 1.37 ( $\pm 1.39$ ), with  $p = 0.040$ , whereas the control group had a mean of 1.63 ( $\pm 1.24$ ) in the 1st and 1.33 ( $\pm 1.33$ ) the second phase with  $p = 0.380$ , thus a slight improvement in the decrease of pain.

Regarding the duration of pain, it is verified that the data do not show a significant decrease between the 1st and 2nd phase of the experimental group. In relation to the first phase, the group obtained a mean of 2.09 ( $\pm 1.32$ ) and in the second phase obtained a mean of 2.05 ( $\pm 1.39$ ), with  $p = 0.939$ , whereas the control group had an average of 2.05 ( $\pm 0.86$ ) in the 1st and 2.06 (+0.82) the 2nd phase with  $p = 0.948$ , and there was no significant decrease in pain.

Regarding pain during video game activity, it is observed that the data present a slight decrease between the 1st and 2nd phase of the experimental group. Regarding the first phase, the group obtained an average of 0.81 ( $\pm 0.73$ ) and in the second phase obtained a mean of 0.41  $\pm 0.57$ , with  $p = 0.033$ , whereas the control group had a mean 0.33 + 0.48 with  $p = 1,000$  in both phases without improvement.

**Table 1.** Descriptive analysis of the experimental group on the variables flexibility, pain and posture.

Variable	Study phase	Average
Flexibility	1 <sup>st</sup> phase	81,80 $\pm$ 14,40
	2 <sup>nd</sup> phase	85,31 $\pm$ 13,43
Pain intensity	1 <sup>st</sup> phase	2,15 $\pm$ 1,32
	2 <sup>nd</sup> phase	1,37 $\pm$ 1,39
Pain during videogames activities	1 <sup>st</sup> phase	0,81 $\pm$ 0,74
	2 <sup>nd</sup> phase	0,41 $\pm$ 0,53
Posture	1 <sup>st</sup> phase	1,89 $\pm$ 0,32
	2 <sup>nd</sup> phase	1,78 $\pm$ 0,42

Finally, it was verified that the values in relation to the total ideal posture presented a slight improvement between the 1st and 2nd phase of the experimental group. Regarding the first phase, the group obtained a mean of  $1.89 (+0.32)$  and in the second phase obtained a mean of  $1.78 + 0.42$ , with  $p = 0.278$ , while the control group had a mean  $1.78 (+0.42)$  in both phases without improvement, as we may see in Tables 1 and 2.

**Table 2.** Descriptive analysis of the control group on the variables flexibility, pain and posture.

Variable	Study phase	Average
Flexibility	1 <sup>st</sup> phase	$74,16 \pm 11,73$
	2 <sup>nd</sup> phase	$74,16 \pm 11,73$
Pain intensity	1 <sup>st</sup> phase	$1,63 \pm 1,26$
	2 <sup>nd</sup> phase	$1,33 \pm 1,33$
Pain during videogames activities	1 <sup>st</sup> phase	$0,33 \pm 0,48$
	2 <sup>nd</sup> phase	$0,33 \pm 0,48$
Posture	1 <sup>st</sup> phase	$1,78 \pm 0,42$
	2 <sup>nd</sup> phase	$1,78 \pm 0,42$

In a review of the literature, the results obtained in the studies show that the use of videogames through the Wii console and its Wii Fit platform, have demonstrated excellent results as a therapeutic tool in various components.

Within the various studies analyzed, there were significant improvements in balance, visual perception, range of motion and improvement of motor function beyond the immersion and motivation it offers.

According to the study by Agmon et al. [15], exercises performed by the elderly group on the Wii Fit platform demonstrated improvements in the Berg Scale after the intervention ( $p < 0.01$ ) and improvement in gait velocity through WT4min ( $p < 0.108$ ).

According to the study Toulotte et al. [16], in a group also of elderly, it was verified after the training plan that the score in the Test of Tinetti reduced significantly ( $p < 0,05$ ).

According to the Braga et al. study [17], the group of young people tested showed a significant improvement in the SEBT test ( $p < 0.05$ ) with the use of the Wii Fit Platform in relation to the group that used the proprioceptive disc.

In the present study, data on flexibility and pain decreased from  $81.80 (\pm 14.40)$  to  $85.31 (\pm 13.43)$  and  $2.15 (\pm 1.32)$  to  $1.37 (\pm 1.39)$  respectively.

In the references of pains in activity in the video game, the values point to a slight decrease with no significance from  $0.81 (\pm 0.73)$  to  $0.41 (\pm 0.57)$ .

When referring to posture, the participants of the experimental group showed a slight improvement from  $1.89 (\pm 0.32)$  to  $1.78 (\pm 0.42)$ .

The therapeutic effects on video game use associated with the Wii Fit platform are poorly explored, focusing in particular on the elderly population and on balance disorders. However, as no similar studies have been found regarding the effects on body

posture, it is not possible to predict the expected results on the efficacy of the intervention. Therefore, it is necessary to intervene in order to demonstrate the existence of benefits and to provide a basis for future studies.

## 4 Conclusion

In this present study based on data analysis, it can be concluded that it is essential that preventive measures be taken in the school environment, not only in prevention actions and postural education in schools, but also a more practical intervention.

As the prevalence of postural changes increases, there is a concern to find increasingly effective measures. Therefore the focus of this project is to prove and consolidate the effectiveness of a more active intervention using videogames using the Wii Fit platform, with the aim of improving postural behavior, but also as a beginning and influence for future interventions similar to this one.

The promotion of behavioral changes, leading to more active and healthy lifestyles is quite complex so it is considered pertinent to seek solutions so that, if they can substantially improve the day to day of these children and become later, elements of society as influencers of appropriate behavior.

After the implementation of the project, it is evident that the exercise plan associated to the platform, besides demonstrating positive effects, has been well received and can be further explored for its future application both in the school environment and in other means. Then the awakening to this theme.

## References

1. Penha, P., Casarotto, R., Sacco, I., Marques, A., João, S.: Qualitative postural analysis among boys and girls of seven to ten years of age. *Braz. J. Phys. Ther.* **12**(5), 286–291 (2008)
2. Macfarlane, G.: Low back pain in schoolchildren: the role de mechanical and psychosocial factors. *Arch. Dis. Child.* **88**(1), 12–17 (2003)
3. Contri, D., Petrucelli, A., Perea, D.: Incidence of postural deviations in schoolchildren from 2nd to 5th year of elementary school. *ConScientiae Saúde* **8**(2), 219–224 (2009)
4. Calvo-Muñoz, I., Gómez-Conesa, A., Sánchez-Meca, J.: Prevalence of low back pain in children and adolescents: a meta-analysis. *BMC Pediatr.* **13**(1), 14 (2013)
5. Verderi, E.: It is postural education and quality of life. *EFDeportes* **8**(51) (2002)
6. Hsu, S., Wen, M., Wu, M.: Exploring user experiences as predictors of MMORPG addiction. *Comput. Educ.* **53**, 990–999 (2009)
7. Young, W., Ferguson, S., Brault, S., Craig, C.: Assessing and training standing balance in older adults: a novel approach using the “Nintendo Wii” Balance Board. *Gait Posture* **33**(2), 303–305 (2011)
8. Halton, J.: Virtual rehabilitation with video games: a new frontier for occupational therapy. *Occup. Ther. Now* **9**(6), 12–14 (2008)
9. Corlett, E., Bishop, R.: A technique for assessing postural discomfort. *Ergonomics* **19**(2), 175–182 (1976)

10. Carmo, H., Ferreira, M.: Metodologia da Investigação – Guia da Auto-aprendizagem. Universidade Aberta, Lisboa (1998)
11. Rebolho, M.: Efeitos da educação postural nas mudanças de hábitos em escolares da 1ª a 4ª séries do ensino fundamental. USP, São Paulo (2005)
12. Verderi, E.: Programa de educação postural. Phorte, São Paulo (2011)
13. Burton, A., Balagué, F., Cardon, G., Eriksen, R., Henrotin, Y., Lahad, A., Le-clerc, A., Müller, G., van der Beck, A.: Low back pain. Guide-lines for prevention in low back pain. *Eur. J. Spine* **15**(Supl. 2), 136–168 (2006)
14. Desouzart, G., Filgueiras, E., Matos, R., Dagge, R.: Postural education: correlation between postural habits and musculoskeletal pain in school age children. In: Rebelo, F., Soares, M. (eds.) *Advances in Ergonomics in Design*, pp. 255–263. Springer, Cham (2016)
15. Agmon, M., Perry, C., Phelan, E., Demiris, G., Nguyen, H.: A pilot study of Wii Fit exergames to improve balance in older adults. *J. Geriatr. Phys. Ther.* **34**(4), 161–167 (2011)
16. Toulotte, C., Toursel, C., Olivier, N.: Wii Fit® training vs. Adapted Physical Activities: which one is the most appropriate to improve the balance of independent senior subjects? A randomized controlled study. *Clin. Rehabil.* **26**(9), 827 (2012)
17. Braga, F., Araújo, J., Tavela, A., Vilela, V., Soares, F., Araujo, J., Queiroz Magalhães, L., da Silveira, W.F., Feitosa, T.F., Dantas, E.S., Atahyde, A.: First report of interaction of nematophagous fungi on *Libyostrongylus douglassii* (Nematoda: Trichostrongylidae). *Revista Brasileira de Parasitologia Veterinária* **22**(1), 147–151 (2013)



# Eye-Tracking Examination of the Anthropological Race, Gender and Verbal-Pictorial Relative Positions on Ergonomics of Visual Information Presentation

Rafał Michalski<sup>(✉)</sup> and Joanna Koszela-Kulińska

Faculty of Computer Science and Management,  
Wrocław University of Science and Technology,  
27 Wybrzeże Wyspiańskiego st., 50-370 Wrocław, Poland  
{rafal.michalski, joanna.koszela}@pwr.edu.pl

**Abstract.** Information on how to present visual content in an ergonomic way is crucial in various fields. The current study examines how the gender, race of a person, and picture-slogan relative location influence subjects' perceived effectiveness about a social advertisement. Relative scores of 45 participants from Wrocław University of Science and Technology were measured by binary pairwise comparisons and formally analyzed by the loglinear model for frequency data. While making comparisons, subjects' visual activity was recorded by an eye-tracking system. Mean fixation durations were comprehensively analyzed in the context of examined factors by a standard, five-way analysis of variance: *Picture race (black, yellow, white) × Picture gender (man, woman) × Picture location (left, right) × Stimulus location (left, right) × Subject gender (male, female)*. Subjective results regarding perceived effectiveness of the advertisement variants were compared with objective fixation durations.

**Keywords:** Eye tracking · Subjective preferences · Display design · Brain lateralization · Digital signage · Visual information ergonomics · Pairwise comparisons

## 1 Introduction

Knowledge how to present visual information in an ergonomic way is crucial in numerous areas beginning with the design of standard control panels, their digital versions, various forms of advertising like, e.g., classic banners, design of packages and their equivalents displayed by a variety of electronic devices. It is also well known that ergonomics of presenting visual information is influenced by various factors (e.g., [1, 7, 13–16]). For instance, it has been repeatedly shown that locating verbal stimuli on the right-hand side is more effective whereas the left-hand side is better for non-verbal components [4, 5]. This type of research are still continued in multiple contexts, e.g., Cao et al. [2] tried to answer the question if visual attention strategies of processing advertisements on web directories are more top-down or bottom-up. The ergonomics of the visual information

demonstration can be evaluated both from the subjective and objective perspective. Recent developments in eye tracking methodology and technological advancements, resulting in better and better and cheaper than ever eye-trackers, allows for more in-depth analysis of human visual behavior from an objective standpoint. For a comprehensive review of the visual activity tracking research in processing advertisements, please refer to Higgins et al. [11].

The current study constitutes another step towards improving our understanding in this regard in the context of digital presentation concerned with racial tolerance promotion and is a direct extension of our research described in Koszela-Kulińska and Michalski [12]. The main goal of the present research is to apply eye tracking methodology to examine the human visual activity depending on three factors, that is, the human race (*white, yellow, black*), gender (*males, females*), and position of the human image in relation to an advertisement's slogan (*picture-text, text-picture*). Specifically, we focused on identification and analysis of the level of visual attention and its distribution. Another aim was to gather once again participants' subjective preferences and compare them with objective eye tracking measures. A review of the crucial literature on investigated in this paper factors is provided in Koszela-Kulińska and Michalski [12].

## 2 Method

### 2.1 Design of the Experiment and Procedure

Subjects were to visually examine a series of picture pairs and select, by a mouse click, the banner that was more convincing in their opinion. The task question “*Which advertisement convinces you more?*” (Polish: “*Która reklama bardziej Cię przekonuje?*”) appeared at the top of each slide, see a sample comparison in Fig. 1. All banners presented a human image together with the campaign text: “*Racism? No, thanks.*” (Polish: “*Rasizm? Nie, dziękuję!*”).



**Fig. 1.** A sample comparison. Faces were not blurred during comparisons

Three factors were explored. The effect of the human race of a person presented in the advertisement was specified on three levels, that is, *white*, *black*, *yellow*. The gender of the visible person involved two levels (*man*, *woman*). Two levels were also employed for the picture-slogan relative location, namely: human picture either on the *left* or on the *right* hand side of the slogan text.

We used the same images as those employed in our previous research [12]. Five students visible in these pictures gave an informed consent for using the photographs for research purposes. The black female picture was bought on <http://www.shutterstock.com>. All images present persons with a neutral facial expression, casually dressed, and standing upright with their arms along a trunk. All the images are presented in Fig. 2.



**Fig. 2.** Pictures of persons used in the study. Faces were not blurred during comparisons.

Since the full factorial, within subject design was employed, all subjects assessed all twelve experimental conditions: 3 (*Races*)  $\times$  2 (*picture gender*)  $\times$  2 (*image-text relative location*). Each participant evaluated all possible pairs of investigated stimuli, that is,  $(12^2 - 12)/2 = 66$ . The data gathered in this way were used to formally verify whether participants' relative likings were significantly influenced by the investigated factors.

While performing randomly presented pairwise comparisons, objective visual behavior data were collected for all participants. For this purpose, a modern SMI RED500 (SMI) stationary infrared eye-tracker system was applied. The system records eye ball movements at 500 Hz sample rate with  $0.4^\circ$  accuracy. SMI BeGaze 3.7 was used for exporting raw fixation data for analyses in an external package. All the statistical analyses were performed in Statistica, version 13 (TIBCO Software Inc.).

The main part of the experiment was preceded by a short electronic questionnaire regarding participants' characteristics followed by an appropriate 5-point calibration and validation procedure. The examination was held in a laboratory environment that has an isolated room equipped with a desk, typical office chair, keyboard, optical computer mouse, and 21 in. monitor. Subjects' behavior was monitored through a one way mirror and registered by video cameras. Communication with participants took place via a set of microphones and speakers. SMI Experiment Center 3.7 software was employed to prepare and control the experiment. The software randomized the comparisons' display order. The stimuli locations on the screen were also randomized and counter balanced.



## 2.2 Participants

Overall, 45 white participants, at the age between 18 and 25 years, took part in the experiment (mean = 20.3, SD = 1.18). The sample was balanced with respect to gender. There were 22 males and 23 females students of Wrocław University of Science and Technology, Poland. Mean eye tracking ratio equaled 96.2% (SD = 4.28). There were no difference between mean eye tracking ratio for males and females ( $F(1, 43) = 0.293$ ,  $p = 0.59$ ). Three persons (2 men and 1 woman) were excluded from further analyses as their eye tracking ratios were lower than 90%. Another three subjects were not included in analyses since too big mean deviations ( $>1.5^\circ$ ) were discovered while examining validation procedure results. Finally, eye tracking data from 39 participants, including 18 males and 21 females, were examined in the section regarding visual activity.

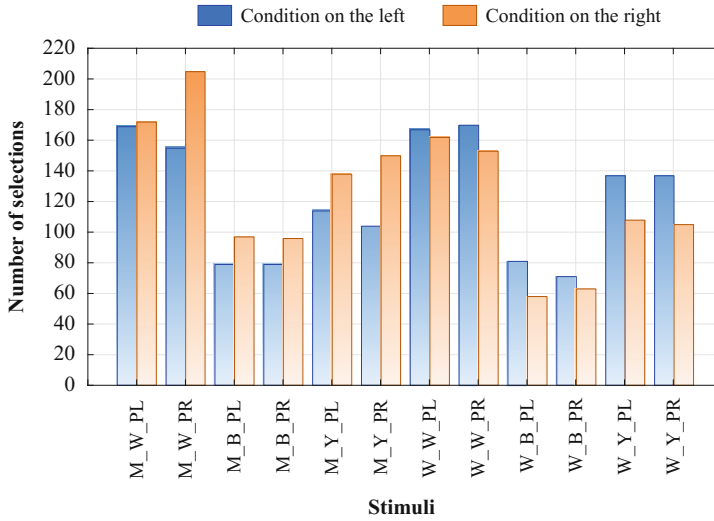
## 3 Results

### 3.1 Preferences – Pairwise Comparisons

**Basic Statistics.** Subjects preferences were collected by binary pairwise comparisons. The registered selections for all three examined effects along with the stimulus location on the screen are put together in Table 1 and graphically presented in Fig. 3. The data suggest that participants were generally more convinced by conditions including a white person, less persuaded by a yellow individual, and the least – by picture with the black one. It can also be observed that advertisements with men were chosen more often if the stimulus appeared on the right hand side of the screen whereas graphical panels with women this phenomenon was reversed. The option with white man presented on the right side of the advertisement and displayed on the right was selected the most frequently. The variant with black women on the left, presented on the right hand side of the screen was the least convincing.

**Table 1.** Frequency statistics for all examined factors.

No.	Picture gender	Picture race	Picture location in relation to text	Stimulus on the left	Stimulus on the right
1.	Man (M)	White (W)	Left (PL)	169	172
2.	Man (M)	White (W)	Right (PR)	155	205
3.	Man (M)	Black (B)	Left (PL)	79	97
4.	Man (M)	Black (B)	Right (PR)	79	96
5.	Man (M)	Yellow (Y)	Left (PL)	114	138
6.	Man (M)	Yellow (Y)	Right (PR)	104	150
7.	Woman (W)	White (W)	Left (PL)	167	162
8.	Woman (W)	White (W)	Right (PR)	170	153
9.	Woman (W)	Black (B)	Left (PL)	81	58
10.	Woman (W)	Black (B)	Right (PR)	71	63
11.	Woman (W)	Yellow (Y)	Left (PL)	137	108
12.	Woman (W)	Yellow (Y)	Right (PR)	137	105



**Fig. 3.** Frequencies of selections for all examined factors

**Loglinear Analysis.** A loglinear analysis was applied to verify whether the observations made in the previous section were statistically significant. The analysis involved five effects. Three main experimental factors were examined: *picture race* (PR: *white, black, yellow*), *picture gender* (PG: *man, women*), *picture-text location* (PL: *left, right*), along with the location of the presented advertisement on the screen (SL: *left, right*) and subject gender (SG: *male, female*). All possible interactions between these factors were also included in the initial model. In the resulting contingency table, minimum and maximum cell frequencies amounted to 22 and 111, respectively.

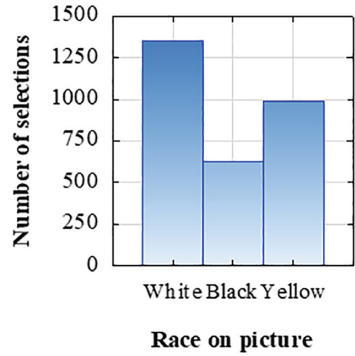
After applying the optimization procedure the recommended model involved one main effect: *Picture race* and two interactions: *Picture gender*  $\times$  *Subject gender*, and *Picture gender*  $\times$  *Stimulus location*. The maximum likelihood Chi-square value amounted to 28.6, with  $p = 0.91$ , and 40 degrees of freedom. The convergence was reached after two iterations with the criterion set at 0.01.

The selection frequencies for the significant *Picture race* factor are given in Table 2 and graphically demonstrated in Fig. 4. The data confirm the conjecture made in the previous section. They show the highest preferences when white individuals are presented in the advertisement. Black persons were the least persuasive for subjects.

The number of advertisement selections depending on the *Picture gender*  $\times$  *Subject gender* interaction are put together in Table 3 and illustrated in Fig. 5. We can observe that male subjects differently perceived tested advertisements than females. For females, the gender of the person presented in the stimulus was important. They, generally, preferred variants with men over those with women. Male subjects seem to pay no attention to the person gender.

**Table 2.** Number of selections for three examined races

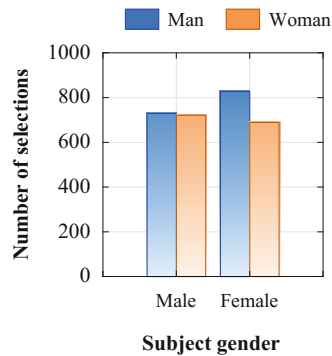
Picture race	No of selections
White	1353
Black	624
Yellow	993
Total	2970



**Fig. 4.** The influence of *Race* on the number of advertisement selections.

**Table 3.** Number of selections for the *Picture gender*  $\times$  *Subject gender* interaction

		Picture gender		Total
		Man	Woman	
Subject gender	Male	730	722	1452
	Female	828	690	1518
Total		1558	1412	2970

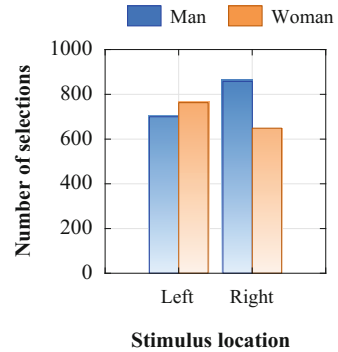


**Fig. 5.** The influence of *Picture gender*  $\times$  *Subject gender* on subjects' preferences

The influence of the *Picture gender*  $\times$  *Stimulus location* interaction on subjects preferences is demonstrated in Fig. 6. Corresponding frequencies are provided in Table 4. The results suggest that when a stimulus appeared on the left part of the screen, subjects tend to select advertisement with women. If the stimulus was demonstrated on the right, the situation was reversed: variants with men were more preferred.

**Table 4.** Number of selections for the *Stimulus location*  $\times$  *Picture gender* interaction

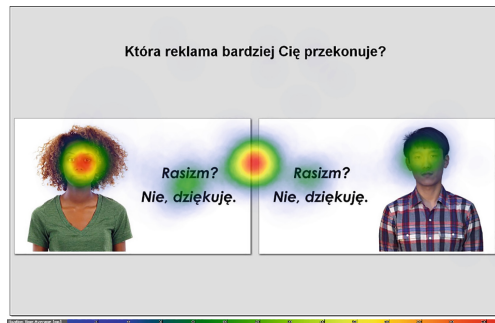
		Picture gender		Total
		Man	Woman	
Stimulus location	Left	730	722	1452
	Right	828	690	1518
Total		1558	1412	2970



**Fig. 6.** The influence of *Stimulus location*  $\times$  *Picture gender* on subjects' preferences

### 3.2 Eye-Tracking Results

Among numerous visual activity parameters, the fixation durations are among the most interesting and most often analyzed. Longer fixations usually mean that subjects' visual attention was drawn to a specific part of the stimulus. Heat maps prepared for all the 66 pairwise comparison slides displayed in the current investigation exhibit very similar pattern. A sample of such a heat map is presented in Fig. 7. These data clearly show that participants generally focused on presented faces while considerably shorter average fixation times were detected on slogans. The top task order text drew attention only sporadically. Long fixations visible at the center of the comparison resulted from focusing on the cross that was displayed before each advertisement appeared.



**Fig. 7.** Sample heat map with average fixation durations for one of the examined comparisons.

A five-way analysis of variance *Picture race* (PR)  $\times$  *Picture gender* (PG)  $\times$  *Picture location* (PL)  $\times$  *Stimulus location* (SL)  $\times$  *Subject gender* (SG) was employed to verify if the mean fixation durations were significantly influenced by these effects. The obtained results regarding significant factors and two-way interactions are put together in Table 5. All other interactions were statistically insignificant.

**Table 5.** Five-way Anova results for significant factors and interactions.

Effect	Degrees of freedom	Mean sum of squares	F	p	$\eta^2$
<i>Picture race (PR)</i>	2	46363	2.36	0.0942 <sup>**</sup>	0.00024
<i>SL</i> × <i>SG</i>	1	115654	5.89	0.0152 <sup>*</sup>	0.00030
<i>PG</i> × <i>SG</i>	1	59676	3.04	0.0812 <sup>**</sup>	0.00015
<i>SL</i> × <i>PL</i>	1	56686	2.89	0.089 <sup>**</sup>	0.00015
<b>Error</b>	19707	19626			

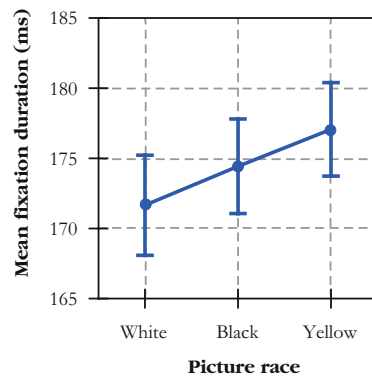
<sup>\*</sup> p < 0.05

<sup>\*\*</sup> p < 0.1

The analysis revealed statistically significant influence of *Picture race*, and three interactions: *Stimulus location* × *Stimulus gender*, *Picture gender* × *Stimulus gender*, and *Stimulus location* × *Picture location* on mean fixation durations recorded for a given experimental condition. The *Picture race* effect, illustrated in Fig. 8 (whiskers in all figures denote 95% confidence intervals) shows that the least visual attention was devoted to white models, whereas yellow models were explored the most intensely. The LSD Fisher post-hoc tests (Table 6) revealed that the difference only between these two levels were statistically meaningful.

**Table 6.** Results of LSD Fisher post-hoc tests for *Picture race* mean fixation durations

Picture race	White	Black	Yellow
White	×		
Black	0.26	×	
Yellow	0.034	0.31	×

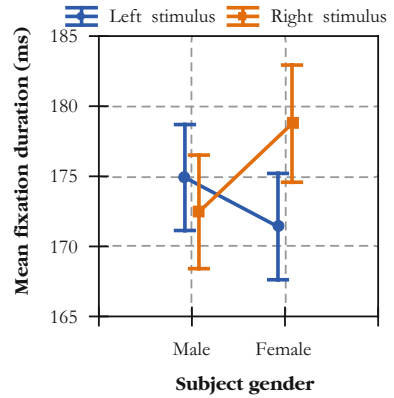


**Fig. 8.** Influence of *Picture race* on mean fixation durations

Table 7 contains the LSD Fisher's pairwise comparisons for the *Stimulus location* × *Subject gender* interaction (Fig. 9). Only in two cases the differences occurred to be significant. For right stimulus location, females' mean fixations durations were longer than the males' ones. Females paid more visual attention when the stimulus appeared on the right than on the left hand side of the screen.

**Table 7.** Results of LSD Fisher post-hoc tests for *Stimulus location*  $\times$  *Subject gender* mean fixation durations

Stimulus location		Left		Right	
	Subject gender	Male	Female	Male	Female
Left	Male	×			
	Female	0.27	×		
Right	Male	0.41	0.81	×	
	Female	0.17	0.015	0.034	×

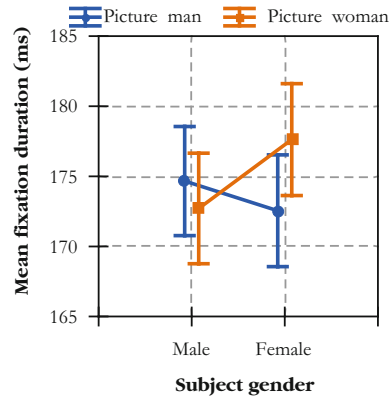


**Fig. 9.** Influence of *Stimulus location*  $\times$  *Subject gender* on mean fixation durations

The *Picture gender*  $\times$  *Subject gender* interaction demonstrated in Fig. 10 seems to be quite weak. The analysis of post-hoc comparisons given in Table 8 suggests that there is only one meaningful ( $\alpha = 0.1$ ) difference: the average fixation durations for female subjects were longer for advertisements with women than with men.

**Table 8.** Results of LSD Fisher post-hoc tests for *Picture gender*  $\times$  *Subject gender* mean fixation durations

Picture gender		Men		Woman	
	Subject gender	Male	Female	Male	Female
Man	Male	×			
	Female	0.53	×		
Woman	Male	0.65	0.86	×	
	Female	0.31	0.10	0.14	×

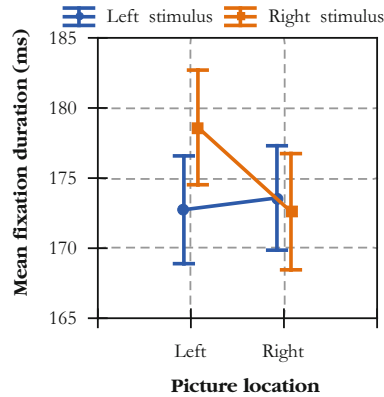


**Fig. 10.** Influence of *Picture gender*  $\times$  *Subject gender* on mean fixation durations

The *Stimulus location*  $\times$  *Picture location* interaction is graphically illustrated in Fig. 11. Post-hoc pairwise comparisons that are put together in Table 9, indicate two significant differences. When stimulus is on the right, the advertisements with pictures located on the left attract visual attention for longer than those with pictures placed on the right side of the slogan. Variants with left positioned pictures have also longer fixations when the stimulus was displayed on the right than on the left side of the monitor.

**Table 9.** Results of LSD Fisher post-hoc tests for *Stimulus location*  $\times$  *Picture location* mean fixation durations

Stimulus location		Left		Right	
	Picture location	Left	Right	Left	Right
Left	Left	$\times$			
	Right	0.85	$\times$		
Right	Left	0.048	0.068	$\times$	
	Right	0.79	0.65	0.030	$\times$



**Fig. 11.** Influence of *Stimulus location*  $\times$  *Picture location* on mean fixation durations

## 4 Discussion and Conclusion

The present research was focused on exploring visual attention recorded while performing binary pairwise comparisons of social advertisements. Digital versions of banners were differentiated by three factors, i.e., race and gender of a person picture along with the text-picture relative position. The stimulus location on the screen and subject gender were counterbalanced in this study, and they were also included in analyses.

The loglinear analysis of selection frequencies showed that white models were the most convincing, while the smallest impact was noted for advertisements with black persons. The race effect occurred to be statistically significant for the fixation duration analysis. It appears that the most convincing advertisements with white persons were associated with the shortest mean fixation durations. Such a result may be related with the subjects' race. All participants were white and, probably, other races were deemed more interesting for them, all the more that in Poland black and yellow people are very scarce. However, it is not clear why the longest average fixations were observed for adverts with yellow models. This will require supplementary research. Subsequent studies could also include other than white subjects.

Female subjects were more persuaded when a man appeared on the stimulus. Again, similar to the race effect, correspondence between preferences and eye tracking data was noticed. The interaction revealed that females processed longer stimuli with women, but these advertisement were less convincing for them than variants with men. For stimuli located on the right, versions with a man were more convincing, and when the stimulus appeared in the left part, subjects were inclined to choose conditions with a woman model. These subjective results have no significant correspondence with the attention distribution measured in the present research only by fixation durations. However, it is not excluded that there are some relations with other visual activity measures [6, 8], which should be further examined.

The analysis of eye-tracking data provided also additional insight of subjects' visual behavior that has not got its equivalent in presented subjective scores. The strongest influence on mean fixation durations (the biggest  $\eta^2$  value) had the interaction of *Stimulus location* and *Subject gender*. For right stimulus location, females' mean fixations durations were longer than the males' ones. Furthermore, females paid more visual attention when the stimulus appeared on the right than on the left hand side of the screen.

The obtained subjective outcomes seem to be in a contradiction with our previous findings [12] where advertisements with a black person were decidedly the most preferred, and participants liked more female models than male ones. The discrepancy probably comes primarily from the different question used. In the earlier study, we asked "*Which advertisements is prettier?*", whereas in the present investigation the question was "*Which advertisement convinces you more?*". Apparently, these two tasks are not identical and subjects may consider prettier advertisements as less persuading. This finding can be pursued further in future research, however, both researchers and practitioners should be very precise and cautious while specifying experimental tasks.

Another source of inconsistency between these two studies is concerned with the sample. Previously, we examined students from the Academy of Art and Design whereas here participated students from the technical university. Considerably different profiles of these two groups could have influenced outcomes. Moreover, in contrast to the current study, the previous sample was not counterbalanced with regard to the subject gender. Therefore, the interaction *Picture gender*  $\times$  *Subject gender* observed in the present research could not be detected in the previous investigation, due to the highly unbalanced Anova (23 females versus 11 males).

The outcomes of the visual activity distribution are, generally, not controversial. The reported focus on the person face has been repeatedly confirmed in numerous studies (e.g., [17]). Similarly, the visual concentration on the panel center during general comparisons of various stimuli was also reported (e.g., [3]).

Presented and discussed in this research results, should be treated with appropriate reserve especially due to the moderate in size, and highly homogenous sample. However, demonstrated findings may be helpful in designing more effective social advertisements and they certainly constitute a next step in better understanding visual behavior in the marketing context. Further research directions can also involve more sophisticated approaches for modelling visual data such as Markov models (c.f., [9, 10]).

**Acknowledgments.** The research was partially financially supported by Polish National Science Centre Grant No. 2017/27/B/HS4/01876.

## References

1. Brewer, C., Rettie, R.: The verbal and visual components of package design. *J. Prod. Brand Manage.* **1**, 56–70 (2000)
2. Cao, Y., Qu, Q., Duffy, V.G., Ding, Y.: Attention for Web directory advertisements: a top-down or bottom-up process? *Int. J. Hum. Comput. Interact.* **35**(1), 89–98 (2019). <https://doi.org/10.1080/10447318.2018.1432162>



3. Djamasbi, S., Siegel, M., Tullis, T.: Visual hierarchy and viewing behavior: an eye tracking study. In: Jacko, J.A. (ed.) *Human-Computer Interaction. Design and Development Approaches*, pp. 331–340. Springer, Heidelberg (2011)
4. Ellis, A.W., Miller, D.: Left and wrong in adverts: neuropsychological correlates of aesthetic preference. *Br. J. Psychol.* **2**, 225–229 (1981)
5. Friedman, A., Polson, M.C.: Hemispheres as independent resource systems: limited-capacity processing and cerebral specialization. *J. Exp. Psychol. Hum. Percept. Perform.* **5**, 1031–1058 (1981)
6. Goldberg, J.H., Kotval, X.P.: Computer interface evaluation using eye movements: methods and constructs. *Int. J. Ind. Ergon.* **24**, 631–645 (1999)
7. Grobelny, J., Michalski, R.: Various approaches to a human preference analysis in a digital signage display design. *Hum. Factors Ergon. Manuf. Serv. Ind.* **21**(6), 529–542 (2011). <https://doi.org/10.1002/hfm.20295>
8. Grobelny, J., Jach, K., Kuliński, M., Michalski, R.: Śledzenie wzroku w badaniach jakości użytkowej oprogramowania. Historia i mierniki. In: *Materiały konferencyjne: Interfejs użytkownika – Kansei w praktyce*, pp. 1–9. Wydawnictwo PIWSTK, Warszawa (2006). <https://repin.pjwstk.edu.pl/xmlui/handle/186319/166>
9. Grobelny, J., Michalski, R.: Applying hidden Markov models to visual activity analysis for simple digital control panel operations. In: Świątek, J., Wilimowska, Z., Borzemski, L., Grzech, A. (eds.) *Advances in Intelligent Systems and Computing*, pp. 3–14. Springer (2017). [https://doi.org/10.1007/978-3-319-46589-0\\_1](https://doi.org/10.1007/978-3-319-46589-0_1)
10. Grobelny, J., Michalski, R.: Zastosowanie modeli Markowa z ukrytymi stanami do analizy aktywności wzrokowej w procesie oceny wirtualnych opakowań techniką porównywania parami. *Zeszyty Naukowe Politechniki Poznańskiej. Organizacja i Zarządzanie* **73**, 111–125 (2017). <https://doi.org/10.21008/j.0239-9415.2017.073.08>
11. Higgins, E., Leinenger, M., Rayner, K.: Eye movements when viewing advertisements. *Front. Psychol.* **5** (2014). <https://doi.org/10.3389/fpsyg.2014.00210>
12. Koszela-Kulińska, J., Michalski, R.: The effects of the anthropological race, gender and location of verbal-pictorial stimuli on the usability of visual information conveyance. In: Kurosu, M. (ed.) *Human-Computer Interaction: Users and Contexts*, pp. 441–451. Springer (2015). [https://doi.org/10.1007/978-3-319-21006-3\\_42](https://doi.org/10.1007/978-3-319-21006-3_42)
13. Lesch, M.F., Powell, W.R., Horrey, W.J., Wogalter, M.S.: The use of contextual cues to improve warning symbol comprehension: making the connection for older adults. *Ergonomics* **56**(8), 1264–1279 (2013). <https://doi.org/10.1080/00140139.2013.802019>
14. Ozkan, F., Ulutas, H.B.: Using eye-tracking data to evaluate medicine information leaflets on-screen. *J. Math. Stat. Sci.* **3**(12), 364–376 (2017)
15. Santos, C., Neto, M.J.P., Neves, M.: The influence of infographics in accessing information: multidimensionality in visual representation and configuration of different media. In: Rebelo, F., Soares, M.M. (eds.) *Advances in Ergonomics in Design*, pp. 497–508. Springer, Cham (2019)
16. Wang, Y., Liu, Q., Lou, W., Xiong, D., Bai, Y., Du, J., Guo, X.: Ergonomics evaluation of large screen display in cockpit based on eye-tracking technology. In: Long, S., Dhillon, B.S. (eds.) *Man-Machine-Environment System Engineering*, pp. 347–356. Springer, Singapore (2019)
17. Yarbus, A.L.: *Eye Movements and Vision*. Plenum Press, New York (1965)



# How to Read Red: Red in Western Culture (Part II)

Leonor Ferrão<sup>1,2</sup>(✉)

<sup>1</sup> Faculdade de Arquitetura, CIAUD – Centro de Investigação em Arquitetura, Urbanismo e Design, Universidade de Lisboa, Rua Sá Nogueira, Polo Universitário, Alto da Ajuda, 1349-063 Lisbon, Portugal  
lferrao@fa.ulisboa.pt

<sup>2</sup> CITAD – Centro de Investigação em Território, Arquitetura e Design, Universidade Lusíada de Lisboa, Rua da Junqueira, 188-198, 1349-001 Lisbon, Portugal

**Abstract.** This article is part of the research project “Glossolalia, an alphabet on Design”. It focuses on the symbolic features of the color red, particularly in material culture in the West, traveling through words representing the various actions that elicit or derive from the use of red (correcting, punishing, prohibiting, protecting, distinguishing, loving, politicizing...). It also discusses similarities in the meanings of pink, purple and orange, the three colors that border RED.

**Keywords:** Human factors · Western culture · Material culture · Semantics · Red (Color)

## 1 Introduction

This is the second part of a first article [1]. The symbolic ambivalence of the color red and its omnipresence in Western culture requires more than the recommended length for submitted articles, so a second (and final) part is justified to address other possibilities of using this color, although, however, it does not cover all such possibilities.

In Antiquity, white was a non-color and black was associated with dirt. Red was *the* color [2]. Therefore, in European languages, the word is confused with the very notion of color (and in some, such as Russian, it is synonymous with beauty). The ubiquity of red is extraordinary: it occurs alone or accompanied, often by black, as in the title of Stendhal – *Le rouge et le noir* (1830) – or in some games, such as roulette.

## 2 Correcting, Punishing, Prohibiting, Protecting

Writing in red is considered bad manners, but red is still used for (handwritten) corrections written on typographic proofs (usually printed in black on white paper) and it is also in red that teachers at all levels correct their students’ written tests.

In soccer, the top sport in European countries, black and red are associated with the exercise of authority on the pitch (the refereeing team is dressed fully or partially in black).

The referee has several tools for communicating with players: verbal language, arm and head gestures, sounding the whistle around his neck and two cards, a yellow one representing a warning and a red one, which can be used immediately after a player has been shown the yellow card or without a prior warning. The red card means immediate expulsion from the game – it is shown very assertively, with the arm outstretched and followed by a gesture indicating the punished player should leave the pitch (Fig. 1).



**Fig. 1.** Red card being shown to Zidane in the France-Italy match at the end of the 2006 FIFA World Cup [3, 4].

The red card is also a punishment for the team of the expelled player, because it loses a team member on the pitch; the punishment remains until the following game, although it is lessened: the punished player cannot play in the second game, but the coach can introduce another to replace him [5]. Use of the two cards is relatively recent. They were introduced in the 1970 Soccer World Cup in Mexico, recovering the meanings of yellow (warning) and red (punishment, prohibition, interdiction) [6]. From soccer, red and yellow cards were extended to other team sports, introduced by the international federations responsible for regulating them.

Unlike most color applications, the interpretation of which is eminently local (i.e. cultural), some uses of yellow, red and blue are transcultural (global). This is the case for traffic lights, although the red color is associated with the idea of prohibition for protection. International standards for safety symbols are defined by ISO 3864 [7–10]. Red is also the color of firefighters’ uniforms and fire engines and is used by two equivalent humanitarian institutions for the protection and assistance of people in war scenarios, linked to two symbols which have religious connotations, the Cross and the Crescent (the Red Cross and Red Crescent movements).

### 3 Distinguishing

The term “blue blood” is used to distinguish nobility, as opposed to achieving status through enrichment. Use of this expression seems to have originated in Spain in the late Middle Ages, early Modern Age, then spreading to other places and languages. “Blue blood” is associated with a white complexion, as opposed to the darker skin tones of

the Moors, ranging from dark gold to black [11]. It is therefore an attribute of purity that seems to lie in a characteristic of very pale skins, whose fineness reveals the fine blue features of the veins. The Spanish and Portuguese aristocracies developed a particular obsession with purity of blood, as observed by endogamous practices to eradicate suspicions of contamination by Jewish and Moorish blood, and the need to prove that they belong to the select group of Old Christians (as opposed to New Christians, i.e. Jews and Moors who converted to Catholicism to escape exile or the Inquisition).

Red has been an aristocratic and omnipresent color in heraldry since the mid-11th century. What mattered, for medieval tastes, was the presence of red (in heraldry, it is called *gules* in English and *gueules* in French), and it could be light or dark, rosy, orange or violet. Richard the Lionheart (1157–1199) adopted *gules* with three leopards from 1195 [12] (Fig. 2). A medieval manuscript depicts two of the kings involved in the 3rd Crusade (Fig. 3): King Richard and his horse wear the colors of England, distinguishing themselves from Philip II of France, dressed in blue (which in heraldry is called *azure*) with the fleur-de-lis.



**Fig. 2.** *Chronica majora* by Matthew of Paris (fragment of illuminated manuscript from the 13th century with the arms of Richard the Lionheart) [13].



**Fig. 3.** *Les Histories d'Outremer*, 1261 (the meeting of King Richard I of England with King Philip II of France) [14].

Until the 19th century, there was a legend that families using *gules* in their arms had at least one ancestor who had been involved in the crusades.

## 4 The Color of Love

Red is the color of beauty and of mystical, carnal love. In some countries, prostitutes were forced to wear red on a garment to mark themselves out from other women. The association between the color red and prostitution dates back to the *Apocalypse* and the *Book of Revelation*. In several illuminated manuscripts, the whore of Babylon – a personification of the Anti-Christ – appears in red (Fig. 4). She also appears in red in

pieces by William Blake (1857–1827) (see Fig. 5 below) and Jean-Michel Basquiat (1960–1988) (see Fig. 6 below).

Red fruits are associated with love, whether chaste or carnal. Cherries symbolize the redemption of man through the sacrifice of Christ, but also youth and spring; using them as a gift is a way of declaring love to someone.



**Fig. 4.** *Douce Apocalypse*, Ms. illuminated, c. 1265–70 [15].



**Fig. 5.** *The Whore of Babylon* by William Blake, 1809 [16].



**Fig. 6.** *Wine of Babylon* by Jean-Michel Basquiat, 1984 [17].

In Antiquity, the pomegranate is associated with the myth of the Rape of Proserpina. In the Middle Ages, it became a symbol of the Resurrection; along with apples, pomegranates are Eucharist symbols. When a pomegranate appears in the hands of the Virgin, it is a symbol of chastity, alluding to an excerpt from the *Song of Songs*. Given its physical characteristics, because inside the outer shell there are many berries, it is associated with fertility [18]. Cesare Ripa (c.1560–c.1622) also considered it a symbol of Concord and Conversation [19].

## 5 Politicizing

At the end of the 18th century, red took on a political dimension for the first time [20]. The first examples occur in the symbols and posters of the French Revolution: the Phrygian cap, the tricolor flag, the rooster, whose crowing symbolizes the birth of a new day and announces a new time of hope, “freedom, equality and fraternity” (Fig. 7). Keeping its political overtones, red (Bolshevik) contrasted with white (monarchical), distinguishing the two warring Russian armies, the “Reds” (Communists) and the “whites” (those faithful to the Tsar).

The revolutionary connotation lies behind its use in flags of all socialist and communist parties, in their highly diverse shades and ideological affiliations, extending to the flags of communist states. Nonetheless, many flags of non-communist countries also contain red, including the flags of countries which are no longer Communist, as is the case of the Russian Federation (Fig. 8 shows the evolution of the Union of Soviet Socialist Republics flag between Dec. 1922 and Dec. 25, 1991).





**Fig. 7.** Prints made in Paris (circa 1792) [21, 22].



**Fig. 8.** Five USSR flags between 1922 and 1991 [23].

Red is also the dominant color on Russian constructivist posters (Fig. 9). Rodchenko (1891–1956) uses some letters from the word “Lenin” to compose other words. In this very particular context, from circulation of the color red to connotations of “red” (meaning “communist”), technical reasons further underlie its use.



**Fig. 9.** Russian political propaganda poster by Aleksandr Rodchenko, 1924 [24].

The same (technical) argument and, of course, Russian constructivism (and communist ideology, inseparable from the artistic avant-garde there) inspire the work of El Lissitzky (1890–1941), a true “visual poem” serving Vladimir Mayakovsky’s poetic text (Fig. 10).



**Fig. 10.** El Lissitzky (1890–1941), 12 spreads of *Dlia golosa* (For the Voice), poem by Vladimir Mayakovsky, 1923 [25].

Reflecting the Russian avant-gardes’ strong visual appeal for the sensitivity of Western artists and looking to other contexts of circulation beyond the usual art sites (art galleries, *salons* and museums), note this advertisement by Kurt Schwitters (1887–1948) in *Mertz* magazine for the Pelikan brand, exploring the graphic versatility of the color red, here stripped of any political connotations (Fig. 11).

The same graphic line inspires the *Neue Typographie* (*New Typography*) movement started by Jan Tschichold (1902–1974) [27], at the origin of the so-called Swiss Design or International Style [28].

Returning to its eminently political potential, red “burned” in the May 1968 posters. Although the USA’s Democratic Party is far from being “red”, it uses on this color, opposing the Republicans’ blue. Curiously, or perhaps not, parties from a vast range of backgrounds – with the exception of environmentalist parties (which usually use green) – from the radical right to the radical left, follow that color code.

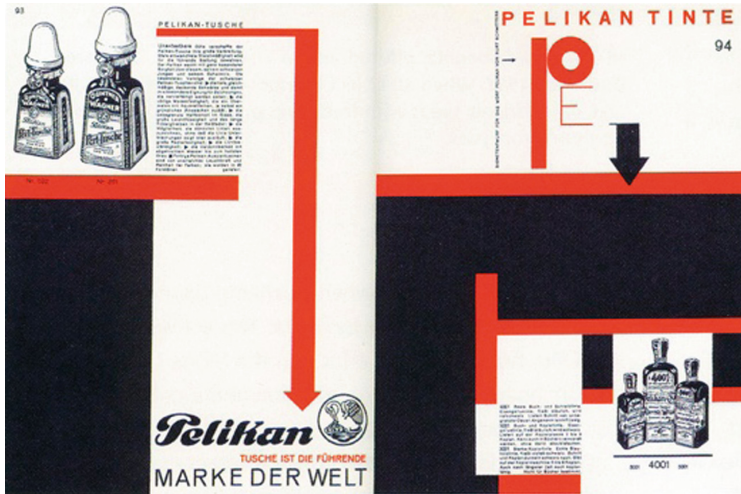


Fig. 11. Kurt Schwitters (1887–1948), advertisement for Pelikan in *Merz* magazine, 1924 [26].

## 6 On the Boundary: Pink, Orange, Purple

A passion for certain flowers, such as poppies, tulips, carnations and peonies – which rival roses in the beauty of their form and color – manifests itself in many aspects of Western material culture, namely, patterns for fabrics, tapestries, male and female clothing accessories, paintings, political symbols and tattoos. The rose has a prominent place, also because its name designates a color, although red roses are also very common and very beautiful (yellow roses were only known of in the 18th century). European social elites of the 17th and 18th centuries were great lovers of still lifes, a genre that alludes to the brevity of life. The painters of northern Europe were skilled in this genre, with Alexander Adriaenssen (1587–1661) and Cornelisz de Heem (1631–1695) featuring prominently among them. The still life in Fig. 12 contains various shades of red; in Fig. 13, orange is added. The transparency and shine of the glass jugs of water (and the reflections of the light on them) denote the mastery of the painters and the fragility of life (*memento mori*). In the two paintings, there are butterflies that flutter or land on the flowers, but they also live for few hours, even less than the cut flowers standing in water.

In 18th century, women of the Catholic European aristocracy wore bright colors. In France, Mme. Pompadour (1721–1764) (Fig. 14) and Marie Antoinette (1755–1793) (Fig. 15) loved the color pink, until then a color used, essentially, in male court dress (Fig. 16), transforming it into a sign of refinement and *bon goût*.





**Fig. 12.** *Still life* by Alexander Adriaenssen, c. 1650 [29].



**Fig. 13.** *Still life* by Cornelisz de Heem, mid 17th century [30].



**Fig. 14.** *Marquise de Pompadour* by François Boucher, 1758 [31].



**Fig. 15.** *Archiduchess Marie Antoinette of Austria, Future Queen of France, at Age Seven* by Jean-Etienne Liotard, 1762 [32].



**Fig. 16.** *The Woolaston White Children* by George Romney inspired by Antony van Dick, c. 1780 [33].

The color pink was also one of the colors of choice for rococo environments (along with white, light blue and gold). Sophia Coppola's *Marie Antoinette* celebrates the favorite color of the ill-fated Queen of France: in the interior design of her apartments at Versailles Palace (Fig. 17), dresses, ribbons, shoes (designed by Manolo Blahnik), and even in the candy (made by Ladurée) (Fig. 17).



**Fig. 17.** *Marie Antoinette*, film directed by Sophia Coppola, 2006 [34, 35].

In English, “pink” can mean “excellence” or “perfection”, as seen in an excerpt from *Romeo and Juliet*, and it contains another semantic element that works only in English (“rose” is also the past participle of the verb “rise”):

“MERCUTIO  
Nay, I am the very pink of courtesy.  
ROMEO  
Pink for flower.  
MERCUTIO  
Right.  
ROMEO  
I knew it when I ‘rose’ this morning.” [36]

The portraits of Pope Innocent X, painted by Diego Velázquez (1599–1660) (Fig. 18) and Francis Bacon (1909–1992) (Fig. 19), despite all their differences, demonstrate the symbolic affinity between red and purple [37].



**Fig. 18.** Portrait of Pope Innocent X by Diego Velázquez (c. 1650) [38].



**Fig. 19.** Portrait of Innocent X by Francis Bacon (1953) [39].

Other works by Francis Bacon (Fig. 20) demonstrate such disparate influences as Velázquez, Rembrandt (1606–1669) (Fig. 21) and Chaim Soutine (1893–1943) (Fig. 22).



**Fig. 20.** *Figure with Meat* (portrait of Innocent X) by Francis Bacon, 1954 [40].

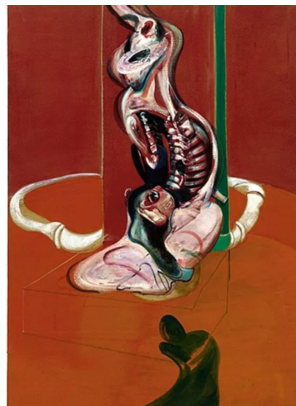


**Fig. 21.** *Carcass of Beef* by Rembrandt, 1657 [41].



**Fig. 22.** *Le Bœuf* by Chaim Soutine, c. 1923 [42].

In the triptych *Three Studies for a Crucifixion* (Fig. 23), Bacon continues a reflection that goes back to 1944, at the height of the atrocities committed during World War II, to paint violence.



**Fig. 23.** *Three Studies for a Crucifixion* by Francis Bacon, 1962 [43].

Returning to red, it is the color favored by children, because it is “playful”, festive, and very common in children’s clothing [44]. Red appears in several European tales of remote origin, told orally, such as “Little Red Riding Hood”, fixed in two versions, one



from the 17<sup>th</sup> century by Charles Perrault (1628–1703) and the other from the 19<sup>th</sup> century by the Brothers Grimm (Fig. 24) [45, 46]; or as “The Red Shoes”, retold by Hans Christian Andersen (1805–1875) [47].



Fig. 24. Three pages of *Little Red Riding Hood* illustrated by Walter Crane, 1875 [48].

Violence associated with desire and sexual drive is clear in both [49, 50], which helps us understand why violence towards children and women persists in families in Western culture. They appear as uncritical testimonies of reality or common narratives to support its normality. Whatever the reason or reasons that justify it, returning to colors, red still preserves an ambiguity between Good and Evil, Ugly and Beautiful, Purity and Lust, Love and Hate, Nobility and Vulgarly, Redemption and Perdition.

**Acknowledgments.** This research is financed by national funds by FCT – Fundação para a Ciência e a Tecnologia, in the scope of the projects SFRH/BPD/98427/2013, UID/EAT/04008/2019, and UID/AUR/04026/2019. The author is grateful to FCT for its support for the postdoc research entitled *Glossolalia: An Alphabet of Critical Keywords on Design*, to CIAUD – Centro de Investigação em Arquitetura, Urbanismo e Design, Faculdade de Arquitetura, Universidade de Lisboa, Portugal, and to CITAD – Centro de Investigação em Território, Arquitetura e Design, Universidade Lusíada, Portugal.

## References

1. Ferrão, L.: Color in Glossolalia: red in western culture (Part I). In: Ho, A.G. (ed.) *Advances in Human Factors in communication of Design*. AHFE 2018, vol. 796, pp. 15–25. Springer, Cham (2019). [https://doi.org/10.1007/978-3-319-93888-2\\_2](https://doi.org/10.1007/978-3-319-93888-2_2)
2. Pastoureau, M., Simonnet, D.: *Couleurs, le grand livre*, p. 26. Éditions Panama, Paris (2008)
3. France-Italie 2006: les aveux de l'arbitre sur l'expulsion de Zidane. <https://rmcsport.bfmtv.com/football/france-italie-2006-aveux-l-arbitre-l-expulsion-zidane-546957.html>
4. Les matchs les plus marquants de l'histoire de la Coupe du monde de foot. [https://www.mennenfrance.fr/article/les-matchs-les-plus-marquants-de-l-histoire-de-la-coupe-du-monde-de-foot\\_a72/1](https://www.mennenfrance.fr/article/les-matchs-les-plus-marquants-de-l-histoire-de-la-coupe-du-monde-de-foot_a72/1)
5. The International Football Association Board (IFAB): Laws of the game 2017/2018. [https://football-technology.fifa.com/media/1245/lotg\\_17\\_18\\_en.pdf](https://football-technology.fifa.com/media/1245/lotg_17_18_en.pdf)

6. FIFA, Ken Aston, the inventor of yellow and red cards. <https://www.fifa.com/development/news/y=2002/m=1/news=ken-aston-the-inventor-yellow-and-red-cards-80623.html>
7. International Organization for Standardization. <https://www.iso.org/standard/51021.html>
8. International Organization for Standardization. <https://www.iso.org/standard/66836.html>
9. International Organization for Standardization. <https://www.iso.org/standard/55814.html>
10. International Organization for Standardization. <https://www.iso.org/standard/51000.html>
11. Pastoreau, M.: Red: The History of a Color. Transl. by J. Gladding, pp. 152–154. Princeton University Press, Princeton and Oxford (2016)
12. Humphrey-Smith, C.: Why three leopards? Coat of Arms. 126 (1983). <https://www.theheraldrysociety.com/articles/why-three-leopards/>
13. Royal MS 14 C VII. [http://www.bl.uk/manuscripts/Viewer.aspx?ref=royal\\_ms\\_14\\_c\\_vii\\_f085v](http://www.bl.uk/manuscripts/Viewer.aspx?ref=royal_ms_14_c_vii_f085v)
14. Richard and Philip of France, French manuscript of 1261. [https://en.wikipedia.org/wiki/Richard\\_I\\_of\\_England#/media/File:Philippe\\_Auguste\\_et\\_Richard\\_IIIe\\_croisade.jpg](https://en.wikipedia.org/wiki/Richard_I_of_England#/media/File:Philippe_Auguste_et_Richard_IIIe_croisade.jpg)
15. Douce Apocalypse, Bodleian Ms180 - p. 078. [https://upload.wikimedia.org/wikipedia/commons/3/3c/Douce\\_Apocalypse\\_-\\_Bodleian\\_Ms180\\_-\\_p.078\\_Destruction\\_of\\_the\\_great\\_whore.jpg](https://upload.wikimedia.org/wikipedia/commons/3/3c/Douce_Apocalypse_-_Bodleian_Ms180_-_p.078_Destruction_of_the_great_whore.jpg)
16. William Blake, the Whore of Babylon. [https://upload.wikimedia.org/wikipedia/commons/4/41/William\\_Blake\\_whore\\_babylon.jpg](https://upload.wikimedia.org/wikipedia/commons/4/41/William_Blake_whore_babylon.jpg)
17. Wine and Whore of Babylon. <https://thegenealogyofstyle.wordpress.com/2014/10/04/wine-and-whore-of-babylon/>
18. Impelluso, L.: La natura e i suoi simboli: piante, fiori e animali (Nature and its symbols: plants, flowers and animals), pp. 144–145. Electa, Milano (2003)
19. Ripa, C.: Iconografia, p. 81. Roma, Lepido Facij (1603 [1593])
20. Pastoreau, M.: Red: Rouge: histoire d'une couleur (The History of a Color), p. 163. Éditions du Seuil, Paris (2016)
21. Unité et indivisibilité de la République. <https://gallica.bnf.fr/ark:/12148/btv1b8412144g/f1.item.r=Unit%C3%A9%20et%20indivisibilit%C3%A9%20de%20la%20R%C3%A9publique>
22. Unité, indivisibilité de la République. Liberté, égalité, fraternité, ou la mort: Dieu, peuple, loi. <https://gallica.bnf.fr/ark:/12148/btv1b69503824.item>
23. Flag of the Soviet Union. [https://en.wikipedia.org/wiki/Flag\\_of\\_the\\_Soviet\\_Union](https://en.wikipedia.org/wiki/Flag_of_the_Soviet_Union)
24. Rodchenko. <https://artedeximena.wordpress.com/arte-contemporaneo/constructivismo/ua-cartel-de-propaganda-rodchenko-1924-litografia/>
25. Outstanding Constructivism Typography - El Lissitzky and Vladimir Mayakovsky. <https://twitter.com/chladek/status/577167446441852930>
26. Kurt Schwitters – Pelikan. <http://indexgrafik.fr/kurt-schwitters/kurt-schwitters-pelikan-02/>
27. Tschichold, J.: The new typography. Transl. by Ruari McLean. Introd. by Robin Kinross. University of California Press, Berkeley (1995 [1928])
28. Eskilson, S.: Graphic Design a New History. Laurence King Publishers, London (2007)
29. Alexander Adriaenssen, still life (c.1650). <http://wga.hu>
30. Cornelisz de Heem, still life, mid 17th century. <http://wga.hu>
31. François Boucher, Marquise de Pompadour (1758). <http://wga.hu>
32. Jean-Étienne Liotard, L'Archiduchesse Marie-Antoinette d'Autriche, future Reine de France, à l'âge de 7 ans (1762). [https://commons.wikimedia.org/wiki/File:Jean-%C3%89tienne\\_Liotard,\\_L%27Archiduchesse\\_Marie-Antoinette\\_d%27Autriche,\\_future\\_Reine\\_de\\_France,\\_%C3%A0\\_1%27%C3%A2ge\\_de\\_7\\_ans\\_\(1762\)\\_-\\_02.jpg#/media/File:Maria\\_Antonia\\_of\\_Austria\\_1762\\_by\\_Liotard.jpg](https://commons.wikimedia.org/wiki/File:Jean-%C3%89tienne_Liotard,_L%27Archiduchesse_Marie-Antoinette_d%27Autriche,_future_Reine_de_France,_%C3%A0_1%27%C3%A2ge_de_7_ans_(1762)_-_02.jpg#/media/File:Maria_Antonia_of_Austria_1762_by_Liotard.jpg)
33. The Woolaston White Children (inspired by Anthony van Dyck), (c.1780). <https://artuk.org/discover/artworks/the-woolaston-white-children-167390>

34. French Beauty Secrets Every Woman Should Know, According to Marie Antoinette. <https://www.vogue.com/article/marie-antoinette-beauty-secrets-french-girl-hair-makeup>
35. French royalty as seen by Hollywood royalty. <https://www.nytimes.com/2006/09/10/movies/moviesspecial/10hohe.html>
36. Shakespeare, W.: The Tragedy of Romeo and Juliet (1597). <http://www.hatrack.com/osc/other/romeoandjuliet/rj.pdf>
37. Paterson, I.: A Dictionary of Colour: A Lexicon of the Language of Colour, p. 405. Thorogood Publishing, London (2003)
38. Portrait of Innocent X (c.1650). [https://en.wikipedia.org/wiki/Portrait\\_of\\_Innocent\\_X](https://en.wikipedia.org/wiki/Portrait_of_Innocent_X)
39. Study after Velázquez's Portrait of Pope Innocent X. [https://en.wikipedia.org/wiki/Study\\_after\\_Vel%C3%A1zquez%27s\\_Portrait\\_of\\_Pope\\_Innocent\\_X](https://en.wikipedia.org/wiki/Study_after_Vel%C3%A1zquez%27s_Portrait_of_Pope_Innocent_X)
40. Figure with Meat (portrait of Innocent X). <https://www.artic.edu/artworks/4884/figure-with-meat>
41. Complete Rembrandt Catalogue: Landscapes. [http://www.rembrandtpainting.net/complete\\_catalogue/landscape/ox.htm](http://www.rembrandtpainting.net/complete_catalogue/landscape/ox.htm)
42. Chaim Soutine. <https://www.christies.com/lotfinder/Lot/chaim-soutine-1893-1943-le-buf-5895984-details.aspx>
43. Collection on line, Francis Bacon, Three studies for a Crucifixion. <https://www.guggenheim.org/artwork/293>
44. Pastoureaux, M.: Dictionnaire des couleurs de notre temps: symbolique et société (Color Dictionary of Our Time: Symbolic and Society), pp. 143–144. Cristine Bonneton, Paris (2007)
45. Perrault, C.: Histoires ou contes du temps passé, avec des moralitez (The Fairy Tales of Charles Perrault), pp. 47–56. Claude Barban, Paris (1697). <https://gallica.bnf.fr/ark:/12148/bpt6k10545223?rk=21459;2>
46. The Annotated Brothers Grimm. Edited with an introduction by M. Tatar, pp. 140–149. W. W. Norton, New York (2004)
47. The Annotated Hans Christian Anderson. Edited with an introduction by M. Tatar, pp. 251–262. W.W. Norton, New York (2008)
48. Little Red Riding Hood by Walter Crane. <http://www.surlalunefairytales.com/illustrations/ridinghood/cranered.html>
49. Jung, K.: Man and His Symbols. Aldus Books, London (1964)
50. von Franz, M.-L.: Shadow and Evil in Fairy Tales. Revised edition. Shambhala Publications, Boston (1995 [1974])



# Contribution of Visual Ergonomics to a Holistic View of the Symbols Applied in Touristic and Cultural Signage: The Portuguese Case

João Neves<sup>1,2(✉)</sup>, Fernando Moreira da Silva<sup>1</sup>, Daniel Raposo<sup>1,2</sup>,  
and José Silva<sup>1,2</sup>

<sup>1</sup> CIAUD, Lisbon School of Architecture, Universidade de Lisboa,  
Rua Sá Nogueira, 1349-063 Lisbon, Portugal  
joaoneves.tag@gmail.com, fms.fautl@gmail.com,  
{draposo, jose.silva}@ipcb.pt

<sup>2</sup> Polytechnic Institute of Castelo Branco,  
Av. Pedro Álvares Cabral, nº 12, 6000-084 Castelo Branco, Portugal

**Abstract.** Traffic signs are not globally standardized, and there are different signage systems all over the world. The system of traffic signaling in Portugal comes from the European System, ratified on 19th September 1949 in Geneva, which has slowly evolved, with occasional changes and often driven by international agreements. Currently the road signaling system is regulated by the Regulatory Decree No. 22-A/98 of October 1st, which approves the Traffic Signaling Regulation. For the present research it is vital to include, in the vertical signaling system to be placed on public roads, tourist-cultural signaling, which is intended to convey information about places, buildings or groups of buildings and other motifs of particular relevance (cultural, historical-heritage or landscape). Following a first case study, it was found that not all pictograms present in vertical signaling are perceptible and understandable. The level of simplification and development of pictograms for application in projects for vertical signaling is very disparate, some of them extremely simplified and easily perceptible and other require a higher level of interpretation by the user, due to sign complexity.

**Keywords:** Visual ergonomics · Graphical symbols ·  
Symbols signs · Touristic signage

## 1 Introduction

The growth of tourism in the last decades, combined with a growing globalization on a world scale, has somehow generalized the abolition of physical, linguistic and cultural boundaries, making the displacement of people and goods easier, enhancing trade and industry, leisure activities and other tourism-related activities. Mobility and a large number of people coming to particular places or attractions have led to the need to guide people into an unknown space and to communicate basic messages using a universal language through pictures, so it can make easy to understand written messages in any language and it will decrease the number of messages.

Massironi [1, p. 118] considers that pictograms are a great help in guiding people in bus and train stations, airports, hotels and other services. These days we can see them as well as in maps, tour guides, apps among many other things. Export requirements and market movements cannot foresee the use of just one language nor the chaos of using many languages at the same time.

The displacement within the tourist activities is carried out over and over in unknown spaces raising the need for learning new rules, which are now formalized with signs that ease the access or movement around certain places.

According to Velho [2, p. 12], the development and the evolution of cities, the complexity of transport routes, trade relations and communications have made signaling essential in the environment and necessary for the safe usage of urban facilities and exchanges business, knowledge and skills.

As an activity that presupposes the movement or mobility of visitors, tourism generates a variety of needs, such as tourist resources, services or supply. Tourist information is of a great contribution to mobility and to the quality of the stay or the provision of tourist services.

Tourist information comes in several ways, digital and printed support, signage, tourist signage, as well as other communication forms. Among the various media of graphic media applied to tourism, it is important in the context of the present investigation to get better acquainted with tourist signage.

According to Britto [3] the creation and transmission of a given message about a tourism product/service or equipment is a process that triggers the connection between supply (product/service/equipment) and demand (real or potential tourist) and ensures its complete satisfaction.

Communication and information for the tourist market are translated into preliminary information on all resources available in the tourist process, initially in the form of leaflets, articles and media advertisements (printed or digital), are then by graphic signs of orientation, permission, prohibition and support, arranged in suitable supports, in and outside the tourist scene.

Such signs are integral components of a repertoire, system or graphic signposting directory, especially designed for the most different occasions, and may or may not be referenced by official tourism signaling systems or directories, mainly in internal signaling issues when freedom of creation can be kept [3].

Tourist signs or symbols cannot be dubious nor be based on a particular access code restricted to certain users. For a correct interpretation of such signs it is also important the physical environment they are in [4, p. 6].

The signaling of tourist and cultural orientation is the communication carried out through a set of signaling plates successively set up along an established route which is provided with ordered written messages, pictograms and directional arrows. This set is used to inform about tourist attractions and other references, or the best access routes and, all the way through, the distance to be travelled to reach the final destination (Brazilian Tourist Signage Guide, 2001).

Tourist signposting aims to provide an easy access to tourist spots and attractions, must start on a route and lead users to a tourists site.

Numerous signage systems have been developed worldwide in the area of information for tourists or visitors, however they do not share common codes, being



designed for a particular entity or location and are unique, isolated from other systems, far from the universal character intended for the signage systems for tourist information.

There are numerous examples of systems developed for tourist information, whether established by countries, regions or tourist authorities, provinces, municipalities, tour operators, or by so many other companies and organizations operating in the area of tourism and culture. However, it is truly impressive to see that systems are generally not interrelated, often causing difficulties in accessing tourist spots.

Taking the example of the Portuguese context, there is a national vertical signaling system (traffic signaling) that includes tourist information symbols for the indication signs, as well as tourist-cultural signage that is not applied throughout the territory. In addition, there is the tourism symbolism of *Turismo de Portugal*, which is applied in different establishments and tour operators, however, they often choose to develop or apply their own systems.

There are systems applied in some touristic regions by intermunicipal communities or by municipalities as well as companies dedicated to the various tourist activities.

As we can easily see, the several mentioned systems produce redundant messages for the user or, in many cases, their absence, due to the enormous deregulation and lack of uniformity in the tourist messages.

Therefore, it is important to deepen the study of symbols used in the traffic signs system, which becomes an important case study at the communication design level, standardization and visual ergonomics because of its own characteristics and its global application.

## 2 Traffic Signs

Traffic signs are not globally standardized because there are internationally different signal systems. The great expansion of traffic signs takes place in the beginning of the 12th century along with car evolution, with private initiative having the merit for being aware of the need to come up with new solutions brought in by the quick development and progress of the automobile industry.

With the development of the automobile industry, the spread of the car and the growing need to cross borders by car it was required a structure that went beyond the national automobile clubs and could also respond to the international standardization of traffic signs. Thus, the first international agreements appeared, which have been at the origin of the standardization of symbols applied in traffic signs.

At the end of the 1940s, in a generalized attempt to standardize traffic signage systems worldwide, we can observe three traffic signaling systems simultaneously.

In 1948 appeared the so-called American signaling system in the United States based in the «Manual on Uniform Traffic Control Devices for Streets and Highways», which mostly consists of written messages. The system is present essentially in much of the American continent, in the Anglo-Saxon countries, Australia and other countries of Oceania. The system is based mainly on the use of black graphics on a yellow background arranged in squares supported on one of the vertices and on the United States «Manual on Uniform Traffic Control Devices for Streets and Highways», 1948.

The European traffic signaling system, ratified in 1949 by several European countries through the «Geneva Convention», is based on graphic signs, which was adopted in most European, African and Asian countries. The Convention on Road Traffic and the Protocol on Road Signs and Signals adopted in 1949 were revised in 1964, 1965 and the Convention on Road Signs and Signals was ratified in Vienna in 1968 [4, p. 43].

The European System is based on pictograms and has been ratified by several European countries through the signing of the Geneva Convention of 1949, currently being implemented in most European countries, a large part of Africa (according to the colonizer) and almost all of Asia.

In 1950, derived from the British system, the system of African road signs appears, established by the «Central Southern Africa Transport Conference» and celebrated in Johannesburg. This system was adopted by some African countries however is less disseminated than the European and American systems.

### **3 The Portuguese System**

The system of traffic signaling in Portugal, which derives from the European System, ratified in Geneva in 1949, has slowly evolved, with a few changes and often driven by international agreements. Currently, traffic signaling in Portugal is regulated by the Regulatory Decree n. 22-A/98 [5], 1st October, which approves the Traffic Signaling Regulation.

According to the Traffic Signals Regulations, traffic signs in Portugal include road signs, traffic signs, temporary signs, signs of traffic regulators, driver signs and vertical signs. The vertical signaling system consists of «danger signs», «regulatory signs», «indication signs», «variable message signaling» and «tourist-cultural signaling». The various signs are thus classified into different categories according to their characteristics and are composed of several elements that contribute to its design, such as size, graphics, color, materials, etc.

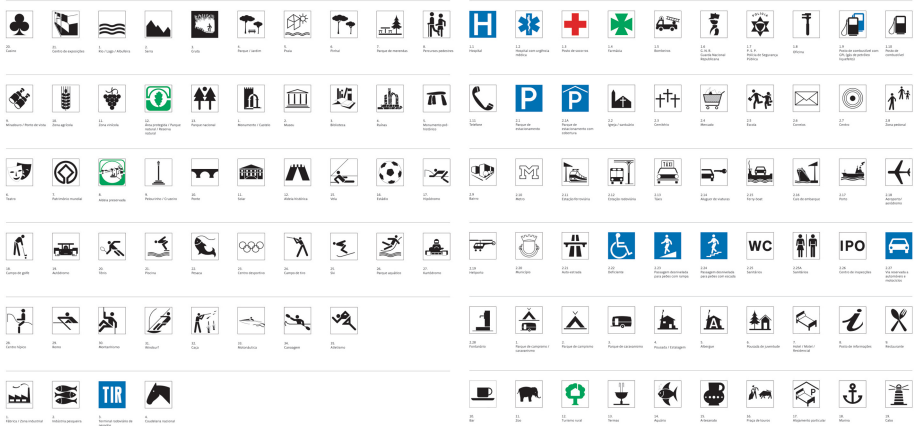
Within the present investigation it is important to deepen the study of tourist-cultural signage, since is the one with the lowest degree of standardization from in each country.

So, in the Portuguese case, tourist-cultural signaling intends to provide information about places, buildings or groups of buildings and other cultural, historical and landscape reasons.

Touristic-cultural signage should be used to point out, in particular: regions that stand out for their heritage or landscape values; cultural, historical, patrimonial and landscape attractions (monumental complexes and city-museums; sets of patrimonial and landscape interest and sets of historical and patrimonial interest; monuments and archeological sites; churches, palaces and castles); geographical features and natural or national parks; tourist routes; places of tourist, geographic, ecological or cultural interest (Regulatory decree n. 22-A/98 [5], 1st October, Article 54 – area of application).

The symbols used in the indication signs and tourist-cultural signs are classified as follows (Fig. 1):

- I – User Support:
  - Emergency
  - Other indications
- II – Tourist Information
- III – Geographical and Ecological Indications
- IV – Cultural Indications
- V – Sports Indications
- VI – Industrial Indications



**Fig. 1.** Symbols used in the indication signs and tourist-cultural signage approved by the Traffic Signaling Regulation in Portugal

## 4 Visual Ergonomics

According to the International Ergonomics Association (IEA), Visual Ergonomics is the multidisciplinary science concerned with understanding human visual processes and the interactions between humans and other elements of a system. Visual ergonomics applies theories, knowledge and methods to the design and assessment of systems, optimizing human well-being and overall system performance [12].

Long and Richter [13] defines Visual Ergonomics as the science which aims to achieve a good balance between what a person can see and the visual demands of a task. This requires an understanding of the human visual system and an analysis of the visual demands of a task.

Relevant topics include, among others: the visual environment, such as lighting; visually demanding work and other tasks; visual function and performance; visual comfort and safety; optical corrections and other assistive tools [14].

Among several domains of interest of visual ergonomics defined by the International Ergonomics Association [15], it is important for the present investigation to highlight the areas of: Visually demanding work tasks and leisure activities; The human visual system, perception and visual Comfort; Visual displays and information design.

The associated mental processes are also considered important in decoding symbols applied in the signaling, namely the perception, the memory and the reasoning, in order to understand how they affect the interaction between the users and the other components of the system.

Thus, the development of the visual system must take into account the issues related to legibility, namely contrast, identification and differentiation between forms or to these forms in comparison to the surrounding background. Readability, that is, comfort in reading or viewing, the way graphic elements are arranged, recognized, hierarchized or proportioned according to the context and to the reading distance.

We must also take into account comprehension, especially the level of decoding or the understanding of a meaning in the shortest time possible. It is the semantic relation of the denotative and connotative meanings from the confrontation of the graphic sign with schemas and mental images. Memorization is linked to the understanding, it is defined as the speed and the ability of the sign in creating fascination or bond that justifies its preservation or retention in the user's memory.

## 5 Holistic View of the Applied Symbols

The symbols applied in tourist-cultural signage in Portugal and throughout the world lack standardization criteria, either in terms of form or in terms of color, making sometimes the process of decoding the sign more difficult. Not all the symbols present in tourist-cultural signage are easily visible and the iconic level used in the design of the symbols is very disparate, some of them extremely simplified and easily perceived while others require the user to have a higher level of decoding, caused by the complexity of the sign.

A particular symbol tends to rule the design of other pictograms which are contained in the same category, and therefore it is essential for the identification of the system that they are recognized as belonging to the same classification, do not need learning and are easily recognizable. In the design of the symbols the objects represented must respect the principles of regularity and continuity, which sometimes does not occur in the symbols used in tourist and cultural signage.

It is important to analyze some principles that can be applied in the graphic development of the symbols used in tourist and cultural signage, in order to create a uniform, coherent and easily decodable system. It is also important to understand the phenomenon of symbol normalization and validation.

The need to transmit information through symbols requires concise, simple and quickly understandable signs; for this, must be sought elementary graphic structures, in order to do justice to a certain type of perception [6, p. 101]. In general, the conceptual model (taking into account the design of pictograms) should present clearer,

simpler and unambiguous information [7, p. 25]. The design has the unique ability to shape information by certain techniques [7, p. 25], as emphasis or understanding; comparing or structuring; grouping or order, selecting or omitting; choosing for immediate or delayed recognition; presenting in interesting ways.

In psychophysical studies of Max Wertheimer, Wolfgang Köhler and Kurt Koffka, known by the development of Gestalt theory, perception is considered as a whole and explains the parts instead of the whole, whereas the whole is not the sum of the parts. The elements of a picture are grouped spontaneously, and in an innate way.

The European Conference of Ministers of Transport in 1991, established basic principles for tourist signs [4, pp. 47–48], such as the principle of safety; principle of proximity; or the principle of specificity.

According to Roque [8] a signaling system must take into account the following principles: Uniformity; Homogeneity; Simplicity; Continuity; Coherence.

In addition, it is also important to mention issues related with the standardization of graphic symbols applied in touristic and cultural signage.

The project developed in 1974 by the American Institute for Graphic Arts (AIGA) to the United States Department of Transportation (DOT), a signaling program developed to a set of facilities linked to the transports in the United States, is an important example in the standardization context. A standardized program developed to inform and guide users in spaces and buildings where there was a large movement of people, such as airports, road and rail stations, international events, etc., and its importance as a systematized program, which aims to communicate readable and legible visual messages to users of different cultures, social classes and age groups.

The World Tourism Organization (WTO-WTO) publishes in 1993 the publication “Tourist Signs and Symbols”, a proposal for standardization of concepts and terminology applied to the tourism sector, together with a study of the systematization of 290 symbols for tourist information. The publication reflects the work done by UNWTO in the areas of standardization and technical standards in the period 1998–2000. The study comes up as a first attempt to classify and standardize the symbols for tourist information, although with little expressive results, presenting a vast set of symbols, without graphical relation between the pictograms, not being related in order to create a common code.

Over the years, there have been several attempts to normalize and standardize the graphic symbols used in the orientation and information of tourists and visitors, from which stand out the projects developed by the ISO Technical Committees (International Organization for Standardization) mainly standards and technical reports related with symbols for public information.

The ISO technical report TR 7239: 1984 shows the development processes and principles for the accomplishment of symbols for public information, the standard ISO 7001 proposes three areas of action: (a) the standard image content; (b) the function; (c) the application field. The ISO 22727: 2007 standard defines some guiding principles for the creation and design of symbols for public information.

The system design is one of the most important stages in the development of the visual program, and will give body to the signaling system. There are several tests to validate the developed system, particularly the ratio of its constituent elements.

For the thematic of guidance and signposting systems the Usability Test is defined as the one which evaluates the relationship between graphic symbols with the user. The test is essential to evaluate the graphic and functional quality of symbols and their ability to communicate with users. The *Visibility Tests "in situ"* in the present context, can be applied to evaluate the graphic and functional quality of the developed program, its application capacity in the in space or territory in validation, as well as their ability to communicate with users.

The standard ISO 9186-1: 2007 defines the *Comprehensibility Tests* which specifies methods for testing comprehensibility of graphic symbols, in particular: (a) the method to test the amplitude a variant in which a graphical symbol communicates the intended message; (b) the method to test the variant of a graphical symbol most understandable. The ISO 9186-1: 2007 (E) presents two types of test: The *Comprehension Test* and the *Judgment Test*.

## 6 Outcomes

The developed research project, which is the basis of this article, presents guiding principles for the development and validation of graphic symbols. Following the results of previous research and research based on design practice, it was possible to arrive at preliminary results, which substantiate and validate previously the research questions.

From the results of the research it is possible to affirm that the systems of orientation and public information are not developed in a systematic way and most of the programs focus on an aesthetic aspect, not being verified in its development the application of methodological, normalizing and validation principles of signaling or signage projects.

Thus, from the research problem and the results obtained, it was possible to develop an essay, which describes a wide set of guiding principles for the design of symbols applied in tourist and cultural signaling. It is considered that the guiding principles developed enhance the graphic and functional quality of visual codes and should be applied in the development of graphic symbols for integration into public information programs. The following principles have been defined: Principle of need; Principle of universality; Principle of participativity; Principle of usability; Principle of simplicity; Principle of uniformity; Principle of normativity; Principle of perceptibility.

Also as a result of the research it was possible to list a set of standards and methodologies applied to the design and development of information and orientation systems, being these standards an important tool for designers and studios that develop signaling and wayfinding projects, generating a set of guidelines for the development, standardization and validation of graphic symbols present in signage programs.

With the growth of citizen mobility, tourism and other similar activities, the number of signaling systems applied in the area of public information around the world has increased. Yet these systems do not share common codes, being designed for a given entity or territory and have a unique character, isolated from other systems, far from the universal character desired for guidance and public information systems.

The several referred sign systems often generate, for the user, redundant messages or lack of information by the deregulation and lack of uniformity in the messages to be transmitted to tourists and visitors.

This research project intended to evaluate the Portuguese signaling system as a whole, the relation of the symbols with the system and the understanding of the interaction in the visual process of the user with the various elements of the system.

An important contribution to a holistic view of the various constituent parts of the tourist-cultural signaling system is found in visual ergonomics. It is important to understand human visual processes and the interactions between the user and other elements of a system. This requires an understanding of the human visual system and an analysis of the visual demands of a task.

## References

1. Massironi, M.: Ver pelo desenho: aspectos técnicos, cognitivos, comunicativos, 1st edn. Edições 70, Lisboa (1983)
2. Velho, A.: O Design de Sinalização no Brasil: a introdução de novos conceitos de 1970 a 2000. (Master's Dissertation in Arts and Design). Rio de Janeiro: Pontifícia Universidade Católica do Rio de Janeiro (2007)
3. Britto, J.: Sistema de sinalização turística: a importância da sinalização turística para o desenvolvimento sustentável do Turismo. *Revista de Estudos Turísticos* **24** (2006). <http://www.etur.com.br/revista/>. ISSN 1809-6468
4. Organização Mundial do Turismo: Sinais e símbolos turísticos: Guia ilustrado e descritivo, 1st edn. Roca, São Paulo (2003). ISBN 85-7241-450-9
5. Decreto Regulamentar n.º 22-A/98. *Diário da República*. I Série B. 227 (1998-10-01) 5006 (2)-5006(119)
6. Aicher, O., Krampen, M.: Sistemas de signos en la comunicación visual, 4th edn. Gustavo Gili, México (2002). ISBN 968-887-174-5
7. Mijksenaar, P.: Diseño de la información, 1st edn. Gustavo Gili, Mexico (2001). ISBN 968-887-389-6
8. Roque, C.: Manual de sinalização vertical, pp. 1–71 (2005). [http://alexandrefs.tripod.com/Sinaliza\\_o\\_Vertical-parte1.pdf](http://alexandrefs.tripod.com/Sinaliza_o_Vertical-parte1.pdf)
9. ISO/TR 7239 (E): Development and principles for application of public information symbols, 1st edn. International Organization for Standardization, Geneva (1984)
10. ISO 22727 (E): Graphical symbols: creation and design of public information symbols – requirements, 1st edn. International Organization for Standardization, Geneva (2007)
11. ISO 9186-1 (E): Graphical symbols - test methods: Part 1 - methods for testing comprehensibility, 1st edn. International Organization for Standardization, Geneva (2007)
12. Toomingas, A.: *Appl. Ergon.* **45**(4), 817–1264 (2013). ISSN 0003-6870
13. Long, J., Richter, H.: Visual ergonomics at work and leisure. *Work* **47**, 419–420 (2014)
14. IEA - International Ergonomics Association: What is Visual Ergonomics? (2019). [http://www.iea.cc/about/technical\\_com\\_visual.html](http://www.iea.cc/about/technical_com_visual.html)
15. IEA - International Ergonomics Association: What are some of the domains of interest of visual ergonomics? (2019). <https://www.iea.cc/about/technical.php?id=51df9aa27ebf9>



# Design, Objects and Memory: A Sustainability-Oriented Project Itinerary

Myrla Lopes Torres<sup>1,3(✉)</sup>, Paulo Maldonado<sup>2,3,4</sup>,  
and Leonor Ferrão<sup>3,4</sup>

<sup>1</sup> Universidade Federal da Paraíba (UFPB), Campus IV, Rua Santa Elisabete,  
s/n, Centro. Rio Tinto, 58297-000 Paraíba, Brazil  
myrla@ccae.ufpb.br

<sup>2</sup> Universidade de Évora, Colégio Mateus d'Aranda, Rua do Raimundo,  
7000 Évora, Portugal  
paulomaldonado@inspaedia.com

<sup>3</sup> CIAUD, Lisbon School of Architecture, Universidade de Lisboa, Rua Sá  
Nogueira, Polo Universitário, Alto da Ajuda, 1349-063 Lisbon, Portugal  
lferrao@fa.ulisboa.pt

<sup>4</sup> CITAD, Center for Research in Territory, Architecture and Design,  
Universidade Lusíada de Lisboa, Rua da Junqueira, 188-198,  
1349-001 Lisbon, Portugal

**Abstract.** Concerns related to sustainability are recurrent in Design. Questioning project practices, reassessing principles which are intrinsic to the design process, promoting the dissemination of sustainability-oriented actions, and contributing with a new awareness-raising process about consumption are attitudes that might help in the inclusion of environmental and social requirements in design practices. The relationship between sustainability and esthetic, symbolic and affective aspects is under explored in project elaboration. The project process that emphasizes subjective and material characteristics of objects with a view towards the appreciation of affective memories, through the analysis of users' real-life experiences, might allow the designer to rethink time, tradition, aesthetics and perception to comprehend characteristics at play that are emotionally sustainable. This paper presents and discusses the ongoing research, whose main objective is to design a sustainability-oriented project itinerary, through affections and memory embedded into the relationship between people and objects.

**Keywords:** Design education · Product design · Design methodology · Sustainability · Emotionally durable sustainability

## 1 Introduction

In Design, concerns related to sustainability are recurrent. Nevertheless, practices that incentivize consumption, excessive production, ownership and materialism are frequently incorporated into the design process. Bonsiepe [1] observes that there is some distortion in the actions of contemporary design, justifying that the activity got close to the ephemeral and distant from the intelligent solution.



To Manzini [2], designers are, indeed, part of the problem. But they can be part of the solution to better the quality of the world. It is then necessary to re-evaluate the context so that strategies in the opposite direction can be developed. The creation of objects has become a technical activity, since there is a great tendency for the use of tools and little reflection about the project actions. In the contemporaneity, the way of designing excessively valorizes the renderings and disregards the specificities of place, space, materials and important elements of an authentic experience of the world. To Walker [3], this “removal of consciousness by process” contributes to unsustainable practices of project and production, such as the exploration of labor force, the waste of non-renewable natural resources and energy, the environmental degradation.

To question the design practices, to review the principles which are intrinsic to the process in design, to promote the dissemination of options oriented to sustainability and to contribute to a new consciousness on the consumption are attitudes that can help the inclusion of environmental and social requirements in the design practices. This position should be emphasized at the beginning of design education, allowing the concern with the environmental impacts to be incorporated into the mentality of the designer and the practice to be developed from the first projects. Only then is it possible to change the conventional patterns of design required by the market. The design practices can boost social, environmental and economic changes in many ways. Manzini and Vezzoli [4] affirm that initially, sustainability in the design was applied in the reduction of impacts in the environment, using alternative materials and cleaner processes directed to the measurable, tangible factors. The relationship between sustainability and aesthetics, symbolic and affective aspects is still little explored in the elaboration of the projects.

While adopting a view to sustainable development, through the analysis of what users have experienced, the project will allow the designer to rethink time, tradition, aesthetics and perception to understand which physical characteristics of the products involve feelings that can extend their use, optimizing the commitment with the sustainability through affection, according to Borjesson [5]. Also concerning an approach to the intangible aspects, Chapman [6] highlights the inspiring strategies to extend the products’ life, investigating the emotionally durable design.

Thus, it is possible to see a project itinerary that - beyond the practical and technical aspects - facilitates the construction of affections and memories. Besides that, it simultaneously stimulates reflexive attitudes in the design practice oriented to sustainability. Finally, it needs to be relevant, from the social, environmental and economical point of view, whether in the short or medium term. It is still added that, while entering the symbolic universe of a specific culture (immaterial or material), affections that motivate the attachment of users to artifacts, which represents an obstacle for the fast discard can be aroused. The proposed itinerary was developed according to the transclassic science described by Bürdek [7] in based on Siegfried Maser in 1972. The transclassic science brings to design theory the possibility of grounding the action, analyzing it, criticizing it or correcting it. It should be noted that the itinerary starts from the static and rational method, according to the Feyerhabend [8] thought, all the statements for the analysis are evident; there is no refusal under any conception; it is admitted that behind an individual choice, reality may be another; and any methodology, whatever it may be, has its limitations.

## 2 Sustainability, Design and Affectivity

The concept of sustainability is complex, since it is related to many areas of human knowledge. In a general way, when there is a concern about the life quality of people and the environment, in which the responsible parameters for the use of natural and technological resources are established, it refers to sustainability. The implications of sustainability are varied in nature. They go through the balanced distribution of income, elimination of social inequality, welfare and social peace, efficiency in the use of natural resources, waste, air quality, democracy, among other factors that are indispensable to human life. These factors reinforce the commitment with the necessity to think about the development of products that incorporate sustainability. For Birkeland [9], the design needs to incorporate a new vision in its actions, such as: to redefine the objectives that focus on the social and economic equality; to create positive synergies that provoke changes; to re-evaluate the concepts of design that consider social transformation; to encourage the eco-efficient production; to focus on the development of methods and appropriate tools for sustainable development. In this context, it is essential that the designer adopts project practices that are adequate to the principles of sustainability. We cannot lose sight of the fact that in the use of natural resources, questions as the generation of solid waste and promotion of satisfaction of individuals are involved. The way artifacts are designed and produced must be the object of reflection, in such a way that damage is softened. Analyzing this issue, Thackara [10] highlights that approximately eighty per cent of the environmental impacts produced in the planet comes from decisions made by designers.

In the perspective of a sustainability-oriented design, it is possible to verify criteria related to the selection and reduction of use of resources in the whole product life cycle, as well as to the clean production. Also, facility of installation and transport are acknowledged as tools for promotion of sustainable awareness. This vision reveals criteria which are oriented to sustainability and, because of that, they can be explored in the elaboration of projects that guarantee longer duration of the products' life. As it is known, the product can be eliminated because of the wear from overuse or for not having achieved the practical, aesthetic or symbolical expectations. They can also be discarded as a consequence of physical damage, among other factors.

From the design perspective directed to sustainability, an effort must be made to have a designed object maintained in the user's life, exploring and highlighting the possible changes of meanings. Unfortunately, this aspect is little explored. In particular, the affective relation between the user and the object must gain space in academic discussion. The affective dimension is manifested through the positive feelings related to people, places, objects, experiences, among other aspects. According to Damásio [11], affection is something manifested through emotions or feelings in a relation among people, objects or situations. In this relation, love is the focus, as assured by Russo [25]. Csikszentmihalyi [28] highlights that the affective connection between objects and their users interfere in social practices, interpersonal relations and experiences, influencing, thus, people's behaviors and attitudes.

The attachment bond between users and objects aiming at the prolongation of the use was conceptualized as affective sustainability by Borjesson [5]. The application of

this concept can be visualized from two perspectives. The first one verifies how the object is processed in the mind of the user as something affectively sustainable. It means that the object must be understood in relation to the function and aesthetics. It is, then, positively acknowledged, awakening tradition and nostalgia. The second perspective regards the way in which designers can include, in the design process, the promotion of affection. This way, it is observed that the way to sustainability that highlights the immateriality is found in the development of objects that have the following characteristics: they do not feature a specific time; they value the traditions; they allow intuition to be relevant during the design process; they explore their own needs and roots.

The designs that aim at meeting the mentioned assumptions need to manifest the affections and the memory; to interact with the experiences lived by the user; to acknowledge the local and regional traditions; to use the simplification as the principle of aesthetic configuration; to consider affection, emotion and pleasure in regard of the emotional joint understanding (affective and cognitive components); to connect the past with the future, according to Ekkekakis [12].

In this perspective, the present paper aims at contributing for awareness about sustainability through adequate practices in the elaboration of the design. Then, while exploring forms, trajectories and use of everyday artifacts, the design will be able to manifest affective connections with the users. Considering Ekkekakis [12], affections are sensations of pleasure, disgust, tension, calm, energy or tiredness. Desmet and Hekkert [13] add that the affective state assumes subjective experiences that highlight feelings of pleasure and displeasure.

The affective bonds that are established in the relation between users and objects evoke the positive experiences involving pleasure, contentment and enthusiasm, arousing good memories. The affections are processed as a central feeling in people's memories, generating various meanings and evoking different memories. According to Cardoso [14], the memory is placed among the factors that influence the development of affective bonds the most. The establishment of a vehicle of long duration is promoted by the affection. Considering Russo and Hekkert [15], some aspects of this feeling are: there is continued pleasure in the interaction; the object arouses affective memories related to people, places or pleasurable experiences; the object is related to a common symbolic meaning and, for that, they are shared in the social environment. This affection of long duration overcomes the transitory feelings, as attraction at first sight or a simple fad. These are feelings that arouse a special relation of long duration, having relevant meanings in the user's life.

### 3 Methodology

This article presents and discusses the ongoing investigation that used a mixed non-interventionist and interventionist methodology of qualitative basis, which was developed in four different moments:

- (a) Review of literature that provided knowledge about the themes: sustainability, genealogy of forms, artifacts' social life and design processes;

- (b) Construction about the analysis of the formal genealogy and the social life of many objects of everyday use. It is held by the selection of objects that are representative of the material culture to understand the possibilities of the affective vehicles incorporated into the design of products;
- (c) Preparation of two itineraries of design:
  - Itinerary 1, designed as a classic itinerary. Its elaboration is based on some authors' classic methodology: Lobach [16]; Munari [17]; Bonsiepe [18], Baxter [19]. These authors were chosen, since they are the most frequently cited in the syllabuses of product design courses in undergraduate courses of Design in Portugal and Brazil;
  - Itinerary 2, elaborated according to the principles of user-centered design: Krippendorff [20], Brown [21], Sanders and Stappers [22]; of sustainability based on the affections and positive memories: Chapman [6]; Walker [3]; Borjesson [5], Woodward [23], Desmet [24], Russo [25], Pantaleão [26], Csikszentmihalyi [28]. In this script, many activities focused on ideation were suggested, such as storytelling, mood boards, drawing, as well as methods of analysis of the forms' genealogy and reconstitution of the artifacts' social life. The design process aimed at reinforcing the social and environmental commitment in the design project learning, from the incorporation of affections and positive memories associated to the use in order to extend the life cycle of objects and postpone its discharge. Sessions with the sample and control groups were planned, according to the protocol of quasi-experience.
- (d) Verification and evaluation: at this stage, the aim was to verify the hypothesis through the verification and evaluation of the achieved results in the real context of learning. For the concretization of the sessions of quasi-experience control groups and sample groups with similar characteristics were created, with undergraduate students of Design from Lisbon School of Architecture and *Universidade Federal da Paraíba (UFPB)*. To both control groups the use of itinerary 1 was suggested. And itinerary 2 was suggested to both groups of sample. At the end of each working session, the participants answered an evaluation questionnaire about the results obtained with the itinerary which was suggested.

## 4 Projects' Itinerary and Its Applications

The projects' itineraries were developed on the basis of literature about project methodology. The first project itinerary, denominated as "classic", considered the problem as a starting point and the solution as the result. The literature related to the classic design methodology was the basis for this itinerary. The authors referred to were selected according to the frequency they are cited in syllabuses of product design courses in reputable under graduation courses in Portugal. Design, Objects and Memories (DOM) was the second itinerary that was developed. It is based on user centered design principles; it considers several issues on sustainability, namely those which are focused on affections and memory. The two itineraries which were

developed demonstrate differences in relation to the stimulus to the reflexive attitudes related to sustainability from the perspective of affections and memory.

The formulation of two design itineraries based on two different methodological paradigms, was intended to evaluate, through the quasi-experience if it is possible to stimulate reflexive attitudes towards sustainability that are focused on affections and memory.

#### 4.1 Results and Discussion About the Application of the Itineraries

The application of the itineraries of design occurred from the development of the quasi-experience which was planned to evaluate if an itinerary of design that considers forms, trajectories and uses of everyday objects, with a focus on affections and memories, is an efficient strategy to stimulate reflexive attitudes oriented to sustainability. The quasi-experience is an instrument considered as an active interventionist methodology, in which the investigator elaborates and participates in some steps; it keeps distance from the artificiality of the experience and allows the events to occur in the real configuration. As defined by Shadish *et al.* [27]: “Quasi-experiments share with all other experiments a similar purpose – to test descriptive causal hypotheses about manipulable causes - as well many structural details, such as the frequent presence of control groups and pretest measures, to support a counterfactual inference about what would have happened in the absence of treatment.”

The quasi-experience took place after the selection of the control groups and of sample that were constituted by designers in formation. The participants were selected in the design courses of Lisbon School of Architecture (Universidade de Lisboa – Portugal) and *Universidade Federal da Paraíba* (Brazil). In each of the institutions two project workshops took place, in which two groups were constituted: the control and the sample ones. As already mentioned, in the workshops constituted by the control group, the itinerary of design 1, the classic one, was demonstrated. In the workshops of projects for the sample groups, the itinerary of design 2 (DOM), took place. During the workshops, the same briefing aiming at developing kitchen and table utilities was presented. Each one of the project workshops was composed of five meetings with four hours of contact, totalizing twenty hours of work conducted and followed up by the researcher. The participants involved handed in three panels in A3 format, containing the following information: description of the phases of the developed process (panel 1); representation, description and justification of the concept, with the use of ideographic schemes, drawings, materials, technologies of production, etc. (panel 2); and representation and communication of the proposed objects, with the resource of technical drawing (2D and 3D), renders and others (panel 3).

We opted to request individual works, although information sharing was part of the process during the meetings. This interaction happened, especially in the DOM itinerary. Each project itineraries that were used were evaluated through the questionnaires which were answered by the participants. The final results were interpreted by the researcher.

In the workshop with the itinerary 1 (classic), the participants were passive. In this aspect, the behavior was very similar between the one adopted by participants from Lisbon School of Architecture and *UFPB*. The concerns of the participants in both

institutions concentrated on functional issues and interactions with the other participants did not take place. The questions related to sustainability were just considered by one participant, but she did not include them in the final panels. In the workshops in which the itinerary 2 (DOM, design, objects and memories) was used, interaction among the participants was observed. In the first moment, they seemed to be reticent with the proposed process. However, little by little they started to interact and to identify affinities among many personal narratives. Also, in this aspect, in both institutions, the participants' behavior was similar. In this itinerary, the activity that motivated the participants the most was the sharing of ideas, registered in post-its. They showed enthusiasm in supporting the work of the other participants with recommendations.

The works which were elaborated aroused affections and rescued memories from the participants, since they were developed with the involvement of the personal histories, regional and cultural habits. From the works that were presented by the participants of the sample groups from Lisbon School of Architecture, we highlight the set of teapots and coffee cups, developed by Débora Nascimento. The project was elaborated from the memories of the participant, who used to drink coffee with her father - from Brazil - and from her perception of the relevance of the cork and the painting of the tiles in Portuguese culture. The second work, developed in the sample groups from *UFPB*, by Thais Golzio, verified the importance of the coconut for the Northeastern people's habits. In the Northeast of Brazil, the coconut and its water are particularly special and one of the common habits is to grate its "meat". The participant rescued the popular utensil, common in regional fairs, developing a project of a new coconut grater, rescuing habits and optimizing its function and ergonomics.

When the work was released in the control groups, it was believed that the classic itinerary did not provoke stimulus and that projects were not interesting. Nevertheless, the classic itinerary was very well evaluated by the participants. They affirmed that they easily absorbed the process, besides highlighting the organization and the detailing in which the content was transmitted. But they did not achieve the concern in relation to sustainability with a focus on the affections and the memory in any of the projects that were developed.

In the sample group in which the itinerary of project DOM was applied, the request of personal references and interaction among participants was highlighted. The process involving the analysis of genealogy of forms, the study of the social life of the objects, the rescue of affections and memories allowed participants to understand the relevance of the objects for people, making them reflect about the extension of the use of objects in the users' life.

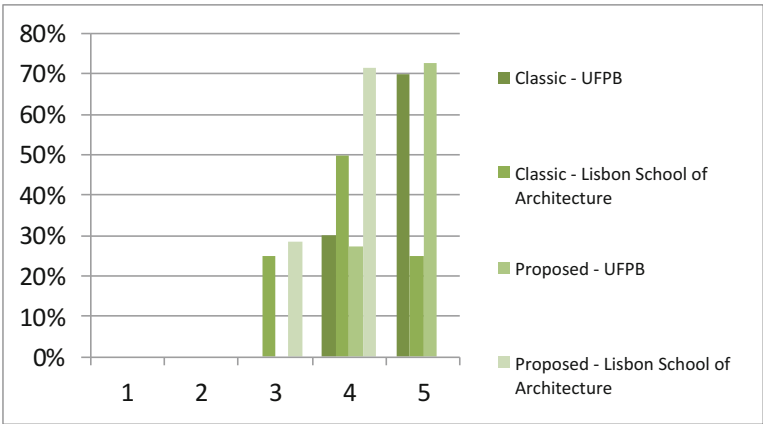
## **4.2 Results and Discussion About the Application of the Questionnaires**

The questionnaires were applied at the end of each workshop. Thirty-six answers were presented: ten from the participants from the workshop of the classic itinerary that took place at *UFPB*; eight from the workshop participants of the classic itinerary from Lisbon School of Architecture; eleven from the workshop participants of the itinerary D.O.M. from *UFPB*; seven from the workshop participants of the itinerary D.O.M. from Lisbon School of Architecture.

In the questionnaires, there were open questions as well as questions using the Likert scale from 1 to 5 to identify the level of satisfaction of the participants: 1 corresponding to minimum and 5 indicating the maximum classification. The analysis of questions, in which the Likert scale was adopted, contained graphics in columns, with percentages. The open questions were evaluated on the basis of a qualitative analysis. The participants reported that in other project experiences, they felt confused and insecure concerning the route to be adopted. In both itineraries proposed, a clear script containing the steps to be followed was available. Probably, for this reason, many participants affirmed that the experience developed in the workshops enabled a better understanding of the importance of planning and carrying out the steps during the project process.

In the first moment it was believed that the classic itinerary could be uninteresting and discouraging. For this reason, the emergency of negative criticism was expected in the evaluation of the workshops that were carried out in the control group. Nevertheless, the classic itinerary was well evaluated by the participants. They felt encouraged and affirmed that the experience provided a better understanding of the process, plus, they highlighted the organization and the detail with which the contents were transmitted. In relation to this itinerary, the participants highlighted, as a positive characteristic of the workshop, the organization and the demonstration of how the steps should be carried out.

During the workshops using the DOM itinerary, the request of personal references and the interaction among the participants were highlighted. The personal references worked as a starting point of the project process to trigger affections and positive memories. They stimulated the participants and contributed to interaction. However, students demonstrated insecurity, since it was their first contact with an itinerary that required a personal and reflexive involvement concerning the social and environmental aspects. For the most part, the participants demonstrated satisfaction with the task, although it was developed in only twenty hours.



**Fig. 1.** Answers to the question: Please point out the importance of the knowledge and competences that you acquired during the workshops of projects for your design education.

When the participants of the quasi-experience from *UFPB* were questioned about the interest in the knowledge and competences which were acquired in these workshops, the answers indicated a level of satisfaction between average and high in both developed itineraries. As it is observed in Fig. 1, 30% of the participants presented their level of satisfaction as 4; while 70% indicated the level 5 in relation to knowledge and competences acquired in the workshop referring to the classic itinerary. In Lisbon School of Architecture, on the other hand, when questioned about the same itinerary, 25% indicated level 3 of satisfaction about the workshop referring to the DOM itinerary, 50% indicated level 4 and 25% answered level 5. At *UFPB*, 72,7% indicated level 5, and 27,3% pointed out level 4. In *FAUL*, while evaluating the same itinerary, 28,5% pointed out level 3 of satisfaction, while 71,6% indicated level 4.

As it can be observed, both itineraries were well accepted both by the participants from *UFPB* and from Lisbon School of Architecture. The classic itinerary, despite being a process which is commonly developed, was well evaluated by the majority of participants. The DOM itinerary was easily assimilated by the participants and generated motivation and interest in relation to the possibility of arousing affections and memories in the user. The data collected allowed a detailed vision in relation to the design projects which are commonly executed in product design. It was observed that the participants, even featuring a lot of diversity, such as geographical location, financial condition, aesthetic sense, world vision, among other aspects, demonstrated many similarities in relation to the understanding of the design processes that were developed in the workshops.

## 5 Final Remarks

The configuration of the design itinerary through the form, trajectories and use of everyday objects, with a focus on the affections and memory, was not a simple task. On the contrary, the analysis encompasses reflections from many perspectives. The challenge was to formulate an itinerary which is oriented to sustainability, rescuing the classic vision of acknowledged authors in the area of design and highlighting the principles of user-centered design. This process led the designers in formation, participants of the itinerary application, to quickly identify the steps, feeling stimulated to think about how affective bonds can be incorporated into the process.

The DOM itinerary provided the systematization of the process, motivating actions of easy absorption and aroused interest about sustainability, even the interest of that designer with little concern about environmental and social issues.

The study and reflections about sustainability, namely, on the perspective of the longevity and the attachment to objects, in addition to the inclusion of aspects which are related to the affective bonds, contributed to awareness, as well as to the environmental and social responsibility of the designer. From these techniques which were adopted in the proposed design itinerary, it was possible to rescue previous experiences, to value and acknowledge habits, traditions, music, crafts, among other cultural references; and to arouse affections and positive memories between the object and the user.



When the proposed itinerary was applied, it was observed that the inclusion of human, cultural and affective aspects in the projects was noticed as something innovative and little explored from the perspective of sustainability. All the process was directed with the objective of causing reflexive attitudes in the designers. Then, the D.O.M. design itinerary, with a focus on the affections and memories, turned out to be an efficient strategy to stimulate reflexive attitudes oriented to sustainability.

**Acknowledgments.** The authors are grateful to National Council for Scientific and Technological Development - CNPq and Paraíba Federal University - UFPB for support in the form of scholarships.

## References

1. Bonsiepe, G.: Design, Culture e Society. Blücher, São Paulo (2011)
2. Manzini, E.: Designing Networks and Metadesign (2008). <http://www.sustainable-everyday.net/manzini/>. Accessed 25 Feb 2015
3. Walker, S.: Unmasking the object: restructuring the design for sustainability In: Revista Design em Foco **II**(2) (2005). [www.redalyc.org/pdf/661/66120205.pdf](http://www.redalyc.org/pdf/661/66120205.pdf). Accessed Jul 2018
4. Manzini, E., Vezzoli, C.: The Development of Sustainable Products: Environmental Requirements of Industrial Products. EDUSP, São Paulo (2002)
5. Borjesson, K.: The Affective Sustainability of Objects; a Search for Causal Connections: Studies of Theory, Processes and Practice Related to Timelessness as a Phenomenon. University of the Fine Arts, London (2006)
6. Chapman, J.: Emotionally Durable Design: Objects, Experience, Empathy. Earthscan, London (2005)
7. Bürdek, B.: Design: History, Theory and Practice of Product Design. E. Blücher, São Paulo (2006)
8. Feyerabend, P.: Against the Method. F. Alves, Rio de Janeiro (1977)
9. Birkeland, J.: Design for Sustainability: a Sourcebook of Integrated, Ecological Solutions. Earthscan, London (2002)
10. Thackara, J.: Plan B: Design and Viable Alternatives in a Complex World. Saraiva, São Paulo (2008)
11. Dámaio, A.: The Feeling of Self: The Body, the Emotion and the Neurobiology of Consciousness. Publicações Europa América, Lisboa (2003)
12. Ekkekakis, P.: The Measurement of Affect, Mood, and Emotion: A Guide for Health-Behavioral Research. Cambridge University Press, Cambridge (2013)
13. Desmet, P.; Hekkert, Paul.: Framework of product experience. Int. J. Des. **1** (2007). <http://studiolab.ide.tudelft.nl/diopd/wpcontent/uploads/2012/02/frameworkproductex.pdf>. Accessed Apr 2018
14. Cardoso, R.: Design for a Complex World. Cosac Naify, São Paulo (2012)
15. Russo, B; Hekkert, P.: On the conceptualization of the experience of love. In: Designing Pleasurable Products Conference (2007). <https://www.researchgate.net/publication/221234275>. Accessed Jul 2018
16. Löbach, B.: Industrial Design: Bases for the Configuration of Industrial Products. E. Blücher, São Paulo (2001)
17. Munari, B.: Da Cosa Nasce Cosa. Appunti per Una Metodologia Pprogettuale. Laterza, Roma (1981)

18. Bonsiepe, G., Kellner, P., Poessnecker, H.: *Experimental Methodology: Industrial Design*. CNPq, Brasília (1984)
19. Baxter, M.: *Product Design: Practical Guide to New Product Design*. Edgard Blücher Ltda, São Paulo (1998)
20. Krippendorff, K.: *The Semantic Turn: A New Foundation for Design*. Taylor & Francis, Boca Raton (2006)
21. Brown, T.: *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation*. HarperCollins, New York (2009)
22. Sanders, L., Stappers, P.: *Convivial Toolbox: Generative Research for the Front End of Design*. BIS Publishers, London (2013)
23. Woodward, I.: *Understanding Material Culture*. Sage, London (2007)
24. Desmet, P.: *Product emotion*. In: *Product Experience*. Delft University of Technology, Delft (2008)
25. Russo, B.: *Shoes, cars and other love stories: investigating the experience of love for products*. Thesis. (Doctorate) Delft University of Technology (2010). <https://repository.tudelft.nl/islandora/object/uuid%3Afb4b87ce-ff66-44f3-9c81-0e7c5bfa7c78>. Accessed Mar 2018
26. Pantaleão, L.F.: *Stuart Walker: the aesthetic sustainable function: mediations between art, design and spirituality*. Thesis (Doctorate). Faculdade de Arquitetura Artes e Comunicação, Universidade Estadual Paulista, Bauru (2017)
27. Shadish, W., Cook, T., Campbell, D.: *Experimental and Quasi-Experimental Designs for Generalized Causal Inference*. Houghton Mifflin Company, Boston (2002)
28. Csikszentmihalyi, M., Rochberg-Halton, E.: *The Meaning of Things: Domestic Symbols and the Self*. Cambridge University Press, Cambridge (1981)



# Effectiveness of Coach Marks or Instructional Overlay in Smartphone Apps Interfaces

Paulo Noriega<sup>1,2(✉)</sup>, Diana Carvalho<sup>2</sup>, Igor Correia<sup>2</sup>,  
Jose Luís Alves<sup>2</sup>, Tiago Oliveira<sup>1,2</sup>, and Francisco Rebelo<sup>1,2</sup>

<sup>1</sup> CIAUD, Centro de Investigação em Arquitetura Urbanismo e Design,  
Faculdade de Arquitetura, Universidade de Lisboa, Rua Sá Nogueira,  
Pólo Universitário, Alto da Ajuda, 1349-063 Lisbon, Portugal  
pnoriega@campus.ul.pt, t.oliveira2010@gmail.com,

fsrebelo@gmail.com

<sup>2</sup> Laboratório de Ergonomia, Faculdade de Motricidade Humana, Universidade  
de Lisboa, Estrada da Costa, 1499-002 Cruz-Quebrada Dafundo, Portugal  
d.r.carvalho89@gmail.com, igorborborema@gmail.com,  
jose.luis@campus.ul.pt

**Abstract.** Some mobile applications present a level of complexity with respect to the functionalities of the graphical interface that are not easily understood by all users in a first approach. The use of instructional overlays (IO) or coach marks is a technique used to guide users to where these features are located in the interface by using a darker layer superimposed to the interface (overlay) where elements are placed such as arrows and text (instructional elements). The effectiveness of the IO was tested by measuring the completion time of a pre-established flow in a prototype. A between-subject design was used, with one experimental group completing four tasks with the help of IO, and the control without. Results show a tendency for lower times to complete tasks with instructional overlays, however, due to the reduced sample, a larger study is needed to confirm this result statistically. Interaction design of non-trivial interfaces should consider the implementation of instructional overlays.

**Keywords:** Usability · UX · Interaction design · Mobile apps design · Instructional overlays · Coach marks

## 1 Introduction

The number of applications for mobile devices in major reference stores today exceeds 6.5 million, according to data taken from the website Statista [1]. Some of these applications have a degree of complexity regarding the functionalities of the graphical interface that is not easily grasped by all users in a first approach. The use of instructional overlays (IO) or coach marks is a technique used to show users where these features are located in the interface by using a darker layer superimposed to the interface (overlay) where elements such as arrows and text are placed (instructional elements).

In this investigation, we tested the effectiveness of this technique by measuring the completion time of a pre-established flow in a prototype. We had two independent groups in which the control group completed a proposed flow without the use of IO and an experimental group that completed the proposed flow with the use of IO. The dependent variable considered was the time to complete the proposed flow in the prototype.

The use of smartphones in recent years has grown massively, and its number is now counted in billions, rising from 2.1 billion in 2016 to 2.53 billion in 2018, according to data taken from Statista.com website [2]. Although the screen size of these devices have been growing in recent years, and users preference for larger screens has also grown in recent years [3], the average number of devices sold is 12.4 cm (4.88 in.), and one study found that screen size does not influence perceived usability, but significantly and positively influences the effectiveness with which users conduct their daily searches for information when they tap into the mobile phone. The same study also suggests that the ideal size for a smartphone is 4.3 in., as it is beneficial for transport and handling and to perform searches using the browser [4]. Another study also indicated that the convenience, mobility, efficacy of introduction of information and ease of reading are the factors that most affect mobile use [5].

Although 4.3 in. is a size considered ideal for a mobile phone, transferring what used to be data and buttons from a desktop computer to a small screen is suggested as a task that can become impossible if we use a trivial approach [6].

In an aging population in developed or developing countries, whose age range over 65 is expected to occupy 27% and 15% respectively by 2050 [7], designing experiments for mobile devices becomes a challenge even more as age increases because there are negative differences in the visual processing of information [8].

“If you can not make a self-evident page, you at least need to make it self-explanatory” [9]. When Steve Krug published this phrase in 2006 the iPhone had not yet been released, however, after 12 years, his words and his book, which referred to web pages, continue to make sense not only for the web experience but also in smartphones user experience. However, when an interface cannot be “self-evident” and “self-explanatory”, it is occasionally used by some professionals in the area of “User Experience” (UX) and “User Interface” (UI) Design a technique from which we can remove the “self” and designate only as “explanatory”, this technique is often called “instructional overlays” (IO) or coach marks, amongst other names, see Fig. 1.

The use of this technique has generated much controversy amongst UX and UI professionals, some of whom are evangelists and others completely discredit their effectiveness. A recent study has hypothesized that the use of smartphones causes a decrease in analytical thinking [10]. In a paper titled “Brain Drain: The Mere Presence of One’s Own Smartphone Reduces Available Cognitive Capacity”, the authors [11] concluded that the mere presence of a smartphone may further limit cognitive ability by stealing memory resources and intelligence fluidity. Searches that took days in libraries are now completed in minutes [12]. Still alluding to Steve Krug’s book, “Do not Make Me Think!”, How much are smartphone users willing to think about their interaction with the device?

The closest studies that exist on the subject are about the use of visual clues as a way of indicating elements that are off the screen, that presents a new approach for the



**Fig. 1.** Example of Instructional overlays or coach marks [19]. Usually, the text is similar to handwriting and the arrows resemble hand drawn arrows. The arrows and text are placed on a black background with faded transparency over the view of the application on which it is intended to help the user. Transparency fading is usually within the range of 90 to 95%.

indication of points of interest that are occluded by other objects in a geovirtual 3D environment [13], however does not present data on the efficacy of the technique used. In another study also on the application of visual clues, was tested a new kind of visualization of information outside the screen that was designated Wedge. The Wedge algorithm was developed to take into account several factors, among which, to avoid the overlap of elements. This is one of the pertinent points for the current research since there is an overlay of a new layer of information on the presented view. The Wedge study concluded that there was a significant improvement in Wedge's accuracy over a concurrent (Halo) system, but does not point to interface overlap results [14].

A 2014 study suggests that modifying the elements of the UI by hiding elements that the user tends not to use can help improve the user experience [15], indicating that it is pertinent to know what elements of the interface are really important to the user. In the current society where users want to access information more and more rapidly, and this is also why they invest frequently in the updating of their equipment, it is not appropriate to add information that leads to the loss of time in accessing information unless it is strictly necessary.

One study hypothesized that the use of visual clues could improve the insertion of text on virtual keyboards of mobile devices in less experienced users. The experience was made as follows: at each stroke of a letter, other letters gained emphasis by offering

a visual clue, as the letters were converted to bold, by prediction of which character would be pressed next. The results obtained in this study indicated a significant reduction of the time in the introduction of text.

The study that comes closest to the project topic is a study whose hypothesis is that the inclusion of examples (faded), that is, that appear and disappear, facilitates learning [16]. This hypothesis was tested with the use of the mentioned technique in a computer game for learning mathematics in which the calculation screens of the control group did not present visual aids of how to perform the calculations. These visual aids were presented to the experimental group in the form of text and arrows that appeared and disappeared. The results of this study showed that faded instructions, help to improve the learning of contents in the computer since the experimental group obtained better results in the game.

Another study tested the use of prompts or popups, with some tips on how to solve calculation problems and concluded that students with access to aid prompts obtained better test scores [17].

Although there is a growing number of studies in the UX area for mobile devices, a study on the use of instructional overlays or coach marks to provide indicators of its effectiveness has not been found, so this current research is important for UX and UI professionals, and to the companies that develop applications, who need to decide whether or not to invest resources and time in the creation and application of instructional overlays. The concern of companies developing applications for both computers and mobile devices today is highly focused on the speed of access to content, so any information that can bring data to evaluate the effectiveness of a technique that will bring another layer of information to an interface of an application is an added value.

Considering the constraints of space on the screen and the amount of information that may need to be shown in a particular view of an application, the integration of elements that can help guide the user and retain information in his memory, lead to the hypothesis that the use of instructional overlays helps users to interact more effectively with smartphone applications. This hypothesis will be tested by analyzing data referring to the time used by the study participants (dependent variable) to complete a particular flow in an application prototype specially designed for the study. The study aims to evaluate participants interaction in an application context and in a graphical environment as generic as possible so that the data collected can not only reflect what could happen if the participants were using any application that uses the IO technique, but also that it is easy to replicate.

## 2 Methodology

### 2.1 Study Design

A between-subject design was used. Participants were assigned to the control or experimental groups through the use of computer-generated randomization [18]. The control group completed a proposed flow without the use of IO and the experimental group, completed the proposed flow using IO.

## 2.2 Sample

Thirty participants of both sexes, 12 female, and 18 male, between the ages of 18 and 55, participated in the study. The 15 participants of the control group had an average age of 35 years old ( $sd = 10$ ;  $min = 18$ ;  $max = 54$ ) and the fifteen of the experimental group an average age of 37 years ( $sd = 9$ ;  $min = 24$ ;  $max = 55$ ).

The criteria for selecting participants for this study was: (1) age between 18 and 65 years; (2) use of an iOS or Android smartphone for a year or more; (3) scholarship higher than the 9th grade; (4) Portuguese as the mother language. (5) good visual acuity for near vision.

(1) age of the participants: the sample is intended to be as comprehensive as possible in terms of age range. (2) the premise of using a smartphone for more than a year is important since a period of contact time with devices of less than one year could cause a parasitic variable in cases of poor perception of the independent variable (instructional overlays). (3) scholarship above grade 9 will ensure that there is minimal contact with learning materials, and since the study is based on a layer that is superimposed with learning instructions for rapid apprehension, this factor is important. (4) Portuguese as the mother tongue is also important since the instructions will be in Portuguese. (5) good visual acuity at close range to ensure that vision does not detract from understanding the interfaces and the implementation of the proposed actions. The use of corrective eyewear is accepted for the accomplishment of the tasks.

## 2.3 Materials

For the test, we used three smartphones with a screen dimension ranging from 4,7 in. (iphone 6s) to 5.5 in. (Nokia 6.1).

We used a prototype of a mobile application, with two variations, one of them without IO (for use in the control group), and the other with IO (for use in the experimental group).

For prototypes creation, we used Adobe XD. The prototype was designed in Adobe XD and the web application (prototype) was installed in the device also through Adobe XD app hosting. Videos of every interaction with the prototype were recorded. For ios it was used the system assistive touch to create a custom gesture to turn visible the clicked area and the screen recording feature of the ios. For android, AZ screen recorder was used. For movies visualization and time measure QuickTime was used. For statistical and data analysis we used SPSS.

As a prototype, Smart City Sense application project [20] was used, that involves the conceptualization, design and implementation of an information technology platform where the wealth of data collected by citizens (volume, variety, and detail), is aggregated with data collected by a variety of other existing sensors in the city, giving in real time, a clearer and more vivid vision of the global “pulse” of the city. This app, among several functions, it could be used to obtain information about the city or to report information about the state of the city in various domains such as cleaning or safety.

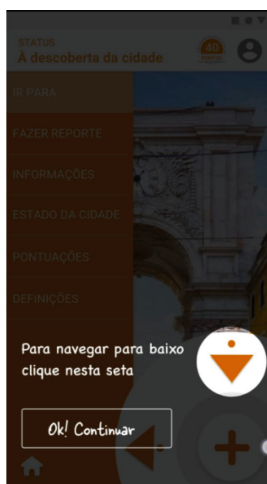
In order to test the effect of IO, a navigation interface that could not be trivial was created. The navigation button in the application (Fig. 2) consisted of an arrow

pointing downwards (down navigation), an arrow pointing to the left, which recedes from the previous action and a button with a plus sign (+) in the center, to enter a menu or sub-menu.



**Fig. 2.** Button of the navigation interface.

As for the use of IO, several studies suggest that short-term visual memory only allows the storage of 4 to 5 objects [21, 22], we did not exceed 5 IO (E.g. Fig. 3)



**Fig. 3.** Instructional overlay example

## 2.4 Procedures

Tests were performed in a closed room where only the experimenter and the participant were present. The mean duration of the tests was 10 min, ranging from 8 to 12 min. Participants were not informed of the methods and purpose of the study.



About 2 min were used for an initial conversation and the completion of a form that collected various information such as demographic data (age and sex), literacy and how long they were using smartphones. Participants also signed a consent.

After completing the form the participants were given a mobile phone with the prototype installed. Before the test started, screen recording was enabled on the device.

During the test, the experimenter provided the objectives, prior to each of the four tasks to be performed. Participants were instructed that after the beginning of the tasks there would be no possibility of questioning the experimenter.

The tasks requested were as follows:

Task1: Within the app there are several types of information. In this task, you are asked to find the weather information, for the next day. Users should be able to find the weather menu and in the submenu find 'see tomorrow'. The task must be performed within the estimated time period and should not cause confusion.

Task 2: In the app, there is a zone with personal information, in this task you are asked to access this area and change the profile photo. Users should be able to find where they can change their data (first and last name) and profile photo. The purpose is to change the profile photo. The task should be performed close to the estimated time period and should not cause confusion.

Task 3: App users can report. In this task, you are asked to report a negative event. Users should be able to find the 'REPORT' menu and be able to make a report, this being of the event type negative, with a priority, a parameter and added a photo. The task must be performed within the estimated time period and should not cause confusion.

Task 4: There are challenges that encourage the community to provide live information about their neighborhood. In this task, the user is asked to find a challenge to do. Users should be able to find the 'CITY STATE' menu and then click on 'Active Zone Challenges' and load a challenge that is free. The task must be performed within the estimated time period and should not cause confusion.

When all tasks are completed the interface turns black and indicates that the test is over. The phone is delivered to researchers who turn off the screen recording and transfer the video to the computer.

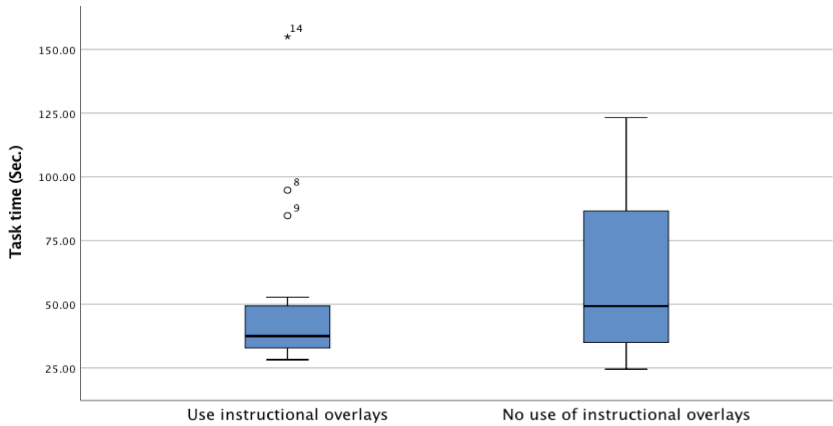
After all the sessions were completed the videos were analyzed in order to survey the times corresponding to each task.

### 3 Results

After data for each time task being collected from videos, it was exported to SPSS.

Average time of the four tasks for each participant was computed. In Fig. 4, we present that average results in the form of boxplots, for the use of instructional overlays and with no use of instructional overlays.

Average, median and standard deviation of participants that used instructional overlays (experimental group) was respectively,  $X = 51,73$ ,  $M = 37,5$  and  $SD = 34,72$ . For the control group, that did not use instructional overlays values of average, the median and standard deviation were respectively,  $X = 60,15$ ,  $M = 49,25$  and  $SD = 32,46$ . A t-test for independent samples was performed to check differences, and



**Fig. 4.** Boxplot of the time of tasks by use or no use of instructional overlays

there were no significant differences between the two groups ( $t = -0.69$ ;  $p > 0.1$ ). Although there is no statistically significant differences, the observation of boxplots and medians reveals a trend towards higher time when the instructional overlays are not used. Probably, with an increase of the sample, a difference in the value of the statistical significance can be verified.

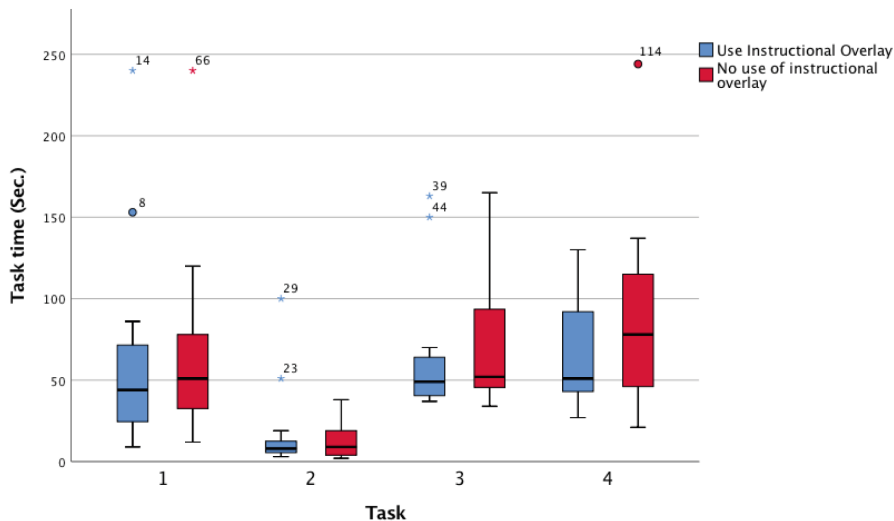
A more thinner analysis of the results obtained by task is presented in Fig. 5 and Table 1. Statistically, there are also no significant differences in any of the tasks ( $p > 0.05$ ). However, the observation of the boxplots and the values of the medians, also show a tendency towards a time of accomplishment highest in the task without instructional overlay. We can observe a more noticeable difference is in task 4 (With overlay median = 51 s. With no overlay media = 78 s). Task four was more complex because it was where people had more doubts about where to find the information

Sessions was recorded and a qualitative analysis was performed. In the comments concerning the instructional overlays made by participants in that condition, about 70% of participants declared some discomfort with the presence of instructional overlays. A lot of users after 2 or 3 instructional overlays wanted to quickly pass it through.

4 Conclusions

The negative comments with instructional overlays may be explained as caused by a change in the usual operating mode of app users. However, that does not mean that from the cognitive performance point of view there can be no advantage in using instructional overlays.

This study clearly has a statistical limitation because of the small sample size. Nevertheless, from the trends observed in the boxplots, and from a more qualitative analysis of the participants' comments during the tests, we conclude that for a company to know whether or not to invest in instructional overlays, it depends of the novelty or complexity of the tasks to be performed.



**Fig. 5.** Boxplot of the time of the four tasks by use or no use of instructional overlays

**Table 1.** Descriptive statistics for the use or no use of instructional overlays in the 4 tasks.

		Task 1	Task 2	Task 3	Task 4
Use of instructional overlays	Average	60,9	17,2	63	66
	Median	44	8	49	51
	SD	61,8	25,8	39,5	33,2
No use of instructional overlays	Average	67	13	74,7	85
	Median	51	9	52	78
	SD	56,6	12,6	44,1	57

If the app is simple and respects usual mental models or operating modes, the company should not invest in the use of instructional overlays. However, if it is predictable that users will have to create new mental models and use different types of operating modes, the company should consider investing in the use of instructional overlays.

The latter case may also apply to users not accustomed to using apps like elderly people. In this case, it would be interesting for accessibility reasons, to consider the use of instructional overlays as an option, of course, if there is a temporal and financial availability of the company.

It is also important to note that during the tests most participants demonstrated annoyance after the third coach mark, so it is advisable not to use several coach marks at once and their use should be in context.

**Acknowledgements.** This work was co-financed by the Portuguese Foundation of Science and Technology under the project UID/EAT/04008/2013 (CIAUD).

## References

1. Anon.: number of apps available in leading app stores as of 3rd quarter 2018 (2018). <https://www.statista.com/statistics/276623/number-of-apps-available-in-leading-app-stores/>. Accessed 1 Feb 2019
2. Anon.: Number of smartphone users worldwide (2019). <https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/>. Accessed 1 Feb 2019
3. Kim, K.J., Sundar, S.S.: Mobile persuasion: can screen size and presentation mode make a difference to trust? *Hum. Commun. Res.* **42**, 45–70 (2016)
4. Raptis, D., Tselios, N., Kjeldskov, J., Skov, M.B.: Does size matter? investigating the impact of mobile phone screen size on users' perceived usability, effectiveness and efficiency. In: *MobileHCI 2013 Proceedings of the 15th International Conference on Human-Computer Interaction with Mobile Devices and Services*, pp. 127–136 (2013)
5. Karlson, A., Meyers, B., Jacobs, A., Johns, P., Kane, S.: Working overtime: patterns of smartphone and PC usage in the day of an information worker. In: Tokuda, H., Beigl, M., Friday, A., Brush, Tobe, Y. (eds.) *Pervasive Computing, Lecture Notes in Computer Science*, vol. 5538, pp. 398–405. Springer, Heidelberg (2009)
6. Chittaro, L.: Visualizing information on mobile devices. *Computer* **39**(3), 40–45 (2006)
7. Sarcar, S., Munteanu, C., Jokinen, J.P.P., Oulasvirta, A., Silpasuwanchai, C., Charness, N., Dunlop, M., Ren, X.: Designing mobile interactions for the ageing populations. In: *Proceedings of CHI EA 2017*, pp. 1131–1134. ACM, New York (2017). <https://doi.org/10.1145/3027063.3027074>
8. Levine, B.K., Beason-Held, L.L., Purpura, K.P., Aronchick, D.M., Optican, L.M., Alexander, G.E., et al.: Age-related differences in visual perception: a PET study. *Neurobiol. Aging* **21**, 577–584 (2000)
9. Krug, S.: *Don't Make Me Think*. New Riders, Berkeley (2006)
10. Barr, N., Pennycook, G., Stolz, J.A., Fugelsang, J.A.: The brain in your pocket: evidence that smartphones are used to supplant thinking. *Comput. Hum. Behav.* **48**, 473–480 (2015)
11. Ward, A.F., Duke, K., Gneezy, A., Bos, M.W.: Brain drain: the mere presence of one's own smartphone reduces available cognitive capacity. *J. Assoc. Consum. Res.* **2**(2), 140–154 (2017)
12. Carr, N.: Is Google making us stupid? *Atlantic Monthly* **302**(1), 56–62 (2008)
13. Trapp, M., Schneider, L., Holz, N., Döllner, J.: Strategies for visualizing points-of-interest of 3D virtual environments on mobile devices. In: *6th International Symposium on LBS & TeleCartography*. Springer, Heidelberg (2009)
14. Gustafson, S., Baudisch, P., Gutwin, C., Irani, P.: Wedge: clutter-free visualization of off-screen locations. In: *CHI 2008*, pp. 787–796. ACM, New York (2008)
15. Hashemi, M., Herbert, J.: UIXSim: a user interface experience analysis framework. In: *Fifth International Conference on Intelligent Systems, Modeling and Simulation*, pp. 29–34. IEEE (2014)
16. Vrugte, J., de Jong, T., Vandercruysse, S., Wouters, P., van Oostendorp, H.: Computer game-based mathematics education: embedded faded worked examples facilitate knowledge acquisition. *Learn. Instr.* **50**, 44–53 (2017)
17. Atkinson, R.K., Renkl, A., Merrill, M.M.: Transitioning from studying examples to solving problems: effects of self explanation prompts and fading worked-out steps. *J. Educ. Psychol.* **95**, 774–783 (2003)
18. Urbaniak, G.C., Plous, S.: *Research Randomizer (Version 4.0) [Computer software]* (2013). <http://www.randomizer.org/>. Accessed 1 Feb 2019

19. Anon.: correct name of transparent instructional overlays/coach marks for announcing new features or first time use (2018). <https://ux.stackexchange.com/questions/91586/correct-name-of-transparent-instructional-overlays-coach-marks-for-announcing/>. Accessed 1 Feb 2019
20. Rebelo, F., Noriega, P., Oliveira, T., Santos, D., Oliveira, S.: Expected user acceptance of an augmented reality service for a smart city. In: Marcus, A., Wang, W. (eds.) *Design, User Experience, and Usability: Users, Contexts and Case Studies*. DUXU. LNCS, vol. 10920, pp. 703–714. Springer, Cham (2018)
21. Alvarez, G.A., Cavanagh, P.: The capacity of visual short-term memory is set both by visual information load and by number of objects. *Psychol. Sci.* **15**, 106–111 (2004)
22. Luck, S.J., Vogel, E.K.: The capacity of visual working memory for features and conjunctions. *Nature* **390**, 279–281 (1997)



# Communication Design as Tool for Social Transformation: A *Co-design* Project with the Residents of the Rego Neighborhood, in Lisbon

Teresa Olazabal Cabral and Inês Farmhouse Coimbra<sup>(✉)</sup>

Faculdade de Arquitetura, Universidade de Lisboa, Rua Sá Nogueira, Polo  
Universitário, Alto da Ajuda, 1349-055 Lisbon, Portugal  
teresaoc@fa.ulisboa, ines\_farmhouse@hotmail.com

**Abstract.** Organizations that develop work in neighborhoods with complex social problems can benefit from collaboration with communication designers. This paper presents a study of a co-design project, developed with young people from Rego Neighborhood, in Lisbon, with the purpose of creating the image for an event called “Festival Passa Sabi – Geração RG”. The preparation of the festival consisted of a set of meetings that involved IPAV workers, residents, former residents and the young people that we considered to have good leadership skills and responsibility. The graphic images and medias were created in close collaboration between the designers and young leaders. The responsible work carried out by the young leaders involved allowed them to acquire skills so that in the future they could lead other similar projects, building bridges between different communities. We therefore believe that this study may help other designers who work in the social field.

**Keywords:** Social design · Communication design ·  
Conflicts within communities · Co-design · Participation design ·  
Collaborative design

## 1 Introduction

Our interest in the theme presented in this paper is based on ethical values, which led us to take an active attitude towards social inequalities, realizing the potential that the practice of design can have for intervention in needy and socially stigmatized communities. The practice of design in the specific context of social neighborhoods, as long as it includes an appropriate and respectful social and cultural component, can result in benefits for the residents. The feeling of unease towards the social reality that is experienced in certain neighborhoods in Lisbon, particularly when there is great conflict between and within different communities, led us to look for design methods suitable for these realities.

We place ourselves here in a less current, non-commercial position as designers, where the idea of intervening in socially difficult urban contexts results not only from our nonconformity, but also from the motivation we obtain from undertaking actions

that contribute to the well-being of communities in these neighborhoods. In the case study of the action developed in the Rego neighborhood, the goal was to run a short action covering cultural aspects, but with potential for “social transformation”, including a collaborative design project.

## 2 Social Design and Participation

In order to better contextualize the proposal that we developed, we need to mention important concepts discussed by several critics and designers. The 1960s were the main origin of what we now call social design. Particularly of note is the importance of the “First Things First” manifesto (1964) written by Ken Garland and signed by a group of graphic designers, photographers and students, inviting designers to communicate meaningful products that have an educational and social impact rather than creating projects limited to encouraging consumption.

The manifesto makes an appeal and positively questions, offering a new attitude for designers in their interaction with society, and in essence of the ideas expressed, and the text is still relevant today (having been resumed in the year 2000) [1]. Alongside other texts, we have Vitor Papanek’s “Design for the Real World: Human Ecology and Social Change” (1972) [2], which is an essential reference in the defense of an ethics of accountability for design professionals regarding the new problems that society faces. More recently, in 2014, Vitor Margolin stated that: *“It may not be realistic to believe that designers will save the world, but it makes sense to recognize that design – when practiced with ethical conscience – is one of the most powerful tools humanity has ... Design is the activity that flows from our ability to respond to problems, starting from the imagination in the direction of action”* [3].

In 1972, Reyner Banham (architecture and design critic) mentioned the concept of Participation during a conference organized by the Design Research Society. According to Banham, the idea of including the users’ wishes in an architecture or design project was something innovative, and his presentation signaled the emergence of the concept of participatory design [4].

Community members’ participation in a social design intervention is vital to provide a detailed survey of the situation of conflicts that are intended to be reduced and so they can be mobilized to carry out a social or cultural intervention. In this type of project, for the benefit of the community, it is necessary for designers to work with the people in the community, giving them the opportunity to express themselves, assert their opinions without constraints, and get involved in projects. Rather than creating eye-catching images, the designer must understand the exact meaning and root of the social problems identified. Often his or her work can only be only part of a larger system, and it is crucial that issues of substance that relate to the social context are explored so they can be integrated into the project [5].

A preparation process is necessary, including an accurate diagnosis of the context where the action is to take place, ensuring active participation in the project by community members. Without residents’ motivated and voluntary participation, it will be hard for the action to be implemented, let alone to achieve the desired success. This involvement of chosen individuals from a neighborhood to be part of a design project is

a participatory process, also referred to as co-design, which means “*designing with others*” [6]. In a co-design action, there is thus a dialogue between the designer and the people in the neighborhood (those who demonstrate the greatest ability to undertake the necessary tasks), and they also have decision-making power, which requires mutual learning among the actors involved. Participants can contribute to the “*idea, conceptualization, from/to the prototype or selection of the proposal, to the design specification, and finally to the detailing, implementation, construction or contributing to the design results/solutions*” [7].

There is a wide range of situations that can be included in participatory design, involving the most active members of the community and making use of their ideas and expertise. In a co-design process, the designer decides on the final solution to be adopted and knows how to integrate this participatory collaboration.

### 3 The Rego Neighborhood and the Work of IPAV in the Field

As a consequence, in part, of the PER – Special Rehabilitation Program of municipal re-housing policies (started in the 1980s), internal conflicts pre-existing in the Bairro do Rego in Lisbon were intensified by the buildings constructed for this program. This is particularly in the area of Santos ao Rego, where we worked, which presents physical characteristics that result from the policies followed by Lisbon City Council during the construction of this social accommodation for rehousing (Fig. 1). The PER buildings are characterized by a typology of definitive rehousing models, with dense, tall constructions inhabited by different people who had come from dwellings in shacks [8]. Despite their improved living conditions, the PER buildings did not help bring the communities together [9] and they were not able to counteract the socioeconomic segregation and spatial zoning that affected the now-rehoused populations, but instead contributed to making their situation much worse, leading them to become stigmatized areas [8]. The communities that came to occupy the neighborhood of the PER rehousing are socially excluded due to their fragile socio-economic profile and low academic and vocational qualification. The housing projects for the Santos ao Rego neighborhood were built without any concern for the particular characteristics of their future tenants, not following a participatory, inclusive process with residents, and losing their habits and customs [10]. For this reason, occupancy of the new housing was joined by a trend towards rejection by the people who came to occupy the dwellings of the neighborhood [8].

The residents of the Rego neighborhood fall into three main groups: the gypsy community, the community of immigrants (or descendants of emigrants) of African origin, and a group of Portuguese Caucasian people. With very diverse ethnic and cultural groups, there are frequent conflicts and disagreements between and within them.

Many members of the gypsy community remain closed to coexistence with other external groups, due to their traditions and customs [11], and many social stigma problems remain in the Rego neighborhood.

It is possible to observe very different socialization characteristics in the community of immigrants (or descendants of emigrants) of African origin, and they are better





**Fig. 1.** Perspective of the intervention location in one of the PER groups in Rego Neighborhood where we can observe a gallery hall, a place of daily coexistence among the residents, one of the inner courtyard where IPAV intervened and an external view of an apartment complex displaying PER building characteristics. (Photos: December 2017)

integrated into Portuguese society and culture. It is a community with more varied day-to-day coexistence and a greater propensity to socialize without prejudice. A taste for celebrations and festivities was observed in this community, with regular get-togethers, sharing music and food in the neighborhood courtyards.

Since 2013, the IPAV (Padre António Vieira Institute) has intervened in the Santos/Rego neighborhood with social projects, starting with the “O Nosso Km<sup>2</sup>” (Our square mile) project – an initiative of the C. Gulbenkian Foundation [12]. The project started with a first phase of identifying the most dramatic social problems in this area. Subsequently, a local structure was created to combat the marginalization of the population and the neighborhood’s closedness in relation to surroundings. Finally, it sought to empower some neighborhood people and associations to create and take on new initiatives themselves later on.

Due to the IPAV’s work, we note that in recent years there has been greater openness on the part of the various communities, particularly the gypsy community. The “O nosso Km<sup>2</sup>” project ended in 2016, with numerous changes being observed in several spatial and social aspects: *“we used to say that when we arrived it seemed that the street was very narrow and the buildings were very tall, and today the feeling we have is that the neighborhood has opened up, and so it seems that the street is suddenly much bigger and that the buildings are not so high. Because in fact it was a neighborhood that was very difficult to get into [10]. Much of this work to open up the neighborhood was thanks to the creation of friendly, trusting relationships between the IPAV technicians and the residents, established through daily work in the field that contributed to more peaceful life among communities: “My volunteering consisted of giving ballet lessons to girls (...) that was important to them! (...) The other activity of painting the lots also had an impact because it stimulated the idea that we all have to help ... it was these small activities that changed people’s mentality and helped them trust us” [13].*

Of this work it is important to highlight two important IPAV initiatives in Bairro do Rego, which positively marked the residents’ memories. We should mention the impulse given by the IPAV to the residents in creating the Passa Sabi Neighborhood

Association (the term “pass sabi” comes from *crioulo*, meaning being well) and the Festival da Ponte (Bridge Festival, belonging to the project “O Nosso Km<sup>2</sup>”), which received support for its second edition from the Master’s Degree in Communication Design at FA-Ulisboa to create the image for the Festival’s advertising campaign. This fieldwork performed by students and needy communities was the origin of this research, where students acquired pedagogical competence such as: “*further development of essential ethical and social awareness in professional practice; a further development of critical faculties; [and] appreciation of the importance of cultural identity when doing design*” [14].

However, at the beginning of March 2016, despite the constant stimuli of the IPAV, attempts to meet with the neighborhood residents presented a challenge, highlighting a general lack of interest in the initiatives launched in the projects, including the neighborhood association. After a thorough analysis of the history of the place and the IPAV’s actions in it, we came to the conclusion that there were several aspects of the institute responsible for this change in behavior, highlighting: the transformation of the “O Nosso Km<sup>2</sup>” space into a space dedicated mostly to office work, with the focus going to work in the network of partners and the constant turnover of the team that were in the field.

#### **4 Communication Design in the *Passa Sabi* Festival Planning Process**

We identified one of the biggest problems in the field as being the demobilization of contact networks between IPAV members and the community in the Rego neighborhood, partly due to the constant turnover of the institute team. Given the fragmentation of the network, it was urgent to re-establish bridges between the two parties. Without this, any future action by the IPAV in Rego would be ineffective.

In February 2016, IPAV was confronted with little uptake of the “Líderes Ubuntu” initiative, namely the youngsters of the Passa Sabi association. This activity sought to empower young people from the Rego neighborhood following the principle of “*servant leadership*” [15]. Therefore, we believed that it was necessary to set a specific objective in line with the interests of young people to enable them to become active. The objective was to hold a neighborhood festival, since resumption of the “Festival da Ponte” was revealed to be a common desire transversal to all generations and community groups, and was the initiative remembered with the greatest affection by residents.

We started by creating a list of names of potential candidates with leadership skills. These young people aged between 15 and 30 stood out for their participation in the activities developed for the neighborhood by the IPAV over the years. This list was created by the IPAV team with the help of Mariana Jeca (a member IPAV staff) and Eugénio Silva (president of Passa Sabi Neighborhood Association). The initial approach with young people took place through telephone contacts and social networks provided by the Mariana Jeca and in some cases in person on the street. From this point, it was possible to schedule the first of 11 meetings that were to be held during June 2017 to plan the Festival.

The first meeting was attended by 13 young people from the three community groups, involving the support of technicians from the institute (Fig. 2). We opened with an exercise to break the ice, consisting of a brief individual presentation, where each person was asked to say their name and a passion without which they could not live. Although all the people already knew each other, this exercise was fundamental to break the tension and the resistance to coming closer. From here, we started by defining the “action fronts” that we wanted to work on, establishing activities for children, the presence of live African and Gypsy music and the sale of food at small stalls as the structural elements of the Festival’s program. We set a date and time for the day, ideas and resources for the activities, names of potential artists, potential residents interested in selling food, and suggestions for obtaining and distributing profits.



**Fig. 2.** Moments from the first and second preparation meetings for the Festival. In the left image we can see the participation of the young people in organizing the initiative. In the right photo, we see the conversation with the neighborhood women interested in selling food at stalls. Photographs by Mariana Jeca, June and July 2017

In spite of the general enthusiasm and commitment of the young people, the second meeting – focusing on organizing food in small stalls with women from the neighborhood – had practically no support from the young people (Fig. 2). We asked them how we could engage more locals to help with the event. They argued that the initial approach should be more focused on questions about what they would like to see happen [16]; that regular rather than occasional events would not only contribute to the credibility of the team in order to achieve possible collaborations and financial support, but increase residents’ participation [17]; and that technicians on the ground should be less concerned, leaving the implementation of the action in the hands of the participants, forcing them to take on responsibility and commitment [18]. At the following meetings, the number of young people varied, with an average of 5 to 7 participants per meeting.

The moment of greatest tension arose during the fourth meeting, when we tried to restrict the number of food and sales items on the stalls. At a meeting that comprised all the young people, technicians and residents, there was disagreement among some of the residents regarding these restrictions, with a tense atmosphere that clearly came

from past situations. Despite this situation, the following meetings were held without further incidents.

The creation of the image for the Festival took place using a participative process of *co-design*, in a meeting with the young people dedicated exclusively to communication design. We had detected in previous situations that the creation of names for the Festival and setting objectives and structuring concepts were challenges for the residents of the neighborhood. We thus sought to provide the young people with the necessary tools to help them “unlock”, starting with creating the concept and name for the Festival, then developing the image for the poster – in this case, symbols, graphic language, message and discourse tone with which they identified – and ending with the strategy and choice of means of dissemination. The meeting was attended by 5 young people.

We started with a *brainstorming* of keywords that they associated with the Festival, in which the participants suggested words such as: autonomy; community; neighborhood development; fun; and meeting/socializing. Based on these elements, we tried to combine words and create acronyms that would allow us to define a name for the Festival. After several proposals, the name established was “Festival Passa Sabi – Geração RG”. The word “Passa Sabi” clearly came from the positive memory left by the actions of the Neighborhood Association, while the expression “Generation RG” (Rego Generation) expressed a desire by this new generation of young people to work for the benefit of the residents and communities. For them, the message transmitted by the name to the festival was loaded with symbolism, which related to the history of past actions, opening a path to the future they wanted for the neighborhood.

We proceeded to a second phase, aimed at developing an image for the Festival. The young people present expressed the importance to them of creating an identity symbol for the Festival, but when we asked them about the message they wanted to convey, they did not know how to answer. The young people also explained that if the image of the poster only included text, no one in the neighborhood would read it, since images/photographs would always be needed to capture their attention. During the meeting, one of the young people was drawing some ideals on a piece of paper without apparent purpose, composing an image from three main symbols: buildings, a hand and a path. We made an interpretation of the possible message that the symbols could convey together, in which the hand would represent the people and the work of the community in building a path to a better neighborhood (represented by the road and buildings). In other words, the people’s work is what makes the neighborhood. The young people received this interpretation enthusiastically, arriving at an image that everyone accepted as their own, thus providing a new image of the Festival (Fig. 3). We choose representative buildings from three different areas of the neighborhood, thus opening the initiative to all residents – even if they belonged to different territories. We established black, blue and white as the main colors, which were present in the recognizable graffiti on one of the main entrance facades for the neighborhood. In the end, the young people reviewed the poster created, commenting that “*the image was excellent!*” [19].

In the third phase – aimed at the means and strategy of dissemination – we suggested the creation of different communication media for the two existing audiences: the placement of posters on the streets to publicize the activities that would happen in the morning for children; and the launch of another poster on social networks for the



**Fig. 3.** Posters promoting the Passa Sábí Festival. At the top, a poster with the names of the artists for the night program, at the center of which we can see the identity symbol created at one of the meetings with the young people through a participative process of *co-design*. Below, three examples of the artists' individual *posts* released on social networks

older people, containing the names of artists who would perform in the evening. The posters on the street and social networks were more than enough and, furthermore, in these contexts part of the dissemination is by “word of mouth” [20].

After the meeting, the images for the different media were worked on by the designer, always accompanied by young people’s opinions. The biggest obstacle was the short time frame for creating the images, which involved, on one hand, bringing the date of the Festival forward – thus compromising the dissemination time that would be necessary – and, on the other, that in these contexts the time spent on planning and executing any initiative by the people is extremely short because of the speed and efficiency with which they mobilize resources and means.

The Festival was held on July 29, 2017, from 11:00 am to 2:00 am the following morning, and took place in the inner courtyards and the vacant space in the neighborhood (Fig. 4). It was aided by 5 members of IPAV staff, 5 volunteers (2 of whom belong to the





**Fig. 4.** Key moments of the Passa Sabi Festival. From left to right: Games and activities with children performed in the inner courtyards; Cultural dance by the gypsy community at the end of the afternoon; Children watching a music performance by gypsy artists; Live music at night with performances by artists from the African community of Rego; Team photo of the people involved in the Festival, with the presence of IPAV technicians, young people and volunteers for the day. Photographs by Mariana Jeca, IPAV, July 2017

gypsy community) and 8 of the young people who were involved in the process of creating the festival. The Festival opened with activities for the youngest, with the participation of more than 50 children from inside and outside the neighborhood, and the positive spirit that was felt was noted: *“The parents liked it very much, because the children came home cheerful, happy, they enjoyed the activities, had no reason to complain, they had food, everything was good”* [19]. The evening’s program opened with a performance by Gypsy musicians from the neighborhood. This was one of the biggest successes of the night, and it was the first time, in an IPAV action at this location, that young people from the gypsy community were able to perform on stage, bringing together different gypsy families from various parts of the neighborhood in a unique moment and celebration: *“... it was good to see how all the communities in the neighborhood came together and had fun at the event.”* [17] The night of music reached its peak with a performance by artists from the African community of Rego, accompanied by the sale of food at the team’s stall.

The internal IPAV survey and individual interviews with the young people showed that they valued what they had learned throughout the process: developing their skills to take on responsibilities (and commitments); increasingly their trust in the other; skills and concepts learned about how to organize an event of this nature; developing a greater understanding of the preparation of dissemination materials; the ability to cope and respond to stressful situations; and learning related to the relationship between generations and interculturality [21].

## 5 Conclusion

The work and responsibility taken on by the young leaders involved in the Passa Sabi Festival process allowed them to acquire skills to set up events that can keep providing moments of exchange and shared identity among the different communities, thereby making themselves active elements of the neighborhood association.

The literature review and the experience acquired in the field have reinforced how indispensable it is to have persistent, continuous and regular work on the relationship with members of the community, establishing relations of friendship and trust. In order for a social design action to succeed, these relationships must be established between the staff and designers of the organizations that are in the field, and the residents, leaders and collaborators in the communities themselves.

Our experience in communication design has been enriched, particularly in pedagogical and social intervention aspects. We can say that this project, through its social action led using co-design achieved the objectives proposed and exceeded our expectations, and allows us to face similar new actions with more skills and new knowledge. We understand that it is essential for the community to see itself in the image, symbols, graphic language, tone of the speech and message, in the promotional media. If these media do not contain elements that the community recognizes and sees itself in, they will be rejected. Designers should be aware that members of communities will not know immediately which symbols they feel represent them. They will only be able to do so using tools, principles, games and activities organized by the designers that allow them to decode these symbols and elements over several meetings with the designers.

**Acknowledgments.** The authors are grateful for the support given by CIAUD – Research Centre in Architecture, Urbanism and Design and FCT – Foundation for Science and Technology (Portugal). We would also like to thank the IPAV team, the young people from Rego Neighborhood and the volunteers, who were involved in the preparation and implementation of the Passa Sabi Festival.

## References

1. Garland, K.: First things first manifesto 2000: thirty-three visual communicators renew the 1964 call for a change of priorities. *Eye Magazine* (1999)
2. Papanek, V.J.: *Design for the Real World: Human Ecology and Social Change*. Academy Chicago, Chicago (1985)
3. Margolin, V., Côrte-Real, E.: *Design e risco de mudança*, p. 78. Verso da História e ESAD, Portugal (2014)
4. Banham, R.: Alternative networks for the alternative culture? In: *Design Participation: Proceedings of the Design Research Society's Conference*, pp. 15–19. The Design Research Society, UK (1972)
5. Shea, A.: *Designing for Social Change: Strategies for Community-Based Graphic Design*, p. 10. Princeton Architectural Press, New York (2012)
6. Fuad-Luke, A.: *Design Activism: Beautiful Strangeness for a Sustainable World*, p. 179. UK, Earthscan (2009)
7. Fuad-Luke, A.: *Design Activism: Beautiful Strangeness for a Sustainable World*, p. 148. UK, Earthscan (2009)
8. Gonçalves, A., Pinto, T.C.: Os Bairros Sociais Vistos por si Mesmos: Actores, Imagens Públicas e Identidades. *Cidades – Comunidades e Territórios*, vol. 3, pp. 111–131 (2001)
9. Pereira, Á.P., Silva, D.S., Baptista, I., Perista, P.: *Habitat e Minorias: Processos de (Des) integração de Grupos Étnicos em Lisboa e no Porto*. *Cidades – Comunidades e Territórios*, vol. 3, pp. 93–109 (2001)
10. Teles, M.: Recolha de informação sobre a história do local e das ações do IPAV no Bairro de Santos ao Rego. In: Coimbra, I. (ed.) *Design social e relações de bem-estar em pequenas comunidades locais: design de comunicação como ferramenta de transformação social*, Anexos, pp. 195–207. Faculty of Architecture, University of Lisbon, Lisboa (2017)
11. Mendes, M.: *Ciganos: identidades, racismo e discriminação*. Caleidoscópio, Portugal (2012)
12. Calouste Gulbenkian Foundation: *O nosso km2 (Our square mile)*. <https://gulbenkian.pt/en/project/o-nosso-km2/>
13. Jeca, M.: Recolha de informação sobre as características do Bairro de Santos ao Rego e das ações do IPAV no terreno. In: Coimbra, I. (ed.) *Design social e relações de bem-estar em pequenas comunidades locais: design de comunicação como ferramenta de transformação social*, Anexos, pp. 208–221. Faculty of Architecture, University of Lisbon, Lisboa (2017)
14. Cabral, T.O.: Creativity and a social graphic design project in the Rego neighbourhood in Lisbon. In: Bagnara, S., Tartaglia, R., Albolino, S., Alexander, T., Fujita, Y. (eds.) *Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018)*. *Advances in Intelligent Systems and Computing*, vol. 825, pp. 717–726. Springer, Cham (2019)
15. Programa BIP/ZIP 2016 – Ficha de Candidatura refª: 004 Ubuntu no Bairro. [http://bipzip.cm-lisboa.pt/cgi-bin/utills/ficha\\_candidatura.cgi?l=2016;n=4;p=9](http://bipzip.cm-lisboa.pt/cgi-bin/utills/ficha_candidatura.cgi?l=2016;n=4;p=9)



16. Cabral, L.: Entrevista de Feedback sobre o Festival Passa Sabi, Lisboa. In: Coimbra, I. (ed.) Design social e relações de bem-estar em pequenas comunidades locais: design de comunicação como ferramenta de transformação social, Anexos, p. 230. Faculty of Architecture, University of Lisbon, Lisboa (2017)
17. Monteiro, É.: Entrevista de Feedback sobre o Festival Passa Sabi, Lisboa. In: Coimbra, I. (ed.) Design social e relações de bem-estar em pequenas comunidades locais: design de comunicação como ferramenta de transformação social, Anexos, pp. 226–227. Faculty of Architecture, University of Lisbon, Lisboa (2017)
18. Parrinha, M.: Entrevista de Feedback sobre o Festival Passa Sabi, Lisboa. In: Coimbra, I. (ed.) Design social e relações de bem-estar em pequenas comunidades locais: design de comunicação como ferramenta de transformação social, Anexos, p. 231. Faculty of Architecture, University of Lisbon, Lisboa (2017)
19. Rosa, S.: Entrevista de Feedback sobre o Festival Passa Sabi, Lisboa. In: Coimbra, I. (ed.) Design social e relações de bem-estar em pequenas comunidades locais: design de comunicação como ferramenta de transformação social, Anexos, p. 233. Faculty of Architecture, University of Lisbon, Lisboa (2017)
20. Santos, H.: Entrevista de Feedback sobre o Festival Passa Sabi, Lisboa. In: Coimbra, I. (ed.) Design social e relações de bem-estar em pequenas comunidades locais: design de comunicação como ferramenta de transformação social, Anexos, p. 228. Faculty of Architecture, University of Lisbon, Lisboa (2017)
21. Alves, A.: Documento Interno IPAV “Avaliação Geral Festival. In: Coimbra, I. (ed.) Design social e relações de bem-estar em pequenas comunidades locais: design de comunicação como ferramenta de transformação social, Anexos, pp. 222–224. Faculty of Architecture, University of Lisbon, Lisboa (2017)



# The Brand Mark Competitors Map as Visual Research Tool. Using Graphic and Symbolic Data in the Brand Visual Identity Project

Daniel Raposo<sup>1,2(✉)</sup>, Rogério Ribeiro<sup>2</sup>, Mariana Amaral<sup>2</sup>,  
Fernando Moreira da Silva<sup>1</sup>, and Juan Ramón Martín Sanromán<sup>3</sup>

<sup>1</sup> CIAUD, Lisbon School of Architecture, Universidade de Lisboa,  
Rua Sá Nogueira, 1349-063 Lisbon, Portugal  
draposo@ipcb.pt, fms.fautl@gmail.com

<sup>2</sup> Polytechnic Institute of Castelo Branco, Av. Pedro Álvares Cabral, nº 12,  
6000-084 Castelo Branco, Portugal  
r.paulo.ribeiro5@gmail.com,  
mariana.amaral.design@gmail.com

<sup>3</sup> Pontifical University of Salamanca, Calle de la Compañía, 5,  
37002 Salamanca, Spain  
jrmartinsa@upsa.es

**Abstract.** In the scope of Branding projects, the (re) designing of the Visual Identity of Brands or in the scope of audits of Brand Image, we proceed to the research on Brand Marks. This analysis falls on the Brand Marks that will be intervened, but also on Brand Marks of competitors or cases considered as good practices. The research stage on Brand Marks is common in academic or professional projects and students and professionals have difficulty in giving meaning and usefulness to the information collected. The most widely used visual analysis tools allow for the characterization of samples made up of Brand Marks, but these do not help in the extraction of specific conclusions centered on meaning and design. This article describes the development of the competitors map, the Visual Research Tool which allows the objective analysis of Brand Marks, which allows for decision making about the design effectiveness of an isolated Brand Mark or about its (re) design by comparison to a sample of competing Brand Marks. This Visual Research Tool has been developed through literature review, analysis of other tools, the inclusion of a semantic, syntactic and pragmatic analysis, which also includes classifications such as the iconicity scale or the Vienna Classification, as well as principles of visual rhetoric. Using visual and symbolic data, this Visual Research Tool supports professionals and students to create strategic strategies for Brand Visual Identity. This article reports on the creation and evaluation of the Brand Marks' competitor map.

**Keywords:** Brand identity · Brand mark · Competitors map · Visual analysis · Syntactics · Pragmatics · Semantics

## 1 Introduction

Most designers start a Brand Visual Identity design project with a research phase that includes collecting information on Brand Identity and analysing other competing brands. Research is an intrinsic component of design activity and the way in which the context of problems is known, and solutions are found [1].

Clarifying Brand Identity is essential to defining Brand Personality, which consists of a set of Brand Identity features combined with strategic attributes according to a market context (needs for differentiation and appreciation of the Brand Identity).

During a phase of research on the market context different data such as public maps, consumer profile and expectations, fashion and tendencies, legislation, competing brands and products and their communication media, symbols, etc. are collected. The research on the communication of competing brands aims to ensure the identification and differentiation capacity of the Visual Identity Brand system to be designed. A Brand Visual Identity system is composed of selected graphic signs, designed and organized so that they express a certain Brand Personality in a particular market and culture. The Brand Mark is one of the many components of the Brand Visual Identity system, but it is the most important in that it is one of the most used (only the name is repeated more) to identify the brand and the one whose meaning is the brand [2, 3].

In this way, the result of the design of a Brand Mark depends both on the knowledge about Brand Identity and on the Brand Marks competing. Knowing the competing Brand Marks is relevant to identifying common graphic codes and denominators that can be followed or can be graphically contrasted.

In the design project, the use of tools for data visualization and or thought through a variety of visual techniques has become frequent [4]. During the research phase, most designers tend to collect Brand Marks in a particular industry or market. However, the collected Brand Marks are analysed empirically and superficially, from a digital folder or through mood boards.

The idea that the Brand Marks can constitute the research data and the need to extract useful information from the research will have led to the appearance of the competitor map as a Visual research tool, that is, a way to map the variables of a diverse nature that influence a problematic in a context [5]. As Elian and Pigneur [6] refer, the Visual research tool helps to increase understanding skills about wicked problems and to find ways to improve the state of things.

## 2 Methodology

This study began with the question: How to create a Brand Marks analysis process that uses defined and common parameters in order to obtain useful information for the (brand) Visual Identity (re) design project?

And as a hypothesis: Brand Marks can be analysed in terms of semantics, syntactics and pragmatics, using categories that allow us to gauge the role of each infra-sign (graphic components that form the sign. The meaning of the sign is more than the sum of the parts).

According to Avdiji [7] a Visual research tool implies the definition of an ontology that delimits and articulates the management of the wicked problem (components and semantic characteristics that define and help to understand based on academic theories and knowledge and on practices that may be common); that ontology can be common and shared; that the tool facilitates the analysis of the problem and enables hypotheses or prototypes to be generated.

Thus, given that Brand Marks result from a correlation between the selection of conventional symbols, the way the graphic signs are designed and how they are used in a given context and culture, it was considered that the ontology should be based on the three levels of semiotics proposed by Charles Morris in 1937 [8]: semantics (what is represented); the syntactic (how it is represented) and the pragmatic (how it is understood by the recipient in a given context and culture) and from this point on include other design principles proposed by authors like Dondis [9] and classifications used at the international level as the Vox-ATypI classification to classify typefaces into general classes or the international classification of figurative elements of Brand Marks - Vienna Classification (VCL), established by the Vienna Agreement in 1973 [10]. Thus, a non-interventionist methodology based on literature review was selected in order to identify the most relevant parameters for the analysis of Brand Marks, but also to define and clarify them.

In order to ensure that the ontology can be shared, a decision was made to compile the map of competitors from a Brand Marks' analysis sheet, including support tools that aim to make it more common and easy to use. A choice was made to develop a printed analysis form and a digital version.

The competitor map tool should generate quantitative and qualitative results capable of characterizing the Brand Marks of an activity sector, allowing to generate hypotheses or prototypes, namely by the relation between Semantics, Syntactics and Pragmatics.

### 3 The Competitors Map as a Visual Research Tool

The most used visual analysis tools only allow for the characterization of samples of Brand Marks, and they do not help specific conclusions to be extracted, and even less information about meaning and design criteria.

The mapping of competitors arises as a consequence of the limitations of other tools such as mood boards and classifications of graphic signs.

Mood boards are collages used to arouse feelings and meanings together from records of images, photographs, fabrics and other items arranged on a horizontal panel. Thus, mood boards are unsuitable for the analysis of Brand Marks since they emphasize certain components over others and because they are good for identifying sensations but are of little use for extracting descriptive and objective data (Chang, Díaz, Català, Chen and Rauterberg [11]).

Authors such as Mollerup [12], Haig and Harper [13], Chaves and Belluccia [14], Wheeler [15], Solas [16] and Gonzáles [17] and Costa [18] have proposed taxonomical classifications for the study and organization of Brand Marks. However, in addition to lacking consensus, classifications tend to organize the Brand Marks by classes with no

clearly defined boundaries and too broad to study the infra signs that make up the symbol and the logo.

One of the first studies that we can name as a competitor's map was developed by d'A Valls (1980 and 1981) on international banking entities. In his study, the Brand Mark of 611 banks from 80 countries were collected and organized into the categories: iconic, realistic, figurative, abstract, linguistic, acronym, initial, iconic-linguistic. The results obtained by d'A Valls (1980 and 1981) describe the existing reality in that they detect common denominators as to the most frequent symbols, typography, colors and compositions in the Brand Marks of the banks, but they are of little use for decision-making for design.

In his doctoral thesis, Fernández Iñurritegui [19] developed a process of semiotic analysis of Brand Marks, decomposing them into components through an empirical process of discovering design and meaning. In the dissertation, Ribeiro [20] analyzed each graphic component separately: color, symbol, logo, composition, but without presenting an analysis structure of each component.

Coelho [21], advanced towards the work of Fernández Iñurritegui, seeking greater objectivity through drawing criteria explained by Dondis [9], Bertin, Arnheim, Elam for the definition of categories of analysis. Chaves and Belluccia [14] proposed quality indicators to evaluate Brand Marks, which fall into the judgment and experience of the designer: Generic graphic quality; Typological adjustment; Stylistic correction; Semantic compatibility; Versatility; Shelf life; Reproducibility; Readability; Intelligibility; Pregancia of the Form; Empathy; Singularity; Declination.

From 2005, in an academic context, Raposo [3] began to consolidate the competitors' market as a way of analyzing the Brand Marks of a given sector. Through direct observation and an empirical analysis, the data was then arranged in grids and panels where it was sought to categorize brand concept, associated images, typography used, predominant colors, selected symbols, predominant shapes and style/tone or graphic expression, among other aspects. In 2008, videos on HP's rebranding showed a parallel between Raposo's competitors' map in 2005 and the Moving Brands process, a fact that has revived interest in this proposal.

Based on the academic experience and his research group, Helmann [22] advanced a proposal for analysis and design of Brand Marks based on the principles of rhetoric. And in 2018, through the work of Jácome, there was knowledge of the proposal for analysis and description of Brand Marks proposed by Francisco Calles [23].

## 4 A Brand Marks Analysis Sheet for the Competitors Map

The methodology applied here was based on research already developed in the field of questionnaires on Brand Marks. It should be noted that important elements of the work already developed by Héctor Contreras Jácome and Francisco Calles in 2017 were used. For this methodology, Ribeiro's master's dissertation [20] was also important, in which they did a survey of municipal Brand Marks, organizing them by several categories, as we suggested in our proposal. In this organization, the municipal brands were evaluated in terms of the number of colors they use, type of shapes, type of

typography and orientation of the composition of Brand Marks. The principle they used was also one of our starting points.

In order to characterize the nature of the identity of the brands to be analyzed, four categories were defined: Public; Private with sole proprietorships; Private in a partnership; and Mixed. These categories were based on the type of company that could be constituted in Portugal.

We can find a variety of information about the brand architecture written by several authors, one of them being Mollerup [12], who proposed a way to organize the identity as follows: Monistic Architecture is when there is only one brand in one or more products; Endorsed Architecture is when there are several products with their own sub-brands that depend on a parent brand to function; Pluralist architecture is when there are several products with own brands that apparently are not related; Mixed structure is when there are different architectures previously mentioned running concurrently.

Regarding brand names, the authors Rodrigues [24] and Costa [25], mention that the name of a brand can be classified in several ways. This classification can have the name as a descriptive, patronymic, toponymic, suggestive or abstract referential. The descriptive name of a brand describes the nature of the business, product or service in a direct way. Federal Express, founded in 1973, now known as Fedex and Coca-Cola, announced in 1886, are considered descriptive names. The Patronymic is an allusion to the names of the brands that are based on the names of people, be it the founder, inventor or owner of the patent. Colgate was based on the name William Colgate (1804), Ferrari at Enzo Ferrari (1929) and Nestlé at Henri Nestlé (1866). The Toponym refers to the names of a brand that refer to the place of origin or initial action of the institution. TAP, Transportes Aéreos Portugueses, and Porto. Referring to the communication of the city of Porto are names that represent their place of origin, Portugal and Porto, respectively. The Suggestive can be considered as metaphorical names. These reveal the nature of the business indirectly and refer to its product through a common quality that ultimately provokes associations. Jaguar, a car brand, has made an association with the animal's qualities of stature, strength and agility. Abstract refers to a name that has been "found" but has nothing to do with the company or product it represents. This requires good communication and investment to achieve the intended effects. "Oi", a telecommunications company, was based on the simplicity of the "Oi" greeting always given at the beginning of its communications.

In addition to referentiality, the composition of the name should also be analyzed. It is divided into Indivisibles, Compounds, Acronyms and Acronyms. The Indivisible names are already existing words, which cannot be divided or separated. Compound names are neologisms, completely new words that emerge from onomatopoeia, bits of words, or the junction of different words. The Lubrax, came from the result of the sum of the words Lubricant + BR + Grease. The word BR is the representative and denominative acronym for Brazil. Acronyms are contractions of a name composed of several words with an excessive dimension that creates difficulties in reading, pronunciation and memory. IBM, International Business Machines Corporation, CNN, Cable News Network or MTV, Music Television are examples of acronyms. Acronyms are the result of the union of letters or initials of a compound name, but pronounced as a single word as the UN, United Nations.

As mentioned, the organization of the questionnaire follows the subdivision of the semiotics proposed by Morris in 1937 in the semantic, syntactic and pragmatic categories. Where he says that semantics is the reflection on meaning; the syntactic are the principles that control the organization of signs; and Pragmatics is what influences the recipient in recognizing the message, such as the context in which it is inserted and its own culture. In the field of semantics, Skaggs [26] states that “meaning” may refer to what the sign represents or may be referring to an understanding that one has about what the sign represents. He also states that there are different levels of semantics depending on the interpretation. For this, as he defines, there are four ways to have an effect on the receiver of the message. They are presence, expression, denotation, and connotation. The presence and expression refer to more affective records, that is, more intuitive, since denotation and connotation refer to more cognitive and intellectual registers, that is, more influenced by culture, experiences or personal beliefs. In order to obtain a more concrete result than is represented, we opted to use the Vienna classification because it is an international system that classifies the figurative elements of marks. The Vienna classification was established in 1973 and is currently administered by the World Intellectual Property Organization (WIPO). It is a hierarchical system that is developed from the general to the particular, classifying the elements of the Brand Marks into categories, divisions and sections based on their form.

In the field of syntactics, such as Delahunty [27] reference in their master’s thesis, brands have to adapt constantly due to technological advances, originating identity as if they were living organisms, being able to have a new expression with each passing day. Hewitt [28] recognizes that the first metamorphic label was created by the Swiss Karl Gerstners in the 1950 s for a record store in Basel called “Boite a Music”. Many authors have already reflected on these new ways of communicating brands. Kreutz [29], gave rise to the identification of the type of “mutant brand”, Irene van Nes [30] called it “dynamic identity”, Leitão [31] gathered these and other observations and concluding that for the creation and continuity of a visual identity system with dynamic or mutant tags, there must be a structure that provides the identification of the principles of morphology, syntax and narrative, providing the identification of the brand.

In order to create this analysis of the Brand Marks, it is important to distinguish the Brand Marks from its visual identity. Therefore, it was decided to differentiate between metamorphic and stable brands, and metamorphic brands refer to the brand graphics with more than a graphic representation, contributing to their system of visual identity, and stable brands refer to brands with only one visual representation of the Brand Marks, and may have variants in the composition structure but not in its representation. According to Costa [32], the Brand Marks may consist of the symbol, logo or a mix. The graphic sign can be made up of the logo that is a linguistic or readable form that derives from a typography; from the symbol which are iconic, geographic or abstract forms that represent visually replacing words; or both together.

In terms of colors Poulin [33] organizes them by categories: primary colors, secondary colors, tertiary colors, complementary colors, monochromatic colors, analogue colors, triadic colors and quadratic colors.

If the anatomy of the Brand Marks is so important to us, it revolved out to detail the areas of the logo and the areas of the symbol. In the logo and according to Meseguer [34] the calligraphy is the art of writing with beautiful letters, formed by traits that

Brand Mark Analysis		
<b>1. BRAND MARK</b>		
1.1. Brand Mark	1.2. Nature of Identity	1.3. Brand Architecture
	<input type="radio"/> Public <input type="radio"/> Private - Individual Entity <input type="radio"/> Private - Collective Entity <input type="radio"/> Public - Private	<input type="radio"/> Monistic <input type="radio"/> Endorsed <input type="radio"/> Pluralist <input type="radio"/> Mixed
1.4. Brand Type		
<input type="radio"/> Corporate <input type="radio"/> Product <input type="radio"/> Service <input type="radio"/> Event <input type="radio"/> Person		
1.5. Name		
1.5.1. Referentiality		
<input type="radio"/> Descriptive <input type="radio"/> Patronymic <input type="radio"/> Toponymy <input type="radio"/> Suggestive <input type="radio"/> Abstracts		
1.5.2. Composition		
<input type="radio"/> Undivided <input type="radio"/> Compounds <input type="radio"/> Name initials <input type="radio"/> Acronyms		
<b>2. SEMANTICS OF THE BRAND MARK</b>		
2.1. What is represented?		
2.2. Vienna Classification		
<input type="checkbox"/> 1 - Celestial bodies, natural phenomena, geographical maps <input type="checkbox"/> 2 - Human beings <input type="checkbox"/> 3 - Animals <input type="checkbox"/> 4 - Superstition, talismans, heraldic or heraldic-like signs <input type="checkbox"/> 5 - Plants <input type="checkbox"/> 6 - Landscapes <input type="checkbox"/> 7 - Construction, structures for settlements, sites or territories <input type="checkbox"/> 8 - Fossils <input type="checkbox"/> 9 - Textiles, clothing, sewing accessories, headwear, footwear <input type="checkbox"/> 10 - Vehicles, railway, sailing, motor, travel goods, fans, hotel articles <input type="checkbox"/> 11 - Household utensils <input type="checkbox"/> 12 - Furniture, sanitary installations <input type="checkbox"/> 13 - Lighting, wireless valves, heating, cooling or refrigerating equipment, sewing machines, drying equipment <input type="checkbox"/> 14 - Musical instruments, their accessories, musical notation, film pictures, videograms <input type="checkbox"/> 15 - Machinery, motors, engines <input type="checkbox"/> 16 - Mechanical equipment, hand recording or reproduction, cinematography, photography <input type="checkbox"/> 17 - Geographical instruments, jewelry, weights and measures <input type="checkbox"/> 18 - Transport, equipment for animals <input type="checkbox"/> 19 - Containers and packing, representations of miscellaneous products <input type="checkbox"/> 20 - Writing, drawing or printing materials, office supplies, stationary and bookbinding goods <input type="checkbox"/> 21 - Games, toys, sporting articles, roadblocks <input type="checkbox"/> 22 - Musical instruments and their accessories, musical notation, film pictures, videograms <input type="checkbox"/> 23 - Arms, ammunition, armour <input type="checkbox"/> 24 - Heraldic signs, emblems, symbols <input type="checkbox"/> 25 - Ornamental motifs, surfaces or backgrounds with ornaments <input type="checkbox"/> 26 - Geometrical figures and solids <input type="checkbox"/> 27 - Forms of writing, numerals <input type="checkbox"/> 28 - Inscriptions in various characters		
<b>3. SYNTACTIC OF THE BRAND MARK</b>		
3.1. Brand		
<input type="checkbox"/> Metamorphic <input type="checkbox"/> Stable		
3.2. Anatomy of the Brand Marks		
<input type="checkbox"/> Symbol <input type="checkbox"/> Logotype <input type="checkbox"/> Mixed		
3.3. Composition		
<input type="checkbox"/>		
3.4. Colors		
3.4.1. Predominant Colors		
<input type="checkbox"/> White <input type="checkbox"/> Black <input type="checkbox"/> Grey <input type="checkbox"/> Red <input type="checkbox"/> Blue <input type="checkbox"/> Green <input type="checkbox"/> Yellow <input type="checkbox"/> Orange <input type="checkbox"/> Purple <input type="checkbox"/> Brown <input type="checkbox"/> Pink <input type="checkbox"/> Silver <input type="checkbox"/> Gold <input type="checkbox"/> Other		
3.4.2. Secondary/Auxiliary Colors		
<input type="checkbox"/> White <input type="checkbox"/> Black <input type="checkbox"/> Grey <input type="checkbox"/> Red <input type="checkbox"/> Blue <input type="checkbox"/> Green <input type="checkbox"/> Yellow <input type="checkbox"/> Orange <input type="checkbox"/> Purple <input type="checkbox"/> Brown <input type="checkbox"/> Pink <input type="checkbox"/> Silver <input type="checkbox"/> Gold <input type="checkbox"/> Other		
3.5. Logotype		
3.5.1. Characters Origin		
<input type="checkbox"/> Lettering <input type="checkbox"/> Calligraphy <input type="checkbox"/> Typographic font		
3.5.2. Logotype Origin		
<input type="checkbox"/> Redesign <input type="checkbox"/> Design <input type="checkbox"/> No typographic change		
<input type="checkbox"/> Rotation <input type="checkbox"/> Repetition <input type="checkbox"/> Fragmentation <input type="checkbox"/> Reflection <input type="checkbox"/> Overlay <input type="checkbox"/> Integration (Union) <input type="checkbox"/> Extension <input type="checkbox"/> Combination <input type="checkbox"/> Omission <input type="checkbox"/> Stylistic Change <input type="checkbox"/> Kerning		
3.5.3. Typographic form		
3.5.3.1. Typographic Classification		
<input type="checkbox"/> Classical <input type="checkbox"/> Modern <input type="checkbox"/> Calligraphic <input type="checkbox"/> Non-Latin		
<input type="checkbox"/> Humanist <input type="checkbox"/> Didone <input type="checkbox"/> Glyphic <input type="checkbox"/> Garalde <input type="checkbox"/> Mechanistic <input type="checkbox"/> Script <input type="checkbox"/> Transitional <input type="checkbox"/> Linear <input type="checkbox"/> Graphic <input type="checkbox"/> Ontrasque <input type="checkbox"/> Blackletter <input type="checkbox"/> Neo-traditional <input type="checkbox"/> Geometric <input type="checkbox"/> Humanist		
3.5.3.2. Variants		
<input type="checkbox"/> Uppercase <input type="checkbox"/> Condensed <input type="checkbox"/> Light <input type="checkbox"/> Normal <input type="checkbox"/> Lowercase <input type="checkbox"/> Regular <input type="checkbox"/> Medium <input type="checkbox"/> Italics <input type="checkbox"/> Variables <input type="checkbox"/> Extended <input type="checkbox"/> Bold <input type="checkbox"/> Curved		
3.5.3.3. Width		
<input type="checkbox"/> Condensed <input type="checkbox"/> Light <input type="checkbox"/> Normal <input type="checkbox"/> Regular <input type="checkbox"/> Medium <input type="checkbox"/> Italics <input type="checkbox"/> Extended <input type="checkbox"/> Bold <input type="checkbox"/> Curved		
3.5.3.4. Thickness		
<input type="checkbox"/> Light <input type="checkbox"/> Normal <input type="checkbox"/> Medium <input type="checkbox"/> Italics <input type="checkbox"/> Bold <input type="checkbox"/> Curved		
3.5.3.5. Posture		
<input type="checkbox"/> Normal <input type="checkbox"/> Italics <input type="checkbox"/> Curved		
3.5.3.6. Form		
3.5.3.6.1. Shape Contour		
<input type="checkbox"/> Fine <input type="checkbox"/> Continuous color <input type="checkbox"/> Normal <input type="checkbox"/> Gradient <input type="checkbox"/> Thick <input type="checkbox"/> Texture <input type="checkbox"/> No contour		
3.5.3.6.2. Filling in the Form		
<input type="checkbox"/> Continuous color <input type="checkbox"/> Gradient <input type="checkbox"/> Texture		
3.5.3.6.3. Volumetry of Form		
<input type="checkbox"/> Two-dimensional <input type="checkbox"/> Three-dimensional		
3.6. Symbol		
3.6.1. Symbol Origin		
<input type="checkbox"/> Redesign <input type="checkbox"/> Design		
<input type="checkbox"/> Rotation <input type="checkbox"/> Repetition <input type="checkbox"/> Fragmentation <input type="checkbox"/> Reflection <input type="checkbox"/> Overlay <input type="checkbox"/> Integration (Union) <input type="checkbox"/> Extension <input type="checkbox"/> Combination <input type="checkbox"/> Omission <input type="checkbox"/> Stylistic Change		
3.6.2. Form		
3.6.2.1. Shape Characterization		
<input type="checkbox"/> Straight <input type="checkbox"/> Curved <input type="checkbox"/> Mixed		
3.6.2.2. Shape Contour		
<input type="checkbox"/> Fine <input type="checkbox"/> Continuous color <input type="checkbox"/> Normal <input type="checkbox"/> Gradient <input type="checkbox"/> Thick <input type="checkbox"/> Texture <input type="checkbox"/> No contour		
3.6.2.3. Filling in the Form		
<input type="checkbox"/> Continuous color <input type="checkbox"/> Gradient <input type="checkbox"/> Texture		
3.6.2.4. Volumetry of Form		
<input type="checkbox"/> Two-dimensional <input type="checkbox"/> Three-dimensional		
3.6.3. Sign Typology		
<input type="checkbox"/> Iconic <input type="checkbox"/> Arbitrary/Symbol <input type="checkbox"/> Index		
3.6.4. Scale of Iconicity		
<input type="checkbox"/> 7 <input type="checkbox"/> 6 <input type="checkbox"/> 5 <input type="checkbox"/> 4 <input type="checkbox"/> 3 <input type="checkbox"/> 2 <input type="checkbox"/> 1		
3.6.5. Tropes - Figures of Circumscription		
<input type="checkbox"/> Metaphor <input type="checkbox"/> Synecdoche <input type="checkbox"/> Onomatopoeia <input type="checkbox"/> Metonymy <input type="checkbox"/> Emphasis <input type="checkbox"/> Euphemism <input type="checkbox"/> Hyperbole		
3.6.6. Schemes		
<input type="checkbox"/> Figures of Addition <input type="checkbox"/> Figures of Transposition <input type="checkbox"/> Figures of Omission <input type="checkbox"/> Alliteration <input type="checkbox"/> Parenthesis <input type="checkbox"/> Ellipsis <input type="checkbox"/> Anaphora <input type="checkbox"/> Anastrophe <input type="checkbox"/> Diaphora <input type="checkbox"/> Climax and antithesis		
<b>4. PRAGMATICS</b>		
4.1. Name		
Perceived Connotation		
4.2. Brand Mark		
Perceived Connotation		

Fig. 1. Brand Marks' analysis sheet based on Semantics and Syntactics levels

characterize personal writing. In contrast, lettering is drawn and not written. "In the field of typography, we use the term calligraphy for forms produced by handwriting and lettering for drawn forms. Therefore, calligraphy is written, and lettering is drawing."



According to the authors Dabner, Stewart and Zempol [35], both the logo and the symbol may originate in design or redesign. Design consists of creating a new concept with a new image while redesign consists of updating, contextualizing or improving the concept and image of the company. Leborg [36] and Coelho [21] refer that the construction of both the logo and the symbol resort to activities such as rotation, repetition, fragmentation, reflection, overlap, integration, union, stylistic change and omission. The rotation arises when an object/element rotates, moving about a point or an axis, and its movement can be circular or elliptical. Repetition occurs when several elements with a single characteristic between them are placed and arranged in a composition. The repeated element can thus be considered by its shape or repetition of its size. Fragmentation can be considered as a subtraction of an element. This occurs when one part of the element overlaps another and is subtracted from the main element, creating fragmentation. Reflection occurs when an object or element is rendered symmetrically from a vertical or horizontal axis. Overlap occurs when parts of an object lie above parts of another object. The overlap appears in the first element over the second. Integration or union is when two visual elements overlap and visually become a composite form, representing only a new element. The combination arises when one element changes its shape because of another element, being influenced to its modification of the form.

The omission of an object appears based on the negative and positive having as reference values the opaque and transparent, light and dark, convex and concave, solid and hollow. The stylistic change is considered a modification and/or variation. The modification consists of a small change of an element without losing its basic characteristics. A variation can be considered by the repetitions with variable changes of scale/displacement, height or width. We also verified that there was a need to integrate other elements such as kerning, only for the logo, and extension for both cases. The extension consists of an extension of a visual element such as the terminal of a letter and the kerning consists of the adjustment of the spaces between letters.

In the logo there may still be a third option of its origin. This consists of the absence of typographic alteration, using an existing source and not making any changes. Also, in the more detailed scope of the logotype, the typographic form is currently made up of classes based on the division made by the International Typography Association - ATyP in 1962 and Maximilien Vox in 1954 [37]. A classification of nine types was proposed, where the main characteristics were grouped based on the centuries in which they were created. In 2010, ATyPI updated its rating. The typographical classification in the class *Classicals* we group the *Humanist*, *Garalde* and *Transitional*; In the class *Moderns* we group the *Didone*, *Mechanistic* and *Linear* and within the last class we have *Grotesque*, *Neo-Grotesque*, *Geometric* and *Humanist*; In the *Calligraphic* class we have the *Glyphic*, *Script*, *Graphic*, *Blackletter* and *Gaelic*; Finally, we have the *Non-Latin* class.

For both cases the shapes, as Poulin [33] points out, can be solid or contoured, opaque or transparent, smooth or textured. Both Poulin [33] and Leborg [36] further point out that there are three categories of forms: Geometric shapes that are based on mathematical formulas related to the point, line and plane, and their contours are regularized, angular or straight; Organic forms that are created from nature and are usually jagged and smooth; Random forms are created from the imagination and have

no sense of order. Poulin [33] goes further, reinforcing the idea that there is a difference between the term's "shape" and "form". The "shape" is related to the two-dimensional forms and the "form" with the three-dimensional forms.

In the detailed scope of the symbols, Lupton [38] states that the sign can be divided into three basic types: icon, symbol and index. An iconic sign possesses physical resemblance to the idea it represents. An arbitrary/symbolic sign is an abstract symbol; its representative form bears no resemblance to its meaning. An index directs the idea to its object but does not represent it in an abstract or pictorial way. If we think of a chair as an object and analyze it as to its typology of sign, we will define that: the design of the chair is iconic; the written word CHAIR is an abstraction that has no similarity to the object nor does it sound like it; and the shade of the chair or a desk are indexes of the chair.

The scale of iconicity used was proposed by Laginha, Raposo and Neves in 2016 [39], who compiled all the information that several authors had previously carried out on their scales of iconicity. To validate their scale, they tested it with the evolution of some well-known brands, namely Apple, Shell, Peugeot and Quaker. Concluding that the scale proposed by them allows us to perceive that these Brand Marks benefit from artificial appearance and formal exaggeration, contrasting with the environments in which they are used and analyzed.

Helmann [22], refers to the terms chosen here to characterize the forms of circumscription, addition, transposition and omission used in the Brand Mark.

In the forms of Helmann circumscription, he explains that the metaphor, which means in Latin "to carry a meaning", is composed of 3 parts. "(A) The intended meaning or tenor, (1) what is actually said or vehicle, and (A1) the point of comparison, which creates an analogy between (A) and (1)." Thus, creating a new way of conveying the same meaning, being that it is necessary to interpret in same way of transmitting what is said.

The metonymy from Latin means "denomination", and for the author the metonymy consists of two parts: "the actual term (A) and the related term that is used instead (B). In a casual relationship, the cause may be stated while the effect is meant or vice versa. There are two ways to relate to each other: using the inventor to represent the invention or the raw material to represent the product, or vice versa."

The brand of an entity contains in its Brand mark a figurative aspect which has a casual or spatial impact, or which has a temporal relationship with that entity itself. Thus, metonymy is used to transcribe factual characteristics of the detaining entity. The synecdoche has its origin in the Greek language meaning "simultaneous understanding". Unlike metonymy, synecdoche is only representative in that one part represents the whole, or the whole can represent a part. In a Brand Mark, the word of the logo may represent part of a product or service, thus representing the whole or vice versa. Or the symbol can also play that role.

Onomatopoeia comes from the Greek language and means "to compose a sound". In a Brand Mark the onomatopoeia is represented as the way of presenting the sounds as they appear naturally. The emphasis in Greek means "image, appearance." In a Brand Mark, it is the way the letters or words gain prominence in front of the others, with change of colors, shapes or accentuation. In Greek euphemism means, "the use of words for a good omen." In Brand Marks, euphemism is widely used in symbols, using

elements and/or objects to positively illustrate brand identity. Hyperbole also comes from Greek and means exaggeration. In Brand marks, hyperbole manifests itself with the disproportionality of certain forms/shapes, letters or words.

In addition forms Helmann [22] explains that alliteration, which means “nearest letter of alphabet” in Latin, is usually the repetition of the first sound consonant in a sentence. In the Brand Marks, the common one is to observe the symbol composed by the first letter of the logo. The anaphora, which means in Greek “to load”, is transmitted, in the Brand Marks, by the repetition of the few letters of the logo in the symbol or by the repetition of the letters in the logotype forming a symbol. The polyptoton comes from the Greek and means “numerous cases”. Its manifestation in Brand Marks is the use of the same element, repeating it in different ways. The diaphora means in Greek, “difference, in separation.” In Brand Marks are letters of the logo that are highlighted and repeated along the Brand Mark. The Climax and the anticlimax has as meaning “graduated ascent” in Greek. Its way of representing in Brand Marks is the increase or the diminution of some elements that compose the logo. Helmann [22] explains that the parenthesis, which means “put to the side” in Greek, can be represented in Brand Marks by the addition of letters, shapes or colors in the logo. The anastrophe, which comes from the Greek language and means “turning back”, is the representation of distorted or mirrored lefts in the logos.

In the forms of omission, the same author refers to the ellipse, which in Greek means “omission” as a convention form for Brand Marks that omit letters or parts of letters or parts of symbols.

To conclude this proposal, we have the Pragmatics which, as previously mentioned, it is what influences the recipient to recognize the message. Therefore, we opted for more open questions, where we intend to perceive what was perceived by the interpreter in relation to the name and in relation to the entire Brand Mark.

## 5 Previous Results and Next Steps

The results of the panel of experts indicate that, although widely discussed in the specialized literature, several concepts generate problems of understanding. In this sense, the inclusion of a brief definition and the use of graphical examples proved to be relevant for the homogeneity of results.

The division of Brand Marks analysis into Semantic, Syntactic, and Pragmatic has been assertive, although data on Pragmatics are not yet available. It was possible to define identification and analysis parameters of the Brand Marks’ infra-signs, allowing for the detection of common denominators.

We are aware of the limits of the analysis form with regard to the comprehension of each parameter, as well as the need to include Pragmatic analysis. There remains a need to ensure a precise practice-oriented terminology that allows the use of the tool to be standardized.

However, the organization of the parameters in an analysis sheet allows combining concepts from different domains (e.g. trademark registration, rhetoric, etc.), using them in the inquiries or the analysis of Brand Marks.

The next step will be to develop a functional prototype at the level of Pragmatic analysis. In addition, it seems relevant to consider including processes of Computer Vision and related fields such as Machine Learning and Deep Learning, in the recognition, categorization and analysis of Brand Marks.

## References

1. Noble, I., Bestley, R.: Visual Research. AVA Publishing, Lausanne (2005)
2. Olins, W.: The Corporate Personality: An Inquiry into The Nature of Corporate Identity. Mayflower Books, New York (1978)
3. Raposo, D.: La letra como signo de identidad visual corporativa: Codificación y decodificación del sistema de identidad. Ph.D. thesis. Faculdade de Arquitetura da Universidade de Lisboa, Lisboa (2012)
4. Boradkar, P.: Visual research methods in the design process. In: Margolis, E., Pauwels, L. (eds) The SAGE Handbook of Visual Research Methods, pp. 150–168. SAGE Publications, London (2011)
5. Rose, G.: Visual Methodologies. An Introduction to the Interpretation of Visual Materials, 2Ed. Sage Publications, London (2007)
6. Elikan, D., Pigneur, Y.: A visual inquiry tool for brand identity. In: Proceedings of the 52nd Hawaii International Conference on System Sciences (2019)
7. Avdiji, H.: Supporting the challenges of crossboundary teamwork through Design Science Research. Ph.D. final thesis, Université de Lausanne, Lausanne (2018)
8. Morris, C.W.: Logical Positivism, Pragmatism, and Scientific Empiricism. Hermann, Paris (1937)
9. Dondis, D.: La Sintaxis de la Imagen. Editorial Gustavo Gili, Barcelona (1976)
10. Classificação de Viena. <https://euipo.europa.eu/ohimportal/pt/vienna-classification>
11. Chang, H.M., Díaz, M., Català, A., Chen, W., Rauterberg, M.: Mood boards as a universal tool for investigating emotional experience. In: Marcus, A. (eds) Design, User Experience, and Usability. User Experience Design Practice. DUXU 2014. LNCS, vol. 8520. Springer, Cham (2014)
12. Mollerup, P.: Marks of Excellence: The History and Taxonomy of Trademarks. Phaidon Press, Londres (1997)
13. Haig, W., Harper, L.: The Power of Logos: How to Create Effective Company Logos. International Thomson Publishing Company, New York (1997)
14. Chaves, N., Belluccia, R.: La marca Corporativa: Gestión y diseño de símbolos y logotipos, 1ª Ed. Paidós, Buenos Aires (2003)
15. Wheeler, A.: Designing Brand Identity: A Complete Guide to Creating, Building, and Maintaining Strong Brands. Wiley, New Jersey (2003)
16. Solas, J.: Identidad Visual Corporativa: La imagen de nuestro tiempo. Editorial síntesis (2004)
17. Gonzáles, A.: Logo qué? Cerro del Agua: Siglo. XXI Editores, Sa, Diseño y Comunicación (2005)
18. Costa, J.: Modulo 3: Diseñar la marca. Texto de apoyo del Taller Intensivo de Diseño de Marcas, p. 31 (2006)
19. Fernández Iñurritegi, L.: Análisis de significados, formas y usos de los signos tipo-iconográficos de identidad visual corporativa. Ph.D. final thesis, Facultad de Bellas Artes de la Universidad del País Vasco (2007)

20. Ribeiro, M.: Uma cidade, uma marca: o contributo do Design para a representação das cidades. Master's Dissertation in Design, Departamento de Comunicação e Arte da Universidade de Aveiro, Aveiro (2009)
21. Coelho, R.: Semiótica da Marca: Contributos para a construção de uma sintaxe e retórica visual na prática do design de identidade. Ph.D. thesis, Faculdade de Belas Artes da Universidade do Porto, Porto (2013)
22. Helmann, E.: Rhetoric of logos: A primer for visual language. 1ª Edição, Niggli, Zurich (2017)
23. Calles, F.: Análisis y descripción de identidades gráficas. Maestría en Diseño Tipográfico. Unpublished manuscript, Veracruz: Centro de Estudios Gestalt (2017)
24. Rodrigues, D.: Naming: O Nome da Marca, 1ª Edição. 2AB, Rio de Janeiro (2011)
25. Costa, J.: Los 5 pilares del branding- Anatomía de la marca, 1ª Edição. Costa Punto Com Editor, Barcelona (2013)
26. Skaggs, S.: FireSigns: A Semiotic Theory for Graphic Design, 1ª Edição. The MIT Press, Cambridge (2017)
27. Delahunty, D.: The evolution of visual identities from static identities to dynamic identities. Master's Dissertation in Science in Interactive Digital Media, Trinity College of Dublin University, Dublin (2013)
28. Hewitt, J.: Flexible Consistency, Consistent Flexibility, Speak Up. <http://www.underconsideration.com/speakup/archives/004431.html>
29. Kreutz, E.: Identidade Visual Mutante: uma Prática Comunicacional da MTV. Ph.D. thesis, Universidade Católica do Rio Grande do Sul, Rio Grande do Sul (2005)
30. Van Nes, I.: Dynamic Identities: How to Create a Living Brand. BIS Publishers, Amsterdam (2012)
31. Leitão, S., Lélis, C., Mealha, O.: MARCAS DINÂMICAS: Haverá forma de as orientar? In: Conference: 1st International Congress on Branding. [https://www.researchgate.net/publication/267967612\\_MARCAS\\_DINAMICAS\\_Havera\\_forma\\_de\\_as\\_orientar](https://www.researchgate.net/publication/267967612_MARCAS_DINAMICAS_Havera_forma_de_as_orientar)
32. Costa, J.: Design para os olhos: Marca, cor, identidade e sinalética, 1ª Edição. Dinalivro, Lisboa (2011)
33. Poulin, R.: The Language of Graphic Design: An Illustrated Handbook for Understanding Fundamental Design Principles, 1ª Edição. Rockport Publishers, Beverly (2011)
34. Henestrosa, C., Meseguer, L., Scaglione, J.: Como criar tipos: do esboço à tela, 1ª Edição. Estereográfica, Brasília (2014)
35. Dabner, D., Stewart, S., Zempol, E.: Graphic Design School: Principles and Practice of Graphic Design, 5ª Edição. A Quatro Book, Nova Jérícia (2014)
36. Leborg, C.: Visual Grammar, 1ª Edição. Princeton Architectural Press, Nova Iorque (2006)
37. Classificação de VOX, Wikipédia. [https://en.wikipedia.org/wiki/Vox-ATypI\\_classification](https://en.wikipedia.org/wiki/Vox-ATypI_classification)
38. Lupton, E.: Intuição, ação, criação. Editora G. Gili, Ltda, São Paulo (2013)
39. Laginha, C., Raposo, D., Neves, J.: La escala de iconicidad en el ámbito de las marcas gráficas, Conference: Primer Congreso de Diseño Gráfico. [https://www.researchgate.net/publication/317601067\\_La\\_escala\\_de\\_iconicidad\\_en\\_elambito\\_de\\_las\\_marcas\\_graficas](https://www.researchgate.net/publication/317601067_La_escala_de_iconicidad_en_elambito_de_las_marcas_graficas)



# Boundary Dimension Design of Graphical Symbols Based on User Preference

Zhongting Wang<sup>(✉)</sup>, Ling Luo, Linghua Ran, and Liang Zhang

SAMR Key Laboratory of Human Factors and Ergonomics (CNIS),  
Beijing, China  
{wangzht, luoling, ranlh, zhangliang}@cnis.gov.cn

**Abstract.** As the core element of the public oriented sign system, graphic symbols play an important role in People's Daily life. This study explores the humanized design of the boundary dimension of graphic symbols from the perspective of ordinary users. Thirty subjects were recruited for the experiment, and the boundary size design of graphic symbols had 7 levels. The results showed that people did have an obvious preference for the boundary size design of graphic symbols.

**Keywords:** Boundary size · Graphical symbol · User preference

## 1 Introduction

With the development of economy and the change of people's living pattern, the space environment of human being is becoming more and more complex. Public oriented sign system plays an important role in people's cognition of new environment. As the core element of the guiding identification system, graphical symbols also become an effective means of visual communication for people to quickly remember a place or location. Compared with text, graphical symbols in the promotion of memory and communication, eye-catching has a clear advantage. As a symbol to convey information to the public without professional training, graphical symbols of public information are widely used and are attracting more and more attention from researchers.

Rousek et al. analyzed a series of graphic symbols of medical care and investigated the influence of color contrast and complexity of these graphic symbols on normal and visually impaired people [1]. Xiang et al. investigated and studied the understanding degree of public graphic symbols of Guangzhou subway, and found that the understanding degree of some existing public information graphic symbols was low [2]. Taking the hospital signage guidance system as the research object, Gong analyzed the application status and existing problems of graphic symbols in the hospital signage guidance system through the field investigation of several hospitals [3]. Zhang theoretically discusses the methods and significance of emotionalized representation of graphic symbols [4]. In his master's thesis, Ma studied the influence of the size of graphic symbols on the identification and aesthetics under different visual distances. Some studies focus on the standardization of graphic symbols [5]. Mou et al. demonstrated the necessity of standardization of urban public information graphic symbols by

analyzing and comparing the symbol systems of Chinese and foreign cities [6]. Chen et al. analyzed the current situation and existing problems of the standardization of graphic symbols of negative form public information from the aspects of confusion in use, rationality of existence and positioning of meaning, proposed standardization principles and basis, and put forward suggestions on the revision of current symbols in national standards [7]. Zhang et al. reviewed and prospected the series standards of public information graphic symbols for signs in China, and introduced the main technical methods used in the revision of the standards, the comparison with international advanced standards, and the application and promotion of the standards [8].

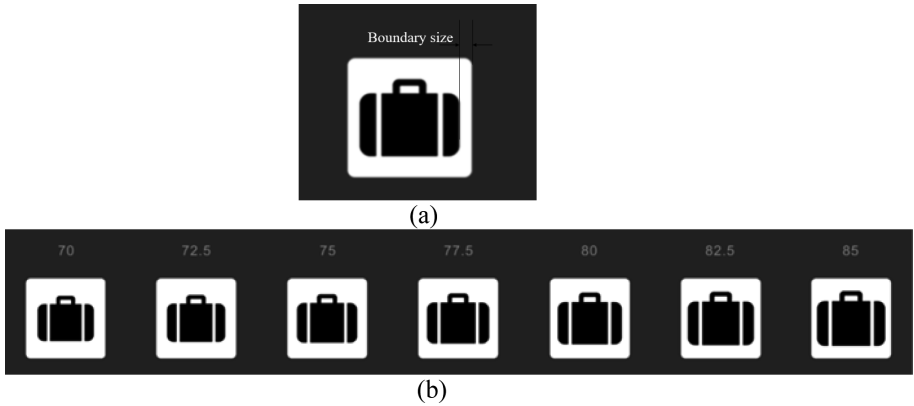
Well-designed graphic symbols should not only meet the basic functional requirements, but also optimize the user experience. Horton systematically summarized six design principles of graphic symbols from the perspective of ergonomics: Understandable, Importance, Distinct, Memorable, Size, Attractive [9]. Barr et al. defined whether the graphic symbol design was successful or not [10]. ISO 29186 stipulates that symbols with 66% accuracy can successfully convey their meanings [11].

Previous studies on public-oriented graphic symbols are mostly theoretical discussions, there are some researches on the structure and size of graphic symbol body [12–14], but few on the size of symbol border. In the related research of imagology, the border is the most basic visual field and the most important form of image representation. Border is a kind of spreading information source, which visually gives the observer a new and concentrated vision space, makes the concept of image more specific and clearer, and endows the image with a shape, and defines the image's "specification" with the absolute size of the image and the relative size of the main part [15]. This study discusses the boundary size design of graphic symbols from the perspective of ordinary users, based on the user-centered design idea, it is hoped that the objective data can be used to obtain the design requirements for the visual frame size of graphic symbols to optimize the user experience.

## 2 Methods

### 2.1 Materials

After elemental analysis of symbols in common information graphic symbol standards, four types of graphic symbols with different shapes (square, circle, horizontal length and vertical length) were selected as experimental materials. In order to exclude the influence of color on the cognitive processing of graphic symbols, the selected graphic symbols are all black and white images. The complexity and familiarity of graphic symbols are also important factors affecting their cognitive processing. All graphic symbols are processed into a black graphic with a white background whose boundary size were different by using professional drawing software. Boundary size is the minimum distance between the graphic symbol and the border. Boundary dimensions for each graphic symbol are 7 levels: 85, 82.5, 80, 77.5, 75, 72.5, 70 (see Fig. 1).



**Fig. 1.** (a) Graphic symbol boundary size schematic diagram (b) 7 levels of boundary dimensions

## 2.2 Experimental Design

A two-factor within subject design was adopted, the independent variables were symbol category (4 levels) and boundary dimension (7 levels). 7 levels of boundary dimension of each graphic symbol were presented at the same time. In order to exclude the experimental order effect, all images were presented completely randomly.

## 2.3 Experimental Environment and Equipment

The experiment was carried out in a laboratory with a stable lighting environment (illumination level around 300lx). The equipment included a laptop (which was used for experimenter to control material presentation and key response) and a large-screen LED display (which was used to stimulate material presentation for the subject). The experimental materials were programmed with e-prime software and projected directly on the LED display screen through the laptop. The subjects were asked to choose one of the seven boundary sizes with the most harmonious distance between the border and the graphic symbol, and then reported it orally. According to the calculation relation between the size of graphic symbol and observation distance specified in the standard [16], the observation distance is determined to be 1 m, where the subjects could see the graphic symbols in detail.

## 2.4 Subjects

Thirty adult subjects (15 males and 15 females) aged from 18 to 60 ( $39.2 \pm 13.3$  yrs.), with normal vision or corrected-to-normal vision (visual acuity of 4.8 or above), participated in this experiment. Mean age  $M = 39.2$  ( $SD = 13.3$ ). Details of the subjects are shown in Table 1.

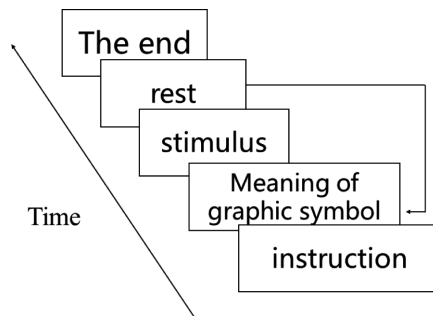


**Table 1.** User information table

Category	Group	Number of people
Sex	Male	15
	Female	15
Age	18–30 yrs	10
	31–50 yrs	10
	>50 yrs	10

## 2.5 Experimental Procedure

The experiment was conducted separately. After entering the laboratory, the subjects were first tested for vision, and those with normal vision or corrected vision could participate in the experiment. Then fill out the basic information form. After that, the subjects were asked to sit in the designated position of the experiment and began to read the instructions on the screen of the large-screen LED display silently. Participants indicated after reading, then the experimenter illustrate the meaning of the instructions again, to ensure that the participants understand the experiment process correctly. Further, the experimenter stressed that “each group of seven graphic symbol has just differences in the boundary size. Please oral presentation which one is the most harmonious and beautiful, then tell me”. Practice test was conducted out to ensure that the subjects can understand and master the experimental process. After the exercise, the subjects were asked to explain the selection criteria, and once again to emphasize the most harmonious and beautiful selection graphic symbol in the white background box. Finally, start the formal experiment. The experimental procedure is shown in Fig. 2, and the whole process lasts about 20 min.



**Fig. 2.** The e-prime procedure

## 3 Result

According to the selection of the subjects, the percentage of the number of people in each boundary size for each type of graphic symbols was counted as an indicator of the experiment. As shown in Table 2, four types of graphic symbols are chosen by a large

proportion of boundary size of 80. A repeated ANOVA result showed that there was no main effect for graphic symbol margin profile category,  $F(3,87) = 2.689$ ,  $p = 0.078 > 0.05$ . Then variance analysis was carried out for different boundary sizes, and the results show that boundary size has main effect,  $F(6,498) = 152.143$ ,  $p = 0.00 < 0.01$ . Further, the LSD post hoc test results (see Table 3) showed that the percentage of the number of people in size 80 was much more than any other size. The results indicate that people do prefer the boundary size of graphic symbols, and this preference has nothing to do with the contour of symbols.

**Table 2.** The average percentage of the number of people of each boundary size for different types of graphic symbols

Category	Size 70	Size 72.5	Size 75	Size 77.5	Size 80	Size 82.5	Size 85
Square	9.2	10	17.5	19.7	30	8.3	5.3
Horizontal	5.8	7.6	22.2	17.1	28.1	11.7	7.5
Vertical	4.5	6.5	20.2	16.6	29.1	13	10.2
Circle	5.8	5.4	21.7	17.9	33.3	5.8	10

**Table 3.** The P-value of the LSD post hoc test on the boundary size

Boundary size	LSD post hoc test result						
	70	72.5	75	77.5	80	82.5	85
70		.046	.00	.00	.00	.00	.004
72.5			.00	.00	.00	.00	.229
75				.002	.00	.00	.00
77.5					.00	.00	.00
80						.00	.00
82.5							.003

## 4 Discussion and Conclusion

The experimental results show that people have a general preference for the design of symbolic boundary size. Based on the symbol type and experimental control in this study, we conclude that when the distance between the graphic symbol and the border is 80, which can achieve the most harmonious and beautiful visual requirements. When the boundary size is too large, relative to the border, graphic symbols were not prominent enough for visual searching, while when the boundary size is too small, the graphic symbol looks like too full, and the boundary is not clear. The results of a study in cognitive psychology in Japan showed that visual images with white space are more likely to attract public attention [17]. Therefore, we propose that appropriate white space is a very important visual design element of graphic symbols.

As an important carrier of information expression, graphic symbols play an important role in the cognitive processing of information. Cognition and emotion are interrelated and inseparable from beginning to end. Well-designed graphic symbols can

enhance users' understanding of graphic symbols and bring people a sense of beauty visually.

Among the information that modern people get from the outside world, the proportion of visual component accounts for 74% to 80% of the total [18]. In the context of visual design in the development of mature, requires that the designers fully understand the visual psychology of people, with a unique artistic creation will have to convey the image connotation, text information into a more rational arrangement, in order to use the appropriate ratio to design graphic symbol carefully each part of the visual elements, make people feel harmonious pleasure when using graphic symbol.

**Acknowledgments.** We would like to thank the participants who took part in the experiment for their many efforts. We gratefully acknowledge the financial support from National Key R&D Program of China (2016YFF0201700) and National Science and Technology Basic Research (2013FY110200).

## References

1. Rousek, J.B., Hallbeck, M.S.: Improving and analyzing signage within a healthcare setting. *Appl. Ergon.* **42**(6), 771–784 (2011)
2. Xiang, F.: Investigation and research on the understanding of public graphic symbols - analysis and redesign of public graphic symbols in Guangzhou metro. *Decoration* **6**, 132–133 (2008)
3. Gong, Y.: Research on Graphic Symbols Recognition. Zhejiang University (2012)
4. Zhang, M.Y.: Research on Emotional Representation of Graphic Symbols in Wayfinding Signage System. Wuhan Textile University (2018)
5. Ma, K.: The research on the Application of Regional Graphic Language in Signage and Wayfinding System Design- Case Study of Symbol Design for the Subway Station Name in Xi'an Metro Line2. Xi'an University of Architectural Science and Technology (2011)
6. Mou, Y.: Standardization of graphic symbols of modern public information. *China Stand. Rep.* **007**, 15–18 (2006)
7. Chen, Y.Q.: Research on standardization of graphic symbols of negative form public information. *Stand. Sci.* **001**, 7–10 (2010)
8. Zhang, L., et al.: Review and prospect of GB/T10001 series standards of public information graphic symbols for logos. *Big View Advertising: Logo Ed.* **3**, 72–75 (2007)
9. Horton, W.: *The Icon Book: Visual Symbols for Computer Systems and Documentation*. Wiley, Chichester (1994)
10. Yu, N.Z.: A literature review of icon ergonomics research. In: 2012 Conference on Psychology and Social Harmony (2012)
11. ISO 9186-2 Graphical Symbol -Test Methods-Part2: Method for Testing Perceptual Quality (2008)
12. Grobelny, J., Karwowski, W., Drury, C.: Usability of graphical icons in the design of human-computer interfaces. *Int. J. Hum. Comput. Interact.* **18**(2), 167–182 (2005)
13. Michalski, R., Grobelny, J., Karwowski, W.: The effects of graphical interface design characteristics on human-computer interaction task efficiency. *Int. J. Ind. Ergon.* **36**(11), 959–977 (2012)
14. Chen, C.H., Chiang, S.Y.: The effects of panel arrangement on search performance. *Displays* **32**(5), 254–260 (2011)

15. Liu, X.H., Chen, Sh.F.: Frame design for point-shaped map symbol based on eye movement experiment. *J. Geomatics Sci. Technol.* **33**(6) (2016)
16. Bai, D.Y., et al.: GB/T20501.1-2013 Public information guidance systems-Design principles and requirements for guidance elements-Part1: General
17. Bovill, C: *Fractal geometry in architecture and design* (1996). <https://doi.org/10.1007/978-1-4612-0843-3>
18. Barnard, M.: *Art, Design and Visual Culture*. Palgrave MacMillan, Basingstoke (1998)



# An Ergonomic Assessment on the Detectability Design of the New Generation Currency (NGC) Coin Series and Bangko Sentral ng Pilipinas (BSP) Coin Series

Diane Denise Francisco, Patricia Michaela C. Gregorio<sup>(✉)</sup>,  
Ninna Ysabel G. Layug, and Nikole Andrei B. Mallare

Melchor Hall, College of Engineering, University of the Philippines,  
1101 Diliman, Quezon City, Philippines  
ieor@upd.edu.ph

**Abstract.** The study assesses the detectability design of coins produced by Bangko Sentral ng Pilipinas. Two sets of coins are currently in circulation: the Bangko Sentral ng Pilipinas and the New Generation Currency Coin Series. Three types of timed detection tests were performed under controlled conditions to measure effectiveness (accuracy) and efficiency (duration) in detecting coins. These tests differ in sense/s used to detect the coins: visual only, tactile only, and both visual & tactile. Results show that BSP coins are generally easier and faster to identify than NGC coins. Furthermore, subjects find it easier to detect the obverse side of coins compared to the reverse. When using the visual sense only, subjects respond faster as compared to only using the tactile sense, and show no significant difference when using both visual and tactile senses. Thus, the tactile design features of the coins may be ineffective for detectability.

**Keywords:** Coins · Currency · Design · Detectability ·  
Bangko Sentral ng Pilipinas

## 1 Introduction

### 1.1 Background of the Study

On March 26, 2018, Bangko Sentral ng Pilipinas (BSP) launched the New Generation Currency (NGC) Coin Series. It is common practice among central banks to redesign currency every 10 years to guard against counterfeiters, and the previous design had already been in place for 25 years [1]. According to BSP, the newly designed coins were thoroughly examined through an extensive and in-depth study by two of their committees: the Numismatic Committee and the Currency Management Committee. These were then reviewed by the Monetary Board and approved by the President of the Philippines [2].

Two sets of coins are currently in circulation. The BSP Coin Series issued in 1995 has 7 denominations: the 10-Piso, 5-Piso, 1-Piso, 25-Sentimo, 10-Sentimo, 5-Sentimo, and 1-Sentimo. These denominations are composed of varying materials such as

Copper-plated steel, Brass-plated steel, Nickel-plated steel, Copper-Nickel, and Aluminum-Bronze [3]. The other set is the NGC Coin Series, which was met with public criticism upon its release due to the difficulty in detecting and distinguishing the design of some denominations [4]. In particular, these denominations are the 10-Piso, 5-Piso, 1-Piso, 25-Sentimo, 5-Sentimo, and 1-Sentimo. All 6 types of NGC coins have the same metallic silver color, Nickel-plated steel material, and circular shape. The use of such material is attributed to its wear and corrosion resistance capabilities [5].

According to BSP, the coins may differ in both obverse (heads) and reverse (tails) design elements, edge profile, thickness, diameter, weight, shape, and color/material for each denomination. Therefore, the tests to be conducted will also be structured under three cases based on the sensory modalities which recognize these elements: (1) visual only, (2) tactile only, and (3) both visual and tactile. To consider both younger adults and older adults, the participants for the study will be divided into two age groups: 18–49 years old and 50 years old and above. Additionally, since the visual aspect is a significant factor in the study, subjects will be classified into with (VI) and without visual impairment (NVI).

The design of the coins in circulation affects all citizens who deal with day-to-day transactions, especially low-income workers (i.e. jeepney drivers, street vendors, tri-cycle drivers) who primarily receive payment in coins.

## 1.2 Problem Statement

There is a lack of ergonomic assessment on the detectability design of the New Generation Currency (NGC) and Bangko Sentral ng Pilipinas (BSP) Coin Series of Bangko Sentral ng Pilipinas.

## 1.3 Objectives of the Study

This study aims to evaluate the detectability design of coins in current circulation, particularly with the following objectives:

1. To analyze the differences in effectiveness and efficiency of the coins with regard to series and face.
2. To analyze the differences in effectiveness and efficiency of the coins with regard to the subject's age group, visual-impairment, and sense/s used in detection.
3. To identify denominations/faces with low detection accuracy and the coins they are commonly interchanged with.
4. To assess user satisfaction scores on the effectiveness, efficiency, and overall usefulness of each design feature as perceived by the subject.
5. To determine the dominant design features detected by the subjects.

## 2 Method

The experiment involves two parts: (1) a timed detection test and (2) a questionnaire to be answered by the subject afterward.

Before conducting each test, the coins were given to the subjects to observe. While doing so, they were told to notice the differences in obverse design, reverse design, color, edge profile, diameter, weight, thickness, and shape. This was to ensure that none of the design features were overlooked. All tests were conducted under controlled lighting (white light), noise, and temperature. Visually-impaired subjects wearing glasses or corrective lenses were asked to remove them before the experiment.

## 2.1 Timed Detection Test

Three different testing procedures were conducted to measure the detectability of each coin. Each test refers to the sense/s used by the subjects. Each test had a total of 32 participants in order to satisfy the assumption of normality (more than 30 samples) in conducting a paired t-test and ANOVA.

### A. Visual Test

- a. Each of the 24 faces were presented once at random at a uniform distance of 5 in. from the edge of the table. The table was covered with a nude cloth to account for color contrast with respect to the palm.
- b. The subject was then asked to identify the denomination and series of each coin without touching it.
- c. If the first response was correct, the time was recorded. If the first response was incorrect, the answer was noted.

### B. Tactile Test

- a. The subject was asked to wear a blindfold and sit with their dominant palm facing upward.
- b. Each of the 11 coins were placed on the subject's palm at random.
- c. The subject was then asked to identify the denomination and series of each coin presented once.
- d. If the first response was correct, the time was recorded. If the first response was incorrect, the answer was noted.

### C. Visual & Tactile (V&T) Test

- a. The subject was asked to sit with their dominant palm facing upward.
- b. Each of the 11 coins were placed on the subjects palm once at random. The subjects were allowed to view and feel the coin with only their dominant hand at any height comfortable to them.
- c. The subject was then asked to identify the denomination and series of each coin.
- d. If the first response was correct, the time was recorded. If the first response was incorrect, the answer was noted.

## 2.2 Questionnaire on Design Features

The subject was asked to answer a questionnaire on the design features of the coins in general. The following instruction was given:

*“The following is a list of design features that vary among the coins initially presented to you. Please rate each of the following statements on how much you agree with it. Encircle the design feature that helped you the most in identifying the coins.”*

Each questionnaire contains only features relevant to the assigned Time Detection Test (i.e. Visual, Tactile, V&T). Under each design feature, three statements describing its effectiveness, efficiency, and overall usefulness were listed.

A rating scale was provided for each statement found in the questionnaire:

- |                        |                           |
|------------------------|---------------------------|
| 1. Strongly agree (+3) | 5. Slightly disagree (−1) |
| 2. Agree (+2)          | 6. Disagree (−2)          |
| 3. Slightly agree (+1) | 7. Strongly Disagree (−3) |
| 4. Neutral (0)         |                           |

Finally, the subject was instructed to encircle the design feature that helped them the most in identifying the coins in each test.

After the experiment, the percentage accuracy and mean duration for each face and denomination were computed. Minitab software was used to compare these values using a paired t-test and ANOVA, respectively. For each denomination under each test, incorrect answers were tallied with regard to demographic.

From the questionnaire, the mean scores of each design feature were determined per test. These were ranked from highest to lowest. The dominant design features selected by the subjects were also tallied.

### 3 Results and Discussion

A total of 74 participants were tested, within which 32 participants were assigned for each of the three tests conducted. Some participants were allowed to undergo two tests. This was done if and only if one was a Visual Test and the other was a Tactile Test, in order to avoid an overlap in sensory modalities.

#### 3.1 Questionnaire Results

The following tables present the effectiveness, efficiency, and usefulness rankings of design features for each test, obtained from the questionnaire (Tables 1, 2 and 3).

**Table 1.** Ranking of visual test features

Rank	Effectiveness	Efficiency	Usefulness
1	Color/Material	Color/Material	Color/Material
2	Obverse Design	Obverse Design	Obverse Design
3	Diameter	Diameter	Diameter
4	Shape	Shape	Shape
5	Reverse Design	Reverse Design	Reverse Design



**Table 2.** Ranking of tactile test features

Rank	Effectiveness	Efficiency	Usefulness
1	Diameter	Diameter	Diameter
2	Shape	Shape	Shape
3	Weight	Weight	Weight
4	Thickness	Thickness	Thickness
5	Edge Profile	Edge Profile	Edge Profile
6	Obverse Design	Obverse Design	Obverse Design
7	Reverse Design	Reverse Design	Reverse Design

**Table 3.** Ranking of V&T test features

Rank	Effectiveness	Efficiency	Usefulness
1	Obverse Design	Obverse Design	Color/Material
2	Color/Material	Color/Material	Obverse Design
3	Diameter	Diameter	Diameter
4	Shape	Shape	Shape
5	Weight	Weight	Weight
6	Thickness	Thickness	Reverse Design
7	Reverse Design	Reverse Design	Thickness
8	Edge Profile	Edge Profile	Edge Profile

As displayed by the tables above, the dominant design features for the Visual Test are color/material and obverse design. The dominant design features for the Tactile Test and V&T Test are diameter and obverse design, respectively.

### 3.2 Analysis of Differences

The percentage accuracy and duration values obtained from the experiment were compared with regard to certain factors. The following tables display paired t-test results for accuracy as well as ANOVA results for duration (Table 4).

**Table 4.** Ranking of V&T test features (BSP & NGC)

Test		Visual Test	Tactile Test	V&T Test
Paired t-test	p	<b>0.002</b>	0.120	<b>0.007</b>
	BSP Accuracy	94.69 ± 5.11 %	65.00 ± 20.66 %	99.38 ± 1.40 %
	NGC Accuracy	70.63 ± 18.17 %	51.88 ± 18.83 %	91.25 ± 2.61 %
ANOVA	p	<b>0.001</b>	0.117	<b>0.003</b>
	BSP Duration (s)	2.86 ± 1.35	6.66 ± 3.36	2.56 ± 1.04
	NGC Duration (s)	3.51 ± 2.05	7.41 ± 4.53	2.98 ± 1.48

As depicted above, BSP coins have a significantly higher percentage accuracy than NGC coins in the Visual Test ( $p = 0.002$ ) and the V&T Test ( $p = 0.007$ ). This is also consistent with the ANOVA results which show that BSP coins are detected significantly faster than NGC coins in both Visual ( $p = 0.001$ ) and V&T ( $p = 0.003$ ) Tests (Table 5).

**Table 5.** Face (obverse & reverse)

Test		
Paired t-test	p	<b>0.007</b>
	Obverse Accuracy	90.31 ± 10.57 %
	Reverse Accuracy	71.88 ± 19.54 %
ANOVA	p	0.798
	Obverse Duration (s)	3.17 ± 1.86
	Reverse Duration (s)	3.21 ± 1.92

The table above shows that coins are significantly ( $p = 0.007$ ) easier to detect when the obverse side is shown as compared to the reverse, although they generally have the same speed of detectability.

**Table 6.** Age group (18–49 & 50+)

Test		Visual Test	Tactile Test	V&T Test
Paired t-test	p	<b>0.000</b>	0.661	0.640
	18–49 Accuracy	87.22 ± 14.50 %	57.95 ± 18.77 %	96.02 ± 5.78 %
	50+ Accuracy	77.84 ± 21.80 %	56.25 ± 21.83 %	94.89 ± 6.14 %
ANOVA	p	<b>0.000</b>	0.777	<b>0.000</b>
	18–49 Duration (s)	2.78 ± 1.40	6.90 ± 3.68	2.37 ± 1.11
	50+ Duration (s)	3.98 ± 2.60	7.05 ± 4.16	3.12 ± 1.30

From Table 6, it is shown that younger adults are both significantly more accurate and faster in detecting coins than older adults ( $p = 0.000$ ) in Visual Tests. They are also significantly faster in V&T Tests (Table 7).

**Table 7.** Visual impairment (VI & NVI)

Test		Visual Test	Tactile Test	V&T Test
Paired t-test	p	0.097	0.806	0.588
	VI Accuracy	79.26 ± 21.94 %	56.25 ± 21.47 %	94.89 ± 6.14 %
	NVI Accuracy	85.8 ± 17.38 %	57.95 ± 23.23 %	96.02 ± 5.06 %
ANOVA	p	0.419	0.260	0.400
	VI Duration (s)	3.25 ± 1.69	7.28 ± 4.34	2.80 ± 1.44
	NVI Duration (s)	3.13 ± 2.05	6.66 ± 3.39	2.68 ± 1.06

For all tests, there is no significant difference in accuracy and duration between subjects who are and are not visually impaired, regardless of the test they have taken.

**Table 8.** Sense (visual only & tactile only)

Test		
Paired t-test	p	<b>0.001</b>
	Visual Accuracy	91.19 ± 10.44 %
	Tactile Accuracy	57.10 ± 19.37 %
ANOVA	p	<b>0.000</b>
	Visual Duration (s)	3.11 ± 1.69
	Tactile Duration (s)	6.97 ± 3.89

It is shown by Table 8 that subjects generally perform better in terms of accuracy ( $p = 0.001$ ) and duration ( $p = 0.000$ ) in Visual Tests than in Tactile Tests. Thus, the results from the Visual Test were compared to V&T Test results, presented in the following table (Table 9).

**Table 9.** Sense (visual only & V&T)

Test		
Paired t-test	p	0.133
	Visual Accuracy	91.19 ± 10.44 %
	V&T Accuracy	95.45 ± 4.50 %
ANOVA	p	0.059
	Visual Duration (s)	2.97 ± 1.71
	V&T Duration (s)	2.74 ± 1.26

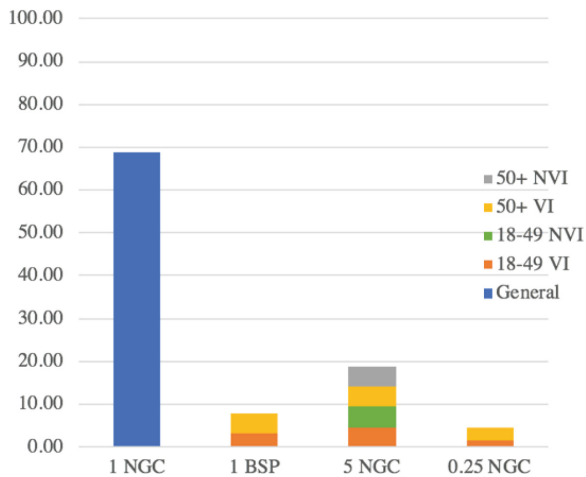
There is no significant difference observed in accuracy and duration between Visual and V&T Tests.

### 3.3 Effectiveness Breakdown of Denominations

Results are divided into three sets representing each timed detection test. The following section contains figures which depict the distribution of subject responses for denominations with the most percentage error (determined through a Pareto Chart), with indicators of age and visual-impairment.

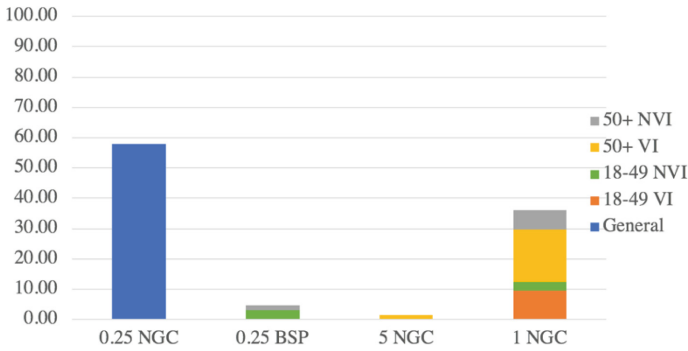
#### 3.3.1 Visual Test

The figure below shows a 68.75% accuracy for the 1-Piso NGC denomination. Its mean duration of detection is 3.08 s. Meanwhile, 18.75% of subjects interchanged this coin for the 5-Piso of the same series, 7.81% responded that it was a 1-Piso of the other series. Lastly, 4.69% thought it was a 25-Sentimo NGC coin. Most of the error comes from older and younger adults who are visually-impaired (Fig. 1).



**Fig. 1.** Visual test responses for 1-Piso NGC

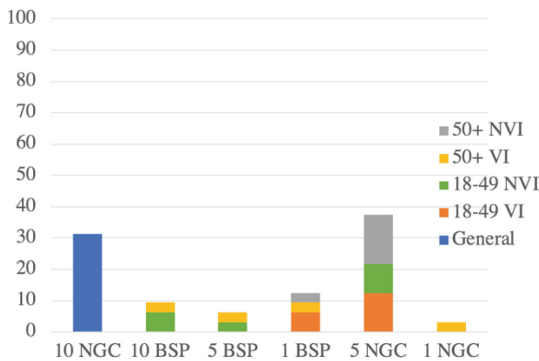
The 25-Sentimo NGC coin is detected with a mean duration of 4.49 s. The following figure shows a 57.81% accuracy for this denomination, and an error of 35.94% for subjects who responded that it was a 1-Piso of the same series. Other incorrect responses were the 25-Sentimo BSP (4.69%) and 5-Piso NGC (1.56%). Majority of the error comes from visually-impaired adults (Fig. 2).



**Fig. 2.** Visual test responses for 25-Sentimo NGC

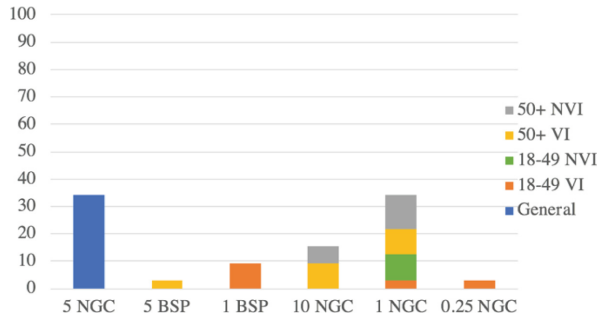
### 3.3.2 Tactile Test

The following figure shows that majority of the subjects incorrectly identified the 10-Piso NGC coin, 37.50% responding that it was a 5-Piso of the same series. Only 31.25% were able to answer accurately, and the other responses had been the 1-Piso BSP (12.50%), 10-Piso BSP (9.38%), 5-Piso BSP (6.25%), and 1-Piso NGC (3.13%). The mean duration for subjects who were able to answer correctly is 9.42 s (Fig. 3).



**Fig. 3.** Tactile test responses for 10-Piso NGC

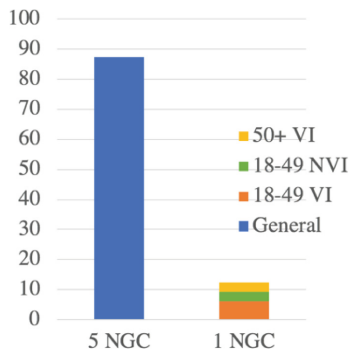
For the 5-Piso NGC presented in the following figure, 34.38% responded accurately, and the same amount responded that it was a 1-Piso NGC. The mean duration for correct responses is 7.00 s. Further, 9.38%, 3.13%, and 3.13% responded that it was a 1-Piso BSP coin, 5-Piso BSP coin, and 25-Sentimo NGC coin, respectively (Fig. 4).



**Fig. 4.** Tactile test responses for 5-Piso NGC

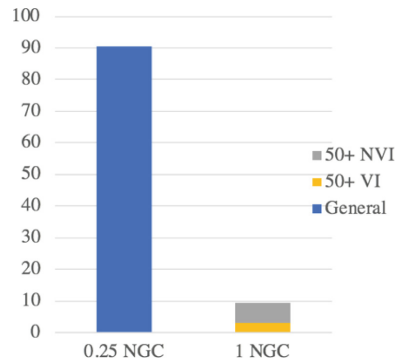
### 3.3.3 Visual & Tactile (V&T) Test

The figure below shows that the 5-Piso NGC coin is detected with an accuracy of 87.5%, and an error of 12.5% which corresponds to responses for the 1-Piso NGC coin. Half of these respondents were visually-impaired younger adults. The mean duration of detection for the 5-Piso NGC coin is 3.17 s (Fig. 5).



**Fig. 5.** V&T test responses for 5-Piso NGC

Figure 6 presents 25-Sentimo NGC results. It has a mean detection duration of 2.92 s and an accuracy of 90.63%. Subjects who responded that it was a 1-Piso of the same series made up 9.37%. All of these subjects were aged 50 and above.



**Fig. 6.** V&T test responses for 25-Sentimo NGC

## 4 Conclusion

When only the visual sense is used, BSP coins are easier and faster to identify than NGC coins. This also holds true when both the visual and tactile senses are used. Furthermore, it is observed that subjects find it easier to visually detect the obverse side of coins compared to the reverse side.

Younger adults aged 18–49 years old are able to detect coins more accurately than older adults aged 50 and above in Visual Tests. Younger adults also have a faster detection time for Visual and V&T Tests. Additionally, there is no significant difference observed for effectiveness and efficiency in detecting coins based on visual impairment. In general, coin detection is faster and more accurate using the visual sense only as compared to only the tactile sense. However, there is no significant difference observed in effectiveness and efficiency between using only the visual sense and using both visual and tactile senses. In conclusion, the tactile design features of the coins are ineffective for detectability.

For all tests, majority of the detection error came from NGC coins. They were commonly interchanged with coins which have similar color/material and diameter.

When viewing coins, users generally consider the color/material and obverse design first. When feeling coins, users initially consider diameter. When both visual and tactile senses are used, the obverse design is generally considered first.

## 5 Recommendation

It is recommended that Bangko Sentral ng Pilipinas improve the reverse design of their coins to increase detection accuracy. It currently has a mean of 71.88% among subjects, approaching 52.34% at the lowest. Including the value of the coin (even in a smaller-sized font) may be tested in future design research. In addition to this, BSP should provide more consideration for the elderly population when designing coin detectability. They should also reconsider the tactile features of their coin designs if they want to improve detectability. At its current state, the tactile features provide no

improvement in the accuracy and duration of detection of the coins. Moreover, Bangko Sentral ng Pilipinas may need to consider incorporating more variation in the design of their coins in terms of diameter, obverse design, and color/material, since these features are primarily considered by most users.

Further studies may be conducted wherein subjects are classified into varying types and levels of visual impairment in order to discover more about its effect on effectiveness and efficiency of detection. It is also recommended that the 1-Sentimo coins in both the BSP and NGC series be included in further analyses.

**Acknowledgments.** The researchers extend much gratitude to their professors, Benette Custodio and Alyssa Jean Portus. They also offer their utmost appreciation for Professor Nikole Andrei Mallare for all her guidance and patience throughout the course of the project.

## References

1. Smith, T.F., Waterman, M.S.: Identification of common molecular subsequences. *J. Mol. Biol.* **147**, 195–197 (1981)
2. May, P., Ehrlich, H.-C., Steinke, T.: ZIB structure prediction pipeline: composing a complex biological workflow through web services. In: Nagel, W.E., Walter, W.V., Lehner, W. (eds.) *Euro-Par 2006. LNCS*, vol. 4128, pp. 1148–1158. Springer, Heidelberg (2006). [https://doi.org/10.1007/11823285\\_121](https://doi.org/10.1007/11823285_121)
3. Foster, I., Kesselman, C.: *The Grid: Blueprint for a New Computing Infrastructure*. Morgan Kaufmann, San Francisco (1999)
4. Czajkowski, K., Fitzgerald, S., Foster, I., Kesselman, C.: Grid information services for distributed resource sharing. In: *10th IEEE International Symposium on High Performance Distributed Computing*, pp. 181–184. IEEE Press, New York (2001)
5. Foster, I., Kesselman, C., Nick, J., Tuecke, S.: *The physiology of the grid: an open grid services architecture for distributed systems integration*. Technical report, Global Grid Forum (2002)
6. National Center for Biotechnology Information. <http://www.ncbi.nlm.nih.gov>





# Research on Optimization of Information Coding for Car Dashboard Based on Eye Movement Analysis

Guilei Sun<sup>1</sup>(✉), Qin Li<sup>1,2</sup>, Yanhua Meng<sup>1</sup>, and Linghua Ran<sup>3</sup>

<sup>1</sup> Department of Safety Engineering, China University of Labor Relations,  
Beijing 100048, China

sunguilei@126.com

<sup>2</sup> The College of Emergency Management and Safety Engineering,  
China University of Mining and Technology, Beijing 100083, China

<sup>3</sup> China Standardization Institute, Beijing 100191, China

**Abstract.** In order to research the effects of interactive designs for different car panels on driving efficiency, the layouts of the current common car dashboard were investigated and 35 experimental stimulus materials were obtained. Tobii X2-30 eye tracker was used to perform eye movement test on 30 subjects. SPSS V21.0 was used to analyze the corresponding data. Results show that the setting of the speedometer in the middle position has a significant impact on the reading of tachometer and water temperature meter. The area on the left panel got less attention and complex color dials get more fixations. The best layout for the overall reading of the instrument is class-A. Moreover, complex color matching design can depress the reading efficiency.

**Keywords:** Interaction design · Eye movement analysis ·  
Automobile instrument panel · Visual search

## 1 Introduction

Instrument is an important component that shows the normal operation of the car or the fault alarm. Some research works are attracted by the distraction and distraction caused by the in-vehicle information system to the driver [1]. As an important component of the car [2], its reasonable design layout plays an important role in the driver's reading efficiency. For the overall design of the instrument, the problem of encoding the instrument information such as shape coding, character coding, color coding, position coding should also be considered. Scholars of China also have relevant conclusions and explanations on the design requirements of manipulator layout settings, color coding, warning characters, etc. [3–5]. From the perspective of information coding, the outer frame structure of the instrument and its size and color, symbol size and its color have a great effect on the driver's reading [6]. At present, scholars mainly tend to study the shape and character encoding of the instrument panel [7, 8], and there are relatively few considerations for the color and position coding of the instrument panel.

Zhang [9] used eye movement technology to study the design of human-machine interface in aircraft cockpit. Liu [10] simulated aircraft in the cockpit with eye tracker and touch screen to obtain eye movement and manual data to optimize the ergonomic design of the aircraft cockpit panel. Sun [11] use eye tracking technology to read the correct rate and task duration of the vehicle dashboard Indicators such as task search duration were analyzed.

Therefore, ergonomics test is used to explore the human-computer interaction design of the instrument panel in order to propose reasonable human-machine interface design requirements and help drivers to obtain information efficiency and reduce driver distraction and inattention.

## 2 Method

### 2.1 Experimental Design

This experiment adopted the two-factor four-level design method, that is, the independent variable - “dashboard layout design  $\times$  color design”, the dependent variable - “reading speed  $\times$  eye movement indexes”, and analyzed the influence of the independent variable factor on the dependent variable. After investigation on the common car dashboard, the classification according to the frequency of each types of dashboards were summarized. The dashboards including 4 different layout designs and 4 different color schemes were obtained, and Adobe Illustrator was used to design the dial so that 35 dashboard analog pictures - experimental stimulus materials were obtained and readings were set on each dashboard. The subjects were required to complete the reading of the pointer on the instrument panel independently. The task completion time and visual search duration, reading time, eye movement data were collected in the process and the subjects were not be disturbed. The screen brightness and indoor illumination were stable and the distance between the subject and the screen was 0.55–0.65 m.

### 2.2 Experimental Equipment

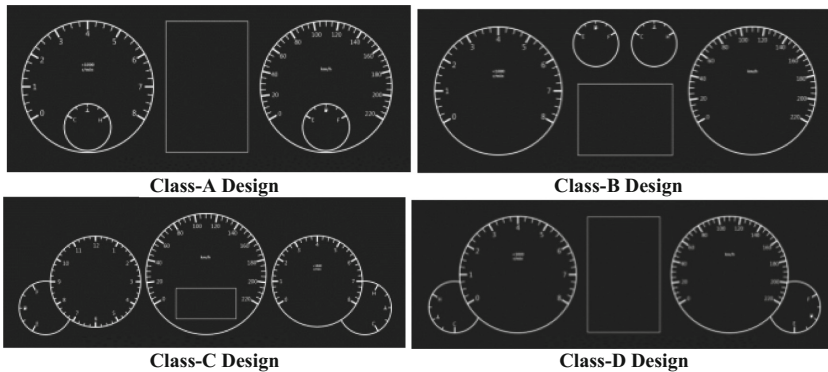
The equipment for experiment includes hardware and software. The hardware is the Tobii X2-30 eye tracker, and the software includes a human-machine-environment synchronization platform system and a data analysis system. The eye tracker was used to capture the eye movement trajectory of the subject. The eye movement data of the subject was recorded in conjunction with the human-machine-environment synchronization platform system.

### 2.3 Experimental Subjects

32 college students and teachers were invited to participate in this experiment, and 2 of them were unable to take part in due to severe astigmatism. Therefore, 30 subjects (23 students and 7 teachers) were effective. The ratio of male to female was 1:1, and the overall age was between 20 and 45 years old. There were 12 drivers with driver's license and driving experience, 8 with driver's license but no driving experience, 10 without driver's license. The experiment requires a right hand, normal vision or corrected vision, no serious astigmatism, and good health. Since most of the subjects are college students and young teachers, the results are more suitable for young drivers.

### 2.4 Experimental Materials

In the current car dashboard design, there are four types of instruments: speedometers, engine tachometers, fuel gauges and water temperature gauges. According to the position of the instrument, four different typical layout schemes were summarized. In order to facilitate the distinction and description, the different dashboard layouts were named A, B, C, D class design (see Fig. 1). Adobe Illustrator software was used to simplify the processing of the instrument panel, and 35 (from 1–35 sequentially numbered) simulated images were obtained as test stimulus materials.



**Fig. 1.** Simplified dashboard design

In order to eliminate the design elements unrelated to the test variables, the size, line width, division value, scale and pointer of dial were unified. The background color of the instrument panel was uniformly set to black. Except the pointer of picture No. 34 was designed to be blue, others are uniformly set to red. The detailed settings of 35 stimulating material are shown in Table 1.

Table 1. Instructions of layout, color and reading about dashboard

Layout type	Layout description	Instrument classification	Color description	No.	Meter value setting				Fuel gauge	Water temperature gauge
A	Left and right structure, tachometer and speedometer are distributed on the left and right sides of the instrument panel, fuel gauge and water temperature gauge are located in the speedometer and tachometer	A <sub>1</sub>	The dial is black, the dial edge, scale and icon are white, and the E-class part is marked red	1	42	0.9	3	2		
				2	67	2.2	2	1		
				3	85	6.7	4	1		
				4	123	1.3	1	1		
		E		29	Same as No. 2				-	
				A <sub>2</sub>	The dial has a black background and the dial edges, scales and icons are gray	15	42	0.9	3	2
		16	67			2.2	2	1		
		17	85			6.7	4	1		
		18	123			1.3	1	1		
		F		33	Same as image No. 4					
B	Left and right structure, tachometer and speedometer are distributed on the left and right sides of the instrument panel, fuel gauge and water temperature gauge are located side by side in the speedometer and tachometer connection			B <sub>1</sub>	The dial is black, the dial edge, scale and icon are white, and the E-class part is marked red	5	37	0.5	1	1
		6	64			7.2	3	2		
		7	88			1.9	2	-		
		E		30	Same as image No. 6					
				B <sub>2</sub>	The dial has a black background and the dial edges, scales and icons are gray	19	37	0.5	1	1
		20	64			7.2	3	2		
		F	The dial is black, the dial edge, scale and icon are white, the pointer is blue, and some scales are red	21	88	1.9	2	-		
				34	Same as image No. 7					

(continued)



## 2.5 Procedure

The test includes three stages: 1. Before the test, explain the test content and precautions to ensure that the subjects understand the purpose and process of the experiment. 2. In the test, each subject only reads one type of instrument at a time; for each reading, subject can rest for 30 s to eliminate the error caused by the fatigue effect; reading is not limited by time and accuracy, the subject recognizes at normal speed. 3. After the test, the participants completed the questionnaire survey, and the main test personnel saved the data and organized the test site.

## 2.6 Data Processing

Data processing mainly includes two parts: analysis of the reading duration and eye movement data.

Search time is the time from scanning dial to find the target dial; reading duration is the time from the beginning of reading to recognize the dial. The sum of the two is the total duration of the task. The duration of the search, the reading duration, the total duration of the task and the number of times of misreading are recorded by the eye-tracker. According to the results of the experimental records, the data is filtered out, and the unreliable data is eliminated: the extreme data is eliminated according to the principle of adding or subtracting 3 standard deviations ( $M - 3SD \leq X_i \leq M + 3SD$ ) [12], where  $X_i$  represents the actual data,  $M$ (Mean) indicates the mean, and  $SD$  indicates the standard deviation. SPSS V21.0 is used to analyze the data.

For eye movement data analyzing, it includes dividing the Area of Interest (AOI), extracting the number of gaze points in the interest of area, calculating the average number of gaze times in different areas, and exploring the influence of different areas of the dashboard on visual search. The visualization function of the data analysis system obtains the eye movement trajectory of the subject and assists in analyzing the research conclusions.

# 3 Experiment Analysis

## 3.1 Influence of Different Types of Dashboard Design on Reading Duration

### 3.1.1 Analysis of Task Duration

Figure 2 shows the search time, reading time and total time of the speedometer in different layouts. From Fig. 2, the total time and average search time of the C-type layout design are the shortest, and the total time and average reading time of the B-type layout design are the longest.

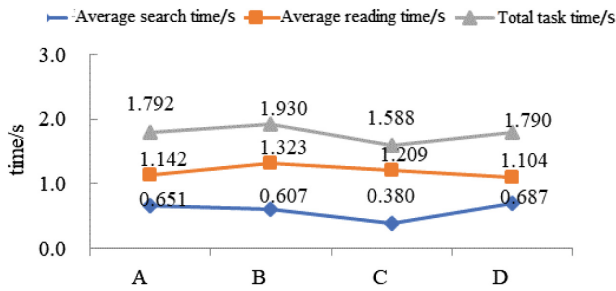


Fig. 2. Reading time comparison of speedometers

Table 2 shows the reading time of the speedometers for different color schemes. Among them, the F-type color matching design has a longer reading time, which indicated that the special color matching design (orange, blue, etc.) has a greater influence on the reading speed of the test.

Table 2. Reading time order of speedometers

No.	Total time/s	Type	No.	Total time/s	Type	No.	Total time/s	Type	No.	Total time/s	Type
1	1.582	C <sub>1</sub>	4	1.782	A <sub>2</sub>	7	1.884	D <sub>2</sub>	9	1.949	B <sub>2</sub>
2	1.594	C <sub>2</sub>	5	1.802	A <sub>1</sub>	8	1.910	B <sub>1</sub>	10	2.091	F
3	1.695	D <sub>1</sub>	6	1.867	E						

Similarly, the statistical analysis of the tachometer, fuel gauge, thermometer reading and reading time, the statistical results are shown in Table 3, which shows the average search time of the class A layout is the shortest and the total task time is also the shortest. To the fuel gauge and water temperature gauge, the average search time of the B-type layout is the shortest, while the A-layout has the shortest reading time. A-class design is the shortest in terms of total mission time.

Table 3. Reading time of different dashboards

Type		Tachometer	Fuel gauge	Water temperature gauge	Type		Tachometer	Fuel gauge	Water temperature gauge
A	Average search time	0.877	0.953	1.107	C	Average search time	1.109	1.091	0.976
	Average reading time	1.060	0.882	0.785		Average reading time	1.159	1.130	0.948
	Total task time	0.968	0.918	0.946		Total task time	1.134	1.111	1.062

(continued)

**Table 3.** (continued)

Type		Tachometer	Fuel gauge	Water temperature gauge	Type	Tachometer	Fuel gauge	Water temperature gauge
B	Average search time	0.956	0.509	0.452	D	Average search time	1.012	1.108
	Average reading time	0.987	0.933	0.865		Average reading time	1.005	0.936
	Total task time	0.971	1.271	1.258		Total task time	1.009	1.022
								1.109

In summary, when the speedometer is the main target, the C-class layout is the best, but it is not conducive to the reading of the other three instruments. Considering the other three instruments, the A or B layout can be chosen.

### 3.1.2 Difference Analysis of the Total Task Time

Significant difference analysis is carried out for the average task time under different layouts, different color combinations and special instruments, and the significant level  $\alpha = 0.05$  was taken.

- (1) Different layout of the meter. The average test time of each instrument corresponding to different layout schemes is analyzed. The significance test results are shown in Table 4.

**Table 4.** Differential analysis in different layout

Type	Speedometer	Tachometer	Fuel gauge	Water temperature gauge	Type	Speedometer	Tachometer	Fuel gauge	Water temperature gauge
A&B	0.296	0.972	0.117	0.279	B&C	0.012*	0.009*	0.575	0.010*
A&C	0.135	0.008*	0.311	0.000*	B&D	0.351	0.944	0.273	0.784

Note: \* indicates  $P < 0.05$  with a significant difference at the 0.05 level.

For the tachometer, water temperature meter, the total task duration of C-class design is significantly different from the other three layouts. The differences between the three types of design, such as A, B, and D, are not significant, and C-class design and the other three types of design are the largest. The difference is that the speedometer of C-class design is placed in the middle and highlighted. It shows that the position of the speedometer has a significant impact on the reading of the tachometer and the water temperature meter, but has no significant effect on the reading of the fuel gauge. For the speedometer, there is a significant difference between class B and C instruments, class A and C. The differences between classes, D and C are not significant. In the previous analysis of the duration of various types of instrument tasks, when the speedometer is the main target, the C-class layout design is the best, but it is



not conducive to the reading of the tachometer, the water temperature meter, the recognition of the tachometer and the water temperature meter. Reading time has a significant impact, considering the other three instruments for consideration, A layout is recommended to adopt.

- (2) Different color schemes of the instrument. The results of the significance test of the average task time of the instrument under different color schemes are shown in Table 5.

**Table 5.** Significant test results in different color matching

Type	Speedometer	Tachometer	Fuel gauge	Water temperature gauge	Type	Speedometer	Tachometer	Fuel gauge	Water temperature gauge
A <sub>1</sub> &A <sub>2</sub>	0.871	0.523	0.931	0.331	C <sub>1</sub> &C <sub>2</sub>	0.887	0.675	0.938	0.955
B <sub>1</sub> &B <sub>2</sub>	0.939	0.941	0.043*	0.753	D <sub>1</sub> &D <sub>2</sub>	0.344	0.868	0.920	0.442

The results show that different color matching designs only have an impact on the fuel gauge, and there is no significant difference in the reading of other instruments. The specific performance is the color matching design of B1 instruments (white on black) and B2 instruments (black and gray). There is a significant difference in the reading of the fuel gauge. With the previous analysis it can be seen that the use of complex color matching should be reduced in the design, and the easy-to-read color matching design is selected to improve the driver's reading speed.

- (3) Special instrument analysis. Comparing the instruments with the scale red and the special color matching with the original image, the significance test results of the average task total time are shown in Table 6. The water temperature table is not set in No. 7, 34, 10, and 35 of the special color matching.

**Table 6.** Significant test results for special dashboard

Factor	Picture number	Original number	Speedometer	Tachometer	Fuel gauge	Water temperature gauge
Scale red	29	2	0.353	0.006*	0.133	0.608
	30	6	0.648	0.121	0.638	0.538
	31	8	0.696	0.086	0.265	0.155
	32	14	0.177	0.011*	0.686	0.950
Special color matching	33	4	0.004*	0.565	0.126	0.022*
	34	7	0.004*	0.202	0.209	-
	35	10	0.000*	0.112	0.159	-

It can be seen that whether the meter scale is marked red or not, there is no significant effect on the reading of the speedometer, the fuel gauge and the water temperature gauge. The special color matching of the meter has a significant influence on the reading of the speedometer and the water temperature meter, but to the tachometer and the fuel gauge it has no significant effect. For the tachometer in A (2, 29) and D (14, 32) instrument layouts, the scale red treatment has a significant impact on it.

### 3.2 Eye Movement Data Analysis

#### 3.2.1 Influence of Dashboard Layout on the Number of Fixation Points

During the test, the subjects stare at the stimulate material to form the fixation, as shown in Fig. 3.



Fig. 3. Fixation on the picture

In this experiment, the more the number of gaze points, the more the subject was unable to determine the target. The attention of subject was attracted by the content of the dial which indicated that the search and reading efficiency was low. Some areas of the dashboard are used as the Area of Interest (AOI) and the number of fixation points are counted in each AOI under different layouts and color matching pictures. As shown in Fig. 4.

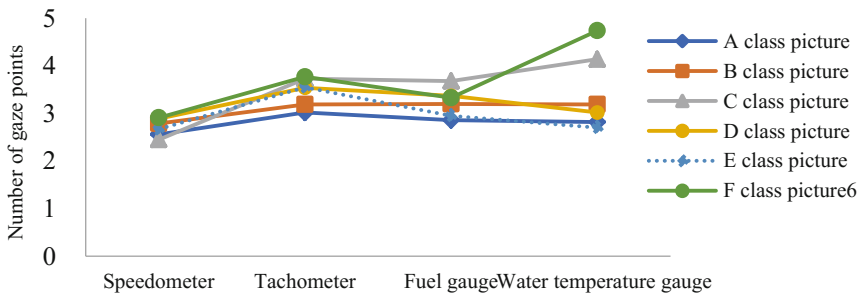


Fig. 4. Means of the number of fixations of different pictures

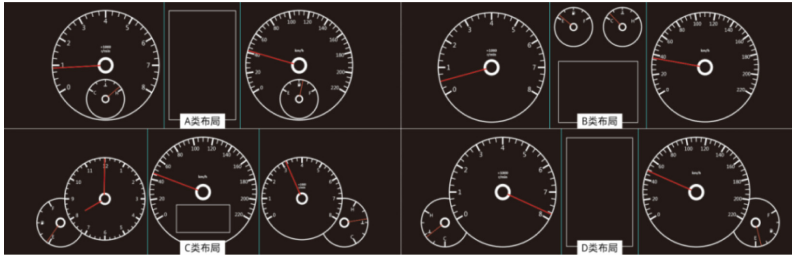
Through the statistical analysis of the number of gaze points of each instrument under different layouts and color matching, it can be clearly found:

- (1) Regardless of the layout and color matching, the number of gaze points of the F-class picture (that is, the dial of the special color design) is generally more. Compared with the A-class picture, the speedometer, the tachometer, the fuel gauge and the water temperature table got more gaze points. The increase was 13.7%, 24.8, 16.4%, and 68.1%, which indicated that the subjects was easy to be affected by the design and the reading efficiency was also reduced. Among them, No.33 and No.34 pictures has more than three color and blue color is used. No.35 picture has a special color orange, so it is not advisable to use more than 3 color schemes and special colors such as blue and orange.
- (2) Overall, the design of Class A pictures is conducive to the overall reading of the instrument. The number of gaze points in the reading process of the speedometer, tachometer, fuel gauge and water temperature meter are relatively small, and it is not difficult to find. In the reading of the speedometer, the number of C-class gaze points is less than the number of A-class gaze points. From the point of view of the number of gaze points, the use of C-class is more conducive to the reading of the speedometer. But there is a problem, that is, it is necessary to consider whether the difference in the number of fixation points between the A and C-class pictures is significant. If the difference is significant, it is necessary to consider the influence of the dashboard layout on the driver's reading. When driving a car, if the speedometer is considered as an important meter and the driver observes the highest frequency and has the greatest influence on the driver, it is recommended to select C-class. If the reading of the other three meters is considered comprehensively, it is recommended to select class A because the overall reading of the meter the Class A layout is the best.

Therefore, the difference analysis is made on the number of gaze points of the A-class and C-class layouts and the color matching speed, and the significant level is  $\alpha = 0.05$ . According to the analysis, in terms of the speedometer, the difference between the number of gaze points in the layout and color matching of class A and class C is not significant ( $P = 0.135 > 0.05$ ), indicating the choice of class A or class C layout and color matching speedometer. The reading has no effect. For the tachometer, fuel gauge and water temperature meter, the number of gaze points in the C-class layout is 23.5%, 28.7%, and 46.8% higher than that of the A class. Therefore, the layout and color matching of the A-class is obviously better than that of the C-class. So, A-class layout and color matching are recommended.

### 3.2.2 The Impact of Different Areas of the Dashboard on Visual Search

When the panel was read, the instrument panel layout in different areas decided to have different visual characteristics, so the instrument panel was divided into three areas (left area, right area and middle area), as shown in Fig. 5.



**Fig. 5.** Visual search area division

The average number of fixation for the three regions during the visual search for the four instruments is shown in Table 7. Average number of gaze in a region equals to the total number of gaze in the area/total people.

**Table 7.** The number of average fixation count during the search

Gaze order	Area	Speedometer		Tachometer		Fuel gauge		Water temperature gauge	
		Average number of gaze	Proportion	Average number of gaze	Proportion	Average number of gaze	Proportion	Average number of gaze	Proportion
1	Left	5.80	10.55%	14.43	22.16%	11.87	17.89%	8.83	12.52%
	Mid	14.53	26.44%	9.33	14.33%	11.60	17.49%	11.80	16.72%
	Right	14.37	26.14%	10.87	16.68%	11.03	16.63%	13.97	19.79%
2	Left	1.93	3.52%	2.00	3.07%	3.17	4.77%	5.00	7.09%
	Mid	0.37	0.67%	1.53	2.35%	1.20	1.81%	2.13	3.02%
	Right	1.57	2.85%	2.40	3.68%	2.97	4.47%	3.83	5.43%
3	Left	6.93	12.61%	14.00	21.49%	10.47	15.78%	10.80	15.30%
	Mid	2.33	4.24%	0.90	1.38%	4.13	6.23%	4.57	6.47%
	Right	7.13	12.98%	9.67	14.84%	9.90	14.92%	9.63	13.65%

According to the average number of gaze times in the visual search process, it was found that the first search in the search process was usually the right region, accounting for 36.29%, indicating that the region was most concerned by the subjects, followed by the middle. The area, accounting for 34.14%, received the least attention in the left area, only 29.57%. In the actual driving process, the driver may search in order according to his own habits on the dashboard. Vehicles of different brands will have different degrees of difference when setting the dashboard, and the driver's driving experience is more sufficient. The habit effect of the vehicle dashboard on the subjects will be greater. On the contrary, if there is no driving experience or less driving experience, the reading of the instrument panel is more inclined to daily reading habits than driving habits or driving experience. Therefore, the speedometer and tachometer can be set in the middle and right areas of the instrument panel, and the dials (such as fuel gauges and water temperature gauges) that are not commonly used can be set in the left area of the instrument panel, which is beneficial to improve the search efficiency of the driver.

## 4 Conclusions

According to the experimental results, the following conclusions are obtained:

- (1) During the driving, the speedometer is most concerned by the driver, and other instruments are secondary concerns. In the design of the car dashboard, A type of layout (left and right structure, tachometer and speedometer are distributed on the left and right sides of the instrument panel, fuel gauge, water temperature gauge in the speedometer, tachometer) is conducive to the overall reading; If the speedometer is read separately, the C type of layout is better for reading.
- (2) Subjects have more fixation under special color schemes, indicating that it is difficult to get information, which makes the reading efficiency of the instrument panel lower. In a word, the appropriate special color matching is good for reading, but complicated color matching will reduce the driver's reading efficiency.
- (3) When designing the instrument, it is not recommended to set the scale vertically, which will lead to the extension of the reading time, reduce the driver's reading efficiency, and be unsafe.
- (4) According to the visual search habits of the subjects and the experimental research results of the number of fixation in the visual search, the main instruments (speedometer, tachometer) are set on the right and middle areas of the instrument panel (visual search efficiency is 70.43%); The dial (fuel gauge, water temperature gauge) that is not commonly used is set in the left area of the dashboard, which can improve the search efficiency of the driver.

**Acknowledgements.** The presented work has been supported by General project of China University of Labor Relations (19YYJS003) and Teaching Reform Project (zyjs201804).

## References

1. Wu, S.B., Liu, X.T., Sun, H.W.: Influence of use of in-vehicle information device on driving behavior. *China Saf. Sci. J.* **28**, 14–19 (2018)
2. Zhu, L., Zhang, X.K., Yang, L.F.: Study on the ergonomic multi-level fuzzy evaluation of fascia. *Comput. Autom. Meas. Control* **12**, 654–656 (2004)
3. Bai, R., Yao, T., Zhao, Y.Y.: Visual coding of manipulator interface design. *Mod. Decor. (Theory)* **05**, 83–84 (2015)
4. Shu, X.L., Dong, D., Dong, W.J.: Analysis of basic requirement for visual warning signals in aircraft flight deck design. *Adv. Aeronaut. Sci. Eng.* **6**, 512–518 (2015)
5. Zhao, T., Chai, L.M.: Automotive dashboard design and manufacturing. *Bus Technol. Res.* **32**, 34–36 (2010)
6. Wang, H.Y., Wang, X.X.: Man-machine design of car dashboards. *Automob. Res. Dev.* **1**, 4–7 (1996)
7. Iqbal, B.M., Suzianti, A., Nurtjahyo, B.: Military vehicle dashboard design using semantics method in cognitive ergonomics framework. In: *International Conference on Engineering Psychology and Cognitive Ergonomics*, pp. 152–163 (2015)
8. Sutaji, Z.: Design of ergonomics car instrument panel and dashboard. *Universiti Teknikal Malaysia Melaka, Durian Tunggal* (2011)

9. Zhang, X.Q., Liu, C.: Overview on the application of eye-movement technology in the safety of civil aviation. *J. Saf. Sci. Technol.* **8**, 91–94 (2012)
10. Liu, W., Yuan, X.G., Zhuang, D.M.: Development of a simulated cockpit for synthetic ergonomic evaluation of pilot. *China Saf. Sci. J.* **13**, 9–12 (2003)
11. Sun, G.L., Li, Q., Fu, P.W., Ran, L.H.: Analysis and optimization of information coding for automobile dashboard based on human factors engineering. *China Saf. Sci. J.* **28**, 68–74 (2018)
12. Zhang, X.M.: *Experimental Psychology (Revised Edition)*. Beijing Normal University Press, Beijing (2007)



# Brand Identity in Motion. Structural Models of Brand Identity on TV Opening Credits

João Brandão<sup>(✉)</sup>, Ricardo Maia Pestana, and Daniel Raposo

CIAUD – Research Centre for Architecture, Urbanism and Design,  
Lisbon School of Architecture, University of Lisbon, Lisbon, Portugal  
joaobrand@gmail.com, daniel.raposo@gmail.com,  
ricardo.pestana@edu.ulisboa.pt

**Abstract.** The television universe is a multibillion-dollar industry. Just like all other major products, tv series need branding. Here identity is used to guide the public into the continuity of the different episodes, and to differentiate them from other series in a highly competitive market. For a successful branding, a clear strategy is needed for these audiovisual products. Our study presents an understanding of the different types of opening credits, establishing a possible classification for them, and how they are used strategically to uphold brand identity ideals. To achieve this, it's important to understand the audiovisual medium and its interactions with Graphic Design, typography and Motion Graphics, areas that play a part in the elaboration of these main title sequences. Based on the analysis of key structural elements and different typologies or structural models of main title sequences, we made the proposal for their classification, from the perspective of structural organization.

**Keywords:** Graphic design · Motion graphics · Main title sequence · Television series · Brand identity

## 1 Introduction

The television universe is a multibillion-dollar industry, with entertainment TV content taking one of the largest portions of producers' budgets. For instance, in its 2018 financial report, NETFLIX—the most popular TV streaming service in the world (with more than 139 million subscribers in 2018)—shows \$13 Billion for the acquisition of content, of which 85% (according to Forbes website [1]) was spent on the production of new content, with massive investments on each project.

Not only investments in production are massive, revenues are also huge. Looking at the data available for the year 2017, the total revenue of just two subscription TV services dedicated to entertainment – NETFLIX and HBO—represents more than \$18 Billion [2, 3]. And that amount has been rising in the last few years (HBO: \$5.61 Billion in 2015, \$5.89 Billion in 2016, \$6.32 Billion in 2017; NETFLIX: \$6.77 Billion in 2015, \$8.83 Billion in 2016, \$11.69 Billion in 2017). In 2017, HBO and Netflix combined had \$4.5 Billion more revenue than CBS Network, with \$13.69 Billion. But CBS revenue in advertising alone was \$5.75 Billion, 42% of total revenues [4]. And why are so many people paying to subscribe these TV services?

One of the reasons may lay in their content's quality, though the Emmy Awards also acknowledge the quality and success of other non- "subscription only" TV channels and networks.

Another reason might be the "add free" policy of HBO and NETFLIX. However, the biggest streaming service in the world, YouTube (with more than 1 billion users and hundreds of millions of hours of video watched each day), is maintained by advertising shown on top or at the beginning of almost all clips. And Amazon plans to launch an ad-supported streaming video channel [5].

Also, the way people are consuming TV products is changing. Consumers are abandoning traditional cable TV for streaming services [6, 7], consuming TV on their computers and mobile devices and consuming streaming services in TV sets [8].

Obviously, if quality of service and absence of advertising are not the main factors contributing to the commercial success of those two TV services, nor to the success of YouTube, then there must be other reasons for that. If the success of YouTube is probably due to new kinds of production supported by technology, namely the "homemade" production of short videos, the success of HBO or NETFLIX (and others, like Amazon Prime Video, HULU, AMC or FX) may lay also in new forms of production and distribution also supported by technology, but with a professional quality. In YouTube, there are also professionally made videos, like music video clips, although these videos are intended not only to the online consumer but also to the TV consumer.

These new computer-based technologies allow the production companies not only to create TV shows with higher visual quality, but also to deliver them directly to consumers. In a market with so much money involved and with the possibility of a viewer to watch TV products at the reach of a fingertip on multiple devices, the competition is high, especially if you don't need a traditional cable service. And streaming services allow their subscribers to act as if they are "directors of network programming", watching whatever and whenever they want.

As such, big productions are forced to have branding strategies to ensure their financial success. Therefore, TV series, with enormous budgets, need branding, especially given the fact that most are spread out into seasons of multiple episodes. Here, identity is used to guide the public into the continuity of the different episodes, and to differentiate them from other series.

But establishing a brand is a complex thing to do.

## **2 What Is Branding and How Can the TV Series Benefit from It?**

Corporate/Brand Identity refers to a set of values, self-perceptions, a vision and ethics created by a corporation as a result of the experiences lived throughout its history. In this sense, according to Chevalier and Mazzalovo [9], the Corporate/Brand Identity is its essence and for this reason Costa [10] refers that it is the DNA of the brand.

Any company, product or service that has a public existence gives rise to a Corporate/Brand image in people's heads. That is, there is a certain reputation (public opinion regarding the conduct of a company or the performance of a product or service) as well as mental images (associated symbols, notions of value, and perceptions of



quality and feelings resulting from a shopping experience). It is a public perception about the “personality” of the brand, created over time as a result of different types of contact and experience of people with the brand and its products or services [10].

In this sense, the brand derives from a Corporate/Brand Identity articulated with a program (articulated strategy that meets business objectives, compatible with competition needs, sectoral legislation, technical issues and expectations of potential recipients).

Thus, the brand is an artificial symbolic system that is communicated, while the brand image is a social phenomenon created naturally by people in society [11].

In this context, it is likely that the biggest difficulty for businesses is to ensure that their actions, products, services, processes and communication create the desired Corporate/Brand Image. Indeed, Branding (brand management) aims to ensure the semantic and operative articulation that underlies the creation and communication of products and services, monitoring the tangible and intangible impacts of all actions, particularly in the design scope, interpersonal communication and Brand Image [12].

The designer plays the important mission of optimizing and giving visible form to the values and discourse of the brand, creating a system of signs designated as Corporate/Brand Identity. Visual Identity is how the Corporate/Brand Identity (which is intangible) is expressed visually in various media [9].

Visual Identity is a system of which the Mark (symbol and/or logo) is part, constituting the minimal symbolic unit to represent the brand. And these Marks can become icons of an era, a generation or a way of life, surpassing the purposes of the sender and the designer, once the brand happens to belong to the people.

The Visual Identity system comes from a set of options in the selection and design of symbols, graphics, colors, textures, formats and styles used according to design principles (style guides) to convey a certain notion of brand and to ensure that it is distinctive, recognizable and memorable. However, this Visual Identity system can adapt to different contexts, through the way the various graphic signs combine to generate different tones of the brand’s discourse, aimed at different audiences.

In the television context, the Visual Identity allows to establish different links between the identity of the station, the channel or the television series, namely by the degree of kinship used in the graphic system.

As previously mentioned, Visual Identity is created through the use of graphic elements and the way these are systematically employed. This systematization of visual language creates a narrative of a brand identity that is recognizable by the public at the beginning of a television series or even when it is subtly promoted throughout television programming.

Increasingly, the Visual Identity project passes through the semantic relationship between graphic elements and other signs such as rhythm, sound (or silence), texture and odor, in order to create multimedia and multisensory communication. In the case of the audiovisual medium, through narratives of continuous or interactive animation, visual identity provides the transmission of various levels of information or meaning, as well as other dimensions of attention and understanding.

### **3 How Can We Think About the Branding of a Television Series?**

Although some visual identity projects developed for television stations or channels have achieved a good degree of notability, the adoption of Branding principles and policies is relatively recent in television. The lack of strong competition probably facilitated the emergence of television brands with high visibility without them having to be aware of their audiences' expectations and allowing them to neglect the processes for holistic management of corporate and interpersonal communication. And for this reason, there is an explanation for an increase in Branding practices alongside the rise of other television brands and multinationals [12].

Nowadays, TV Branding aims to ensure a link between the brand and television contents trying to define an experience capable of fascinating the public so that it becomes loyal, increasing the brand value. In this sense, Branding seeks, on the one hand, to articulate services and all audiovisual and interpersonal media – semantically reconciling the necessary signs so that the experience is coherent and multisensorial – and, on the other, responding to feedbacks given by increasingly heterogeneous audiences.

### **4 Why These?**

Most authors who research and write about branding concur in stating principles for brand success. Among these requirements, specifically consistency, differentiation, flexibility and durability are often limited to Visual Identity, namely the need to create a common graphical language so that different elements are recognized – distinctive, durable in time and adjustable in different contexts. As for the other principles, they are frequently mentioned in marketing literature, in a relationship between the values associated with Brand Identity and the program for the brand, namely its personality, the semantic associations to be established and the particular way in which it will relate to the different the public.

Wheeler's proposal [13] was not selected for its innovative character but rather for its combination of the most common principles found in literature and practice. Also, because it allows us to holistically observe the most relevant bases for the success of a Brand. As proposed by Wheeler [13], the principles of coherence, differentiation, value, meaning, authenticity, longevity, commitment and flexibility should apply both to the definition of Brand Identity and to the selection and design of the Brand Identity.

### **5 Branding and/in Motion**

As previously referred a brand is not just a Logo or a Mark. It's a mental concept that combines a Brand Identity – a set of values, self-perceptions and ethics – with a business strategy. And in the TV series context, a series' visual identity – the brand's visible form – allows us to establish different links between itself and the identity of the

network, the channel or other TV series, as a way to implement the producers' business strategy.

In the audio-visual context, graphic elements relate to other signs, like rhythm, sound (or its absence), texture, etc., and Motion graphics, the combination of graphic design, animation, sound, etc. brought to Visual Identity the ability to communicate different levels of information and/or meaning.

Therefore, and due to cheaper technology, the increasing use of motion graphics in television, plays an important role on the way TV series Visual Identities are nowadays created. The ability to animate some key elements of a Visual Identity like the brand's mark (logo and/or symbol) or its typography or even the possibility to change color(s) allows the designer to convey more meaning to a visual identity with new layers of information.

But the designer must be aware that motion applied to text can be, by itself, part of the message delivered: motion can add (or change the) meaning to what is shown namely when added to typography. If used properly, motion can change a noun in the same way that an adjective can be used to modify or describe it [14].

When movement is added to typography, it can also function as a way to establish a hierarchy to the text. And motion influences the way the reader decodes the text; in the same way punctuation can change the meaning of a text. Just as punctuation marks are used in a text, movement suggests pauses, divisions, and above all establishes syntactic relations between the parts of a linguistic set [14].

This factor is of particular interest in a design project since it allows to highlight or obliterate specific parts of the message and thereby objectively to manipulate its contents. This strategy can be useful in particular in advertising, where information is presented in an appealing and persuasive way in order to influence the attitude of the recipient and determining his action with a precise objective [14].

As we can see, movement can add connotative characteristics to a denotative text. Like language functions in a literary text, the movement contributes to modeling the text, giving it more suggestive and expressive characteristics, while producing a specific effect on the interpretation made by receiver. In this respect, this effect is particularly striking in the application of figures of semantic or syntactic meaning [14].

So, motion applied to typography works as a language that complements the text, with a functional system that works in the same way as a grammar. Knowing this, a designer can achieve a more complete characterization of a Visual Identity [14].

In TV series, this is already being used in the designing of main title sequences.

## 6 Brand Identity on TV Opening Credits

In movies and TV series, a few seconds, sometimes not so few, present information that does not belong to the story line, but that intends to help identifying what is/will be shown and who made it.

This information is usually presented at the beginning, or near the beginning, of the TV series episode. It includes the names of (some of) the people involved in its production, namely the leading actors, the writers, the production team, and the director(s).

The presentation of this information is usually known as opening credits, also called main titles/main title sequences which we believe are more accurate expressions.

While many times the information about the authorship is presented as text alongside images of the episode, often it is displayed in a motion graphics composition introducing the story, or at least helping to suggest the mood of the series/episode. Actually, 4 in 5 series have information regarding their productions – the credits—presented by typographic elements superimposed, shown alongside the images of the episode [15]. And only 1 in 5 has all the information about its authorship in a main title sequence that is independent from the episode.

But all the episodes have main titles, and all main titles help to establish the Visual Identity of a series, as this is where the title is shown – usually as a mark, shown with a higher prominence than all other typographic elements. Besides, main titles often help to cement in the viewer an idea of what the series is and what it is not, contributing to create a brand.

Main titles are not always presented in the same way. In 3 of 4 episodes [15], the main titles interrupt the episode for more than 10 s, and in almost 2 of 5 episodes [15] the main titles “suspend” the episode for more than one minute. As one minute in TV time represents a considerable amount of money, we can deduce that main titles represent an important part in establishing a visual identity.

## 7 Structural Models of TV Main Titles

While it's possible to find many different ways of presenting information about the authorship of a TV series it is inconceivable to say which one is generally the best way to establish a brand identity or a visual identity.

However, it is possible to identify the key structural elements present in main titles. More importantly, one can identify and typify in which sequence those key structural elements are shown.

As the main title is, above all, the “place” where the series or the episode is identified, the main element shown is the title. But there are other elements like the names of its authors and other participants, as actors, producers and/or directors. And this is done using typography. Also, in many cases, this is where a set of images that work as an introductory narrative of the following story is displayed.

Main titles are, therefore, graphic design projects that contemplate several variables: in the purely graphic aspect variables such as information hierarchy, readability, identity and functionality are relevant. But this type of graphic communication projects uses not only the x-y-z axis, in a 3-dimensional space, but also the 4th dimension – time – combining the language of graphic design with the languages of cinema and television, among others. As such, main titles are presented in a sequence of images, known as “opening credits” or “main title sequences”.

In order to identify and typify the structural models of main title sequences, we have to assume that the title of the series is shown in all its episodes, and that in most main title sequences there is also the presence of credits – the names of its authors and other participants. Thus, the moment where the title is shown is an important moment

in the identification of the TV series. And, for that reason, the title gets more prominence than the other elements of the main title sequence.

However, even if all main title sequences show the title and/or credits, this is not enough to say where the main title sequence starts or ends, because in fact, these may not be the only elements that compose a main title sequence. Moreover, 95% of the episodes have their narrative interrupted by an easily recognizable set of still and/or moving images (and often sound), that is not directly related to the storyline taking place at the moment in which the sequence is shown. This set of images (as the sound that goes with it) that interrupts the storyline of the episode is usually repeated in several if not all episodes of the series.

The set of images that cause this interruption, usually called main title sequence (or opening credits), in this text will be called “the autonomous sequence” of the main title sequence. It is autonomous because it does not interfere with the narrative of the episode, being independent of it.

However, it is also considered as “main title sequence” the display of typographic elements or other graphic elements, superimposed on the images of the episode, which may constitute a form of identification of the series, or of its interveners (authors, actresses, team of production, directors, creators, etc.) and that do not interrupt the narrative of the episode. To these elements, we will call “non-autonomous credits”, since they aren’t superimposed on the same images in all episodes of the series. In these non-autonomous credits are also included possible titles of episodes that in some series are presented - usually after the title of the series - and do not interrupt their narrative.

It should be considered that the work of the designer in the creation of the main title sequences is not limited to its autonomous part; in fact, the choice of typography, colors and contrasts essential to the reading of non-autonomous credits, as well as the types of movements appropriate to a correct reading of the information they convey, should also fall under the designer, since this is part of his technical and artistic skills.

Moreover, it should be noted that if the main title sequences were considered to be constructed only by the autonomous part, about 5 out of every 100 series would not have any main title sequence and only 1/4 of the main title sequences would contain all the elements related to the identification of the authors and/or interveners that the production of the series considered necessary (either for contractual reasons or for the obligations of the statutes of some professional associations - such as the directors).

This is because often the title is presented in an autonomous part of short duration that in most cases does not contain credits. If this short autonomous part contains some credits, usually only the creators of the series (*created by*) are mentioned, but always at the moment the title is visible or immediately after. This short-lived autonomous part is composed of still and/or moving images (whether they are shot or an animation product or both) and, in most cases, it lasts not more than 10 s. It is also important to mention once more that not always the elements of the main title sequences imply an interruption in the episode, in which case both the title and the credits (when they exist) appear superimposed on images of the episode. In both cases, and given the emphasis usually given to the title, we will call the visual composition that presents the title (whether considered as an autonomous part or not) ‘presentation of the title’.

Thus, in order to establish the limits of the main title sequence, it is considered that we are in its presence when the episode is interrupted by the autonomous part of the

main title sequence, by the presentation of the title (autonomous or not) or by the appearance of non-autonomous credits and we cease to be in the presence of the main title sequence when the last of these elements disappears.

Based on the definition of where the main title sequences begin and end, it was then possible to look for the patterns presented by them.

As such, it was possible to distinguish two large groups of main titles, which may be identified not only by the duration of the interruption they cause in the episode, but above all by the existence (or not) of credits in the autonomous part - credits that do not exist only at the time of presentation of the title or at the time immediately following, but are distributed throughout the entire interruption.

It would also be possible to make this first classification based on the existence or not of an autonomous part of the main title sequence. However, in terms of organization, main titles without autonomous part have sequences of presentation of credits and title similar to the main titles that only make the presentation of the title in an autonomous way.

**Thus, in the group of main title sequences with credits in the autonomous part the following models can be found:**

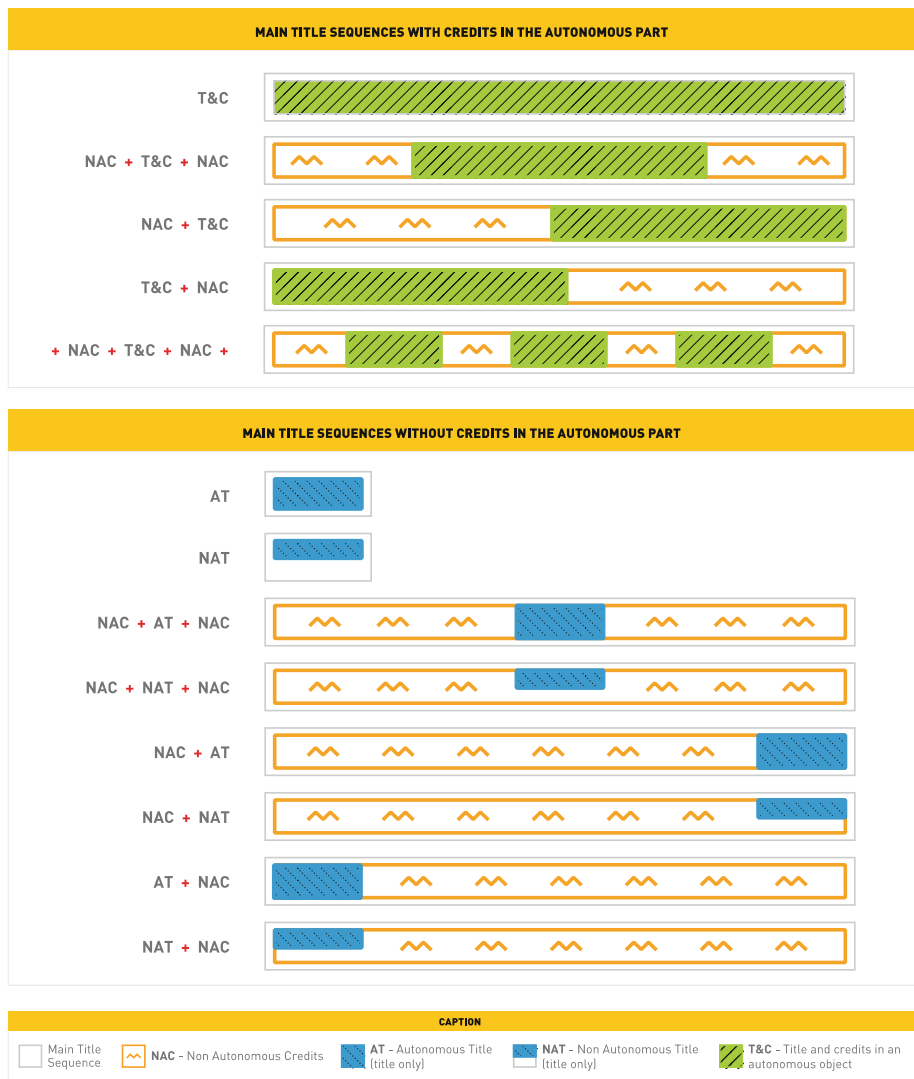
- The main title is presented as a completely autonomous object (T&C);
- There is an autonomous object that precedes non-autonomous credits (T&C + NAC);
- There is an autonomous object that is preceded by non-autonomous credits (NAC + T&C);
- There is an autonomous object that precedes and is preceded by non-autonomous credits (NAC + T&C + NAC);
- The title and credits are presented through several autonomous objects interspersed with the action of the episode, which may or may not have non-autonomous credits (+ NAC + T&C + NAC +), and that may or may not begin with the presentation of the title;

**Regarding the group of main title sequences without credits in an autonomous part, the following models were found:**

- There is only the presentation of the title (AT or NAT);
- The identification of the series is made through the presentation of the title, preceded and followed by non-autonomous credits (NAC + AT or NAT + NAC);
- Non-autonomous credits are shown and only after that the title is presented (NAC + AT or NAC + NAT);
- The presentation of the title is made and is followed by non-autonomous credits (AT + NAC or NAT + NAC).

According to the models found, it is then possible to present in a schematic way the different types of sequences of presentation of credits and title. In the diagram presented below the abbreviations written in the text between parentheses are used to identify the different types of main title sequences structures (Fig. 1).

In this scheme other elements that can function as identifiers of the series by presenting the narrative autonomously were not included. These are the sequences,



**Fig. 1.** Different types of main title sequences structures

with their own narrative and functioning as an introduction to the series, exhibited in about 3 out of 100 series separately from the main title sequence. As they do not have credits or even presentation of the title, those sequences were not considered as an integral part of the main title sequence.

However, the data collected so far suggest that, even though the times dedicated to main titles are increasing, as there are more credits superimposed on the images of the episode, the time they “steal” from the episode is becoming smaller [15].

The same does not happen in one group of series that includes episodes with duration of 50 to 60 min, created mainly for the British market and for HBO or NETFLIX.

This probably means that TV opening credits and main title sequences are an important part of HBO and NETFLIX branding strategies, in their need to gain market share.

The data presented were collected in the scope of an ongoing Ph.D. research project and more complete data and corresponding analysis will be published in a near future.

**Acknowledgments.** 1. CIAUD – Research Centre for Architecture, Urbanism and Design, Lisbon School of Architecture, University of Lisbon, Portugal; FCT—Fundação para a ciência e Tecnologia, Portugal and FLAD—Luso-American Development Foundation.

## References

1. Feldman, D.: Netflix has Record-Breaking Fourth Quarter in 2017, Exceeds \$11B in Revenue. Forbes (2018). <https://www.forbes.com/sites/danafeldman/2018/01/22/netflix-has-record-breaking-fourth-quarter-in-2017-exceeds-11b-in-revenue/>
2. Netflix, Inc.: Annual report pursuant to section 13 or 15(d) of the securities exchange act of 1934 for the fiscal year ended December 31, 2017, Commission File Number: 001-35727, Netflix, Inc. (2019)
3. Time Warner Inc.: Time Warner Inc. Reports Fourth-Quarter and Full-Year 2017 Results (2018)
4. CBS Corporation: CBS Corporation Reports 2017 Fourth Quarter and Full Year Results (2017). <https://investors.cbscorporation.com/news-releases/news-release-details/cbs-corporation-reports-2017-fourth-quarter-and-full-year>
5. IMDb.com, Inc.: IMDb | Help (2019). <https://help.imdb.com/article/imdb/discover-watch/imdb-freedive-faqs/GZML3SK6UQK8EMYV>
6. Bond, S.: HBO joins Netflix in shattering subscription records. Financial Times (2018). <https://www.ft.com/content/c6191822-075e-11e8-9650-9c0ad2d7c5b5>
7. Morris, D.: Viewers are Ditching Cable for Streaming Faster than Anyone Expected. Fortune (2018). <http://fortune.com/2018/04/29/viewers-cable-streaming/>
8. Google: Building a better marketing strategy to reach today's viewers: Changing Channels (2018). <https://www.thinkwithgoogle.com/advertising-channels/video/multi-screen-video-viewing-report/>
9. Chevalier, M., Mazzalovo, G.: Pro Logo: Brands as a Factor of Progress. Palgrave Macmillan, London (2004)
10. Costa, J.: La Imagen de Marca. Paidós Diseño, Barcelona (2004)
11. Raposo, D.: The graphic speech of the brand. In: Barbosa, H., Calvera, A. (eds.) Proceedings of Tradition, Transition, Trajectories: Major or Minor Influences? ICDHS 2014 - 9th Conference of the International Committee for Design History and Design Studies. Universidade de Aveiro, Blucher, São Paulo, pp. 445–450 (2014). <https://doi.org/10.5151/despro-icdhs2014-0063>
12. McDowell, W., Batten, A.: Branding TV. Principles and Practices. Focal Press, Burlington (2005)
13. Wheeler, A.: Designing Brand Identity: A complete Guide to Creating, Building and Maintaining Strong Brands. Wiley, New York (2003)



14. Brandão, J.: Uma gramática do movimento: variáveis estruturais para uma expressão do movimento na comunicação gráfica. Tese de doutoramento. Faculdade de Arquitectura, Universidade Técnica de Lisboa, Lisboa (2012)
15. Pestana, R.: Design gráfico para televisão - proposta de classificação de tipologias de estruturas de genéricos de séries. Tese de Mestrado. Faculdade de Arquitectura, Universidade de Lisboa (2014)



# Human Factors Engineering Research on Folding Umbrellas Design

Xiaohan Zhou<sup>(✉)</sup> and Xiaoping Hu

School of Design, South China University of Technology, Guangzhou University  
Town, Panyu District 510006, Guangdong, China  
han1997xiao Zhou@163.com

**Abstract.** The folding umbrellas are widely loved by consumers because of their small size, light weight and easy carrying. And the comfort of use of folding umbrellas is inseparable from the study of human factors engineering since the folding umbrellas have the most direct contact with the human body. There are many different kinds of folding umbrellas on the market, but almost for commercial purposes, which has led to an increasingly terrible experience of the inconvenience of existing folding umbrellas. Consequently, in order to let consumers get a better experience during the use of the folding umbrellas, this paper, from the perspective of the human factors engineering, attempts to find out the deficiencies of the folding umbrellas design and the possible design breakthroughs, and propose innovative ideas for folding umbrellas design.

**Keywords:** Folding umbrellas · Human factors engineering · Design

## 1 Introduction

As is known to all, the folding umbrellas occupy an extremely important position in the daily life of people, which have a high frequency of use and can be used all year round, almost everyone must have a folding umbrella. So the design of folding umbrellas is particularly important. Folding umbrellas have a very large market now, but most of the current design of folding umbrellas is only based on innovations in appearance, and there still have some problems in terms of human factors. Therefore, it is necessary to study the human factors engineering of folding umbrellas.

## 2 The Development of Folding Umbrellas

### 2.1 The Development of Umbrellas

It cannot be verified where the oldest umbrella in history originated today. The tools used by servants or slaves to protect their masters from the sun can be said to be a kind of umbrella in ancient Egypt, and the wife of Lu Ban also had a record of inventing an umbrella in the Warring States Period.

The umbrella has a history of four thousand years from the emergence of the umbrella prototype in China. About two thousand years ago, there was a relatively

complete umbrella in history. By the time of the post-Wei period, umbrellas had developed into a tool for classifying identities and classes and continued to the Ming dynasty. After the Eastern Han Dynasty, paper-made oil umbrellas began to spread among the public. And around the Tang Dynasty, it began to spread abroad. Tarpaulin umbrella appeared after the Yuan Dynasty, it was durable and had lower cost. Therefore, it has been used for a long time in China through continuous improvement and development [1]. In the west, umbrellas were originally invented to keep out the sun, not the rain, so the west has always had only parasols. And it is widely believed that the Englishman Jonas Hanover brought the umbrella to Europe.

## 2.2 The Appearance of Folding Umbrellas

In 1705, the Frenchman Jean Marius folded the umbrella handle in three sections, and the whole umbrella was much smaller than the original [2]. In order to prevent others from improperly counterfeiting, Marius submitted an application to the Academy of Sciences for the commercial privilege of the umbrella. He won the debate, securing the franchise for five consecutive years from January 1, 1710. In 1928, the German Hans Haupt invented the first telescopic umbrella because it was inconvenient to carry a long handle umbrella while walking with a cane. The kind of umbrella can be almost put into the pocket after shrinking, so it is also called pocket umbrella.

The folding umbrella which is most commonly used today was originally designed by an old professor at a Chinese university. In 1957, Yanruo Lao, a professor at Beijing Normal University, was inspired by the ability of human joints to bend and stretch. Then, he improved the umbrellas on the market at the time, and designed the engineering drawings of the folding umbrellas, made the processing technology and designed the mold by himself [3]. And today, Folding umbrellas are popular because of their small size and portability.

## 3 The Research Direction of Folding Umbrellas

### 3.1 Development Status of Folding Umbrellas

Nowadays, the design of umbrellas on the market is divers, and the folding umbrellas are widely loved by consumers because of their small size and portability. The appearance design of folding umbrellas, including their color and shape, are becoming more and more novel, and the selection of umbrellas surface materials is also more exquisite. In addition to being used for sun protection and rain shelter, the folding umbrella with exquisite shape also has a certain decorative effect, which can cooperate with the different costumes of users and play various roles in different environments. However, most of the design is based on the appearance, with little consideration for human factors, and fail to solve the problems existing in the use of folding umbrellas. They almost always retain the most original features and shapes, without making a breakthrough. However, people have higher requirements when choosing folding umbrellas. They not only have higher requirements for appearance, color, brand effect and other aspects, but also pay more attention to the comfort and functionality of

folding umbrellas. This also reminds designers that they should not only focus on the appearance, but should also change to be more caring about people's life, solve the problems in life and pay more attention to human factors engineering research in the design of folding umbrellas, which are the development trend of folding umbrellas.

### 3.2 Human Factors Problems with Folding Umbrellas

The folding umbrellas play an indispensable role in people's daily life, but people also endure many additional problems caused by them while enjoying the convenience. And these small problems will be infinitely magnified in the use of high frequency, causing a lot of trouble to users. Folding umbrellas are mainly composed of three parts: umbrella cover, umbrella frame and handle (As shown in Fig. 1). Since the handle has the most direct connection with the human body, it is highlighted in the design of the folding umbrellas. But other parts of the folding umbrellas are also important.

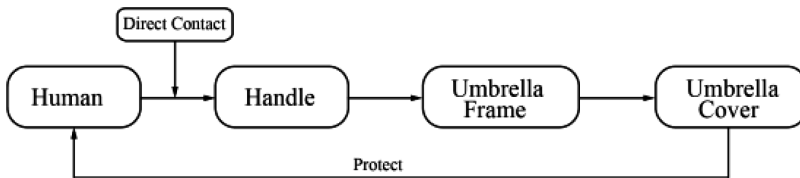


Fig. 1. The system model between people and the folding umbrella.

In order to be smaller and lighter, the folding umbrellas are designed to have some folded structures on the umbrella frames, and the handles are also made particularly compact. Although this kind of design can make folding umbrellas easy to carry and place, it has caused many problems in the process of using. Since the handle of the folding umbrella is designed to be particularly small, the user usually places the hand on the umbrella pole when holding the umbrella. But the umbrella pole is made of metal material, and very thin, the nail will be against the palm to cause a tingling sensation when holding the umbrella, and there will be hand slip, grip is not firm. In addition, there are also some users who put their hands on the handle. However, the force distribution will be uneven since the contact area between the handle and the palm is too small, and cause tingling sensation of the palm and the phenomenon of blood not to circulate. What's more, people's wrists are always in the twisted state of anti-gravity when they hold an umbrella, maintaining this state for a long time will cause damage to their wrists. These problems seem to be small, but they happen to people's lives almost every day, which have a great impact on people.

### 3.3 Design Ideas of Folding Umbrellas

Folding umbrella, as one of the necessities that people will use frequently in daily life, has a very huge market demand. Therefore, the research value of folding umbrellas should not be taken lightly, so the research on human factors engineering of folding

umbrellas is more necessary. In homogenization of today, it is clear that the design goal is folding umbrella and the design is for people. And people's demand for folding umbrellas should not only be limited to the use, but also to better use, so principles of human factors engineering should be applied in design of folding umbrellas to meet the functional and emotional needs of people.

Roberto, a well-known design management scientist, believes that the core of design is the formation and interpretation of meaning. It is extended to the folding umbrella design, triggering the design thinking of folding umbrellas: How to make the design of folding umbrellas meaningful and how to interpret the design by folding umbrella? First of all, the human factors should be taken into account during the process of design work. That is to say that the human should be put in the first place. The rapid development of science and technology and the sharp rise of intelligent productivity have greatly increased the flexibility of production, which have promoted new thinking and new ideas for design of folding umbrellas. At the same time, human nature itself has the nature of breaking through the standard, pursuing and flaunting differences, today even more.

Therefore, in the process of folding umbrellas design, Human Factors Engineering should be integrated into the design to find a more suitable way for use of human. And incorporating differences into the design to present a colorful expression and design vibrancy if conditions allow. In a word, the design of folding umbrellas should meet the physiological needs and the psychological needs of different consumers.

## **4 Analysis of Folding Umbrellas**

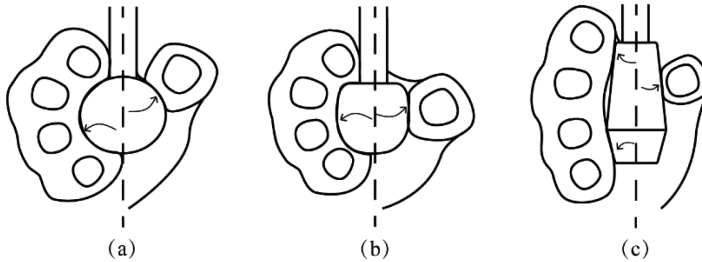
Folding umbrellas have almost become a kind of necessity in people's life, but there are still many problems in the existing folding umbrellas. In particular, the size of handles does not conform to the principles of human factors engineering, which will cause some damage to human hands during use and increase the pain and burden of users. In addition, the size of folding umbrella, shape of folding umbrella cover and psychological factors of users should also be taken into account.

### **4.1 Analysis of Handle**

The handle of the folding umbrella is the part that has the most direct contact with the user, so the handle design should be carefully considered in the design of the folding umbrella. Certainly, the rethinking of the handle design is inseparable from the research on the human hand. In order to make the handle of folding umbrella more convenient for people to use, the handle design of folding umbrella should be discussed according to human factors engineering.

The human hand is a complex structure, which contains many nerve structures, muscles, hand bones and so on. Therefore, it has high degree of freedom and flexibility. In addition, the muscles are mainly distributed in thenar, hypothenar and fingertip areas, and the centre of the palm area is less. Therefore, the shape of the handle of the

folding umbrella should be designed to avoid the centre of the palm as much as possible, and have a large contact surface with the palm to make the pressure distribution evenly (Fig. 2 shows an example).



**Fig. 2.** The figure shows the handle shapes of various folding umbrellas. The shapes shown by (a) and (b) are easy to cause palm fatigue and discomfort, while the shape shown by (c) is better.

**Table 1.** Reasonable handle size and bending angle in human factors engineering.

Handle diameter (mm)	Handle length (mm)	Bending angle (°)
30–40	100–125	10

As far as the wrist is concerned, when people use ordinary folding umbrella, the human wrist forms an angle of non-straight state, which will cause damage to the wrist if the gesture lasts for a long time. Therefore, in order to avoid excessive bending of the wrist and reduce fatigue and damage of the wrist, it should be considered to bend the handle portion. It is generally believed that bending the handle portion by about  $10^\circ$  has the best effect [4].

Reasonable handle size and bending angle in human factors engineering are shown in Table 1, these dimensions can be used directly in the design of straight handle umbrellas, but it is too long for the folding umbrellas to set the handle length to 100–125 mm. Generally, the user is more comfortable when the length of the handle is close to and beyond the length of the handle. Therefore, the length of the handle of the folding umbrella can be close to or slightly smaller than the width of the hand.

## 4.2 Shape of Folding Umbrella cover

There are several reasons for adopting arc shape on the edge of the folding umbrellas. Firstly, the closure and streamline of the circle are better than that of the square. Secondly, the pressure difference between the front half and the rear half is small when the round umbrella face is subjected to the resistance of the wind, which is more labor-saving when walking. Thirdly, the surface of round folding umbrella is easier to excrete rainwater.

### 4.3 Size of Folding Umbrellas

In human factors Engineering, anthropometric data often uses the percentile  $P_K$  as a positional indicator and limit [4]. As folding umbrellas are a kind of general industrial product,  $P_{99}$  of body size standards can be chosen as the basis for the upper limit of size, and  $P_1$  can be selected as the basis for the lower limit of size. In order to protect users from rain and sun as far as possible, the upper limit of body size should mainly be taken into account in design of folding umbrellas,  $P_{99}$  of body size standards for adult men and women are shown in Table 2. The size of folding umbrella is determined by the range of motion of the user under the umbrella [5], and the schematic diagram of arm movement when a person holds a folding umbrella are shown in Fig. 3.

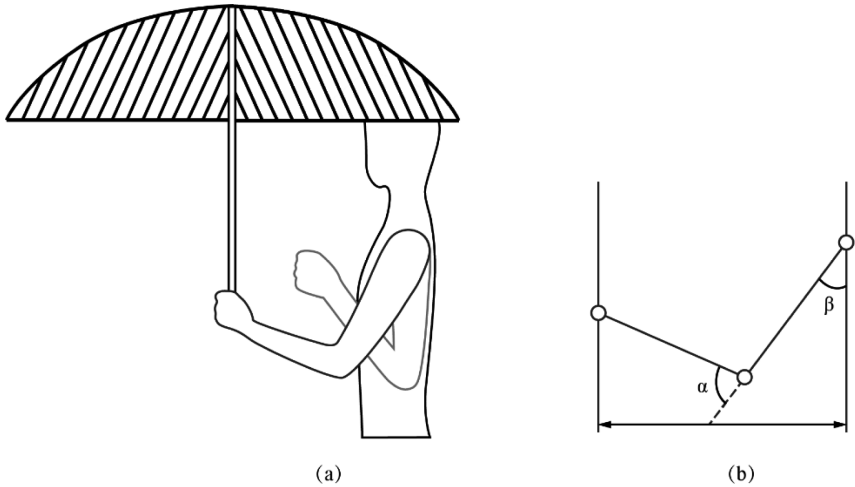
**Table 2.**  $P_{99}$  of body size standards for adult men aged from 18 to 60 years old, and women aged from 18 to 55 years old. (Unit: mm)

Gender	Forearm	Upper arm	Chest depth	Maximum shoulder width
Male	268	349	261	486
Female	242	319	260	458

**Table 3.** The value of the horizontal sum of the upper arm and forearm and size of folding umbrella when the  $\beta$  is  $50^\circ$  and the  $\alpha$  is  $85^\circ$ , and the value range of diameter of folding umbrellas (Unit: mm).

Gender	The value of the horizontal	Diameter of folding umbrellas
Male	457	766–1175
Female	416	694–1092

Assuming that the angle between the forearm and the upper arm is  $\alpha$ , and the angle between the upper arm and the torso is  $\beta$ . According to the size of human factors engineering,  $\alpha$  ranges from  $0^\circ$  to  $145^\circ$ , and  $\beta$  ranges from  $0^\circ$  to  $180^\circ$ . And the body comfort adjustment range of  $\alpha$  is  $85^\circ$  to  $110^\circ$ , and that of  $\beta$  is  $0^\circ$  to  $50^\circ$ . Considering that people will choose autonomously the comfortable angle when using the folding umbrella, and their elbows usually move backwards and have a small range of motion, so the horizontal value of the sum of the upper arm and the forearm is maximized when the  $\beta$  is  $50^\circ$  and the  $\alpha$  is  $85^\circ$ . It is calculated that the maximum diameter of the folding umbrellas is 1175 mm for men and 1092 mm for women after adding half of the chest depth value. In addition, the diameter of the folding umbrellas needs to be more than twice the maximum shoulder width of the users. Therefore,  $P_1$  of the maximum shoulder width is chosen as the basis of the lower limit value. And the  $P_1$  of maximum shoulder width of male and female is 383 mm and 347 mm respectively. The comprehensive analysis indicated that the value range of diameter for male is about 766–1175 mm, and that for female umbrella is about 694–1092 mm (As shown in Table 3).



**Fig. 3.** (a) represents the schematic diagram of arm movement when a person holds a folding umbrella, and (b) represents the simplified diagram.  $\alpha$  ( $0^\circ$ – $145^\circ$ ) represents the angle between the forearm and the upper arm,  $\beta$  ( $0^\circ$ – $180^\circ$ ) represents the angle between the upper arm and the body.

#### 4.4 Psychological Factor Analysis

The psychological needs of consumers, such as seeking novelty and beauty, are the inevitable outcome of the development of material level to a certain stage. There are many folding umbrellas with different materials and colors on the market, but people's psychological needs are not match materials and colors simply, which need to take people's subconscious perception of materials and colors into full consideration. Therefore, in addition to satisfying the material relationship between people and umbrellas, the human factors engineering study of folding umbrellas should also consider the real psychological needs of people.

The materials used in folding umbrellas can give people different feelings in the visual and tactile aspects through its texture, color and so on. Different materials bring people different psychological hints through their own attributes, frosted material gives people a sense of high quality, the material with smooth surface gives people a very smooth visual feeling, and the rough surface will give people a sense of oldness. In the meanwhile, color will bring people a strong visual impact, human beings have formed a large number of feelings and associations about color in their long-term life practice [6]. Different colors of folding umbrellas can make difference in distance by contrast. Warm colors make people feel that the distance between them and the object is shortened, but cool colors make people feel that the distance between them and the object is lengthened [7]. Therefore, it may be dangerous for users to use folding umbrellas with cool or light color in rainy or foggy days. In addition, warm colors make folding umbrellas look like less dense and lighter. Therefore, it is a good choice



to use warm colors on a large area to make the folding umbrellas look lighter. And colors can affect emotions of people in some ways. Accordingly, the psychological effect of materials and colors should be applied correctly in the design of the folding umbrellas, so that people have a sense of comfort while enjoying the beauty.

## 5 Conclusion

Nowadays, with the development of economy and society, people have higher and higher requirements on design. Folding umbrellas are tools used to shelter people from the wind and rain, and have the most direct contact with the human body. But there is not just a simple physical combination between the human body and the folding umbrella, there are still some “chemical reactions” between them. It can be known that the upper limbs of users have very close contact with the folding umbrellas through the analysis of the folding umbrellas and factors of human body. And improper design will cause some damage to users, which will be amplified after a long time of accumulation. Therefore, designers should fully consider the factors of human body and psychological needs of people, and study the knowledge of human factors engineering further.

## References

1. Li, X.D.: Research the Development and Evolution of China's Umbrella Design, Nanchang University, Nanchang (2007)
2. Zhuo, D.Y.: The Origin of All. Hunan Literature and Art Publishing House, Changsha (1987)
3. Ni, S.C.: The First Person in China. China Tourism Press, Beijing (1988)
4. Ding, Y.L., Cheng, G.P.: Ergonomics. Beijing Institute of Technology Press, Beijing (2011)
5. Xiong, X.F., Li, X.D., Wan, L.: Design analysis of umbrella. Packag. Eng. **11**, 119–121 (2007)
6. Wang, P.: Color Composition. Huazhong University of Science and Technology Press, Wuhan (2014)
7. Liu, S.: Design Psychology. Shanghai People's Fine Arts Publishing House, Shanghai (2013)



# Effects of Screen Brightness on Visual Performance Under Different Environments

Qi Tian<sup>1</sup>, Linghua Ran<sup>2(✉)</sup>, Cancan Zhao<sup>1</sup>, Zihan Zhou<sup>1</sup>,  
and Haimei Wu<sup>2</sup>

<sup>1</sup> Capital University of Economics and Business, Beijing, China  
15910816311@163.com, 13693353132@163.com,  
zhaocann@cueb.edu.cn

<sup>2</sup> AQSIQ Key Laboratory of Human Factors and Ergonomics (CNIS),  
China National Institute of Standardization, Beijing, China  
{ranlh, wuhm}@cnis.gov.cn

**Abstract.** This paper takes the office LED display screen as the object, and studies the impact of screen brightness on visual performance under different environmental illuminations when people were processing text tasks. Based on three dimensions of behavioral performance, subjective evaluation and physiological indicators, the optimal screen brightness value under different environmental illuminations and optimal brightness contrast range were obtained. Experimental data show that the interaction of screen brightness, ambient illumination and screen brightness has a significant impact on visual performance, while ambient illumination has no significant impact on visual performance. Brightness and contrast have significant effect on visual performance. When the ambient illumination were 50 lx, 300 lx and 500 lx, the optimal value of the screen brightness of the display were about 128 cd/m<sup>2</sup>, 178 cd/m<sup>2</sup> and 214 cd/m<sup>2</sup> respectively. The optimal brightness contrast range was 26–30.

**Keywords:** LED · Ambient illumination · Screen brightness · Interaction · Brightness contrast · Visual performance

## 1 Introduction

In recent years, due to the immaturity of technology and the lack of humanized design, the problems of visual fatigue and discomfort caused by various visual display terminals were becoming more and more serious, the needs for display terminals has gradually shifted from general functional aspects to human-centred aspects such as health, comfort and convenient use. Different studies on the health and comfort of various visual display terminals have been conducted. The studies show that ambient illumination and screen brightness have significant effects on visual comfort. Li did research on the optimal parameter of 3.2 in. mobile phone screen brightness under different ambient illuminations [1]. Weining, Fang et al. made studies on the effects of different illumination and brightness contrast on visual efficacy of vehicular liquid crystal display, indicating that visual efficacy was not only related to brightness contrast, but also closely related to illumination [2]. The research of Zhang et al. showed

that the brightness of VDT (visual display terminal) screen surface and the illumination of document background had a significant impact on the visual reading operation [3]. Wu et al. believed that the brightness contrast and screen brightness of VDT had an interactive effect on the operator's visual function [4]. Lin studied and discussed the influence of screen brightness combination on visual performance of LCD screen characteristics, indicating that screen brightness combination had a significant impact on visual effect [5]. Lin and Huang studied character recognition performance based on thin film transistor liquid crystal display (TFT-LCD), and the results showed that the influence of screen brightness was greater than that of contrast [6].

At present, LED displays were used more and more in office text task processing. Therefore, this paper takes office LED display as the object, and studies the impact of screen brightness on visual performance under different environmental illuminations when people were processing text tasks. Three dimensions, namely, behavioral performance, subjective evaluation and physiological indicators were used as the study indexes.

## 2 Experimental Design

Study the interaction of different ambient illumination, different screen brightness, ambient illumination and screen brightness, and the effect of brightness contrast on visual performance.

### 2.1 Subjects and Environment

In this experiment, a total of 16 subjects, aged between 18 and 40 years old with no visual impairment were recruited. Their visual acuity were 4.8 or above, often used LED displays and had no obvious physical or physiological obstacles that might affect their search speed and image perception.

The test room was quiet, and the ambient temperature and humidity were comfortable. The ambient illumination (0–800 lx) in the experimental room was adjustable.

### 2.2 Experimental Devices and Instruments

The LED display used in this study was Lenovo P24Q-10, with a resolution of 59 pixels/degree perspective. Before the experiment, the brightness values of screen and character were measured at 0%, 30%, 60%, 80% and 100% under the ambient illumination of 50 lx, 300 lx and 500 lx respectively. The measurement results were shown in Table 1. Brightness and contrast were calculated according to the measured data, as shown in Table 2.

**Table 1.** Screen, character brightness values (cd/m<sup>2</sup>)

The screen brightness	0%		30%		60%		80%		100%	
Ambient illumination (lx)	The screen	Character	The screen	Character	The screen	Character	The screen	Character	The screen	Character
50	65.36	1.953	82.4	2.277	127.9	2.903	174.2	3.722	212.4	4.505
300	69.39	1.966	83.16	2.313	131.5	4.126	178.1	5.28	213.4	6.313
500	70.69	2.205	84.39	3.192	132.7	4.394	179.5	5.929	214.2	7.28

**Table 2.** Brightness contrast (screen brightness/character brightness)

Ambient illumination (lx)	Screen brightness level (%)	Brightness contrast
50	0	33
	30	36
	60	44
	80	47
	100	47
300	0	35
	30	36
	60	32
	80	34
	100	34
500	0	32
	30	26
	60	30
	80	30
	100	29

2.3 Experimental Indexes

In the experiment, the average character search speed was used as behavioral performance indicators, the 9-point evaluation table was used as subjective evaluation method, and the critical frequency value of flash fusion was used as physiological evaluation index.

Search time  $T_i$  recorded by the performance measurement of the subject, namely the average search speed  $V_s$  (the number of characters/second), was calculated by the following formula:

$$V_s = n_t \times n_c \times \left[ \sum_{i=1}^{n_t} T_i \right]^{-1}$$

Among them:  $n_t$  Refers to the number of valid trials completed by test participants.  
 $n_c$  The total number of characters (including embedded Spaces) in the pseudo-text.

## 2.4 Experimental Variables

There were two independent variables. One was the environmental illumination which were 50 lx, 300 lx and 500 lx, the other was the screen brightness levels which were 0%, 30%, 60%, 80% to 100%.

Dependent variables were average character search speed, subjective visual comfort of the nine-point evaluation table and difference before and after flash fusion frequency.

## 2.5 Experimental Materials

The pseudo-text (meaningless text) proposed in ISO 9241-304 “user performance test method for electronic visual display” was used as the reading material for the average character search task. It was designed as 10 rows and 40 columns, and the number of target characters in a single experiment was 8–12. In order to avoid the interference of the reading task to the test, the pseudo-text was designed as a random string composed of upper and lower case letters, numbers and spaces. The proportion of target characters in the total number of characters was between 2% and 3% (including embedded spaces). Text font used was equal width font Courier New, which was black (with a white background) and had a font height of 4 mm at a viewing distance of 690 mm.

## 2.6 Experimental Procedure

- (1) To inform the subject of the purpose of this test.
- (2) To guide the subjects to be seated and adjust the visual distance to about 690 mm.
- (3) To set the program page.
- (4) To adjust the ambient illumination and screen brightness of the display.
- (5) To conduct 5 pre-experiments to make the subjects familiar with the experimental process.
- (6) Before the formal experiment, the flash fusion frequency was measured. Two text search tasks were then performed, with an interval of 5 s. During the text search task, the program automatically recorded the time spent in identifying each target character in the pseudo-text block. The order of the text program was determined randomly. After the experiment, the flash fusion frequency was measured again, and the subjects were asked to evaluate the visual comfort at 9 levels.
- (7) Replace the subjects and repeat the above steps to continue the next set of experiments until all experiments were completed.

# 3 Experimental Results and Analysis

## 3.1 Analysis of Parameters Under Different Ambient Illumination and Screen Brightness

The obtained experimental data was analyzed by repeated measurement variance analysis using SPSS software. The average character search speed, subjective

evaluation value, flicker fusion frequency difference before and after were analyzed under different display screen brightness and different environment illumination.

Average Character Search Speed

In order to analyze whether different ambient illumination, screen brightness and their interaction have significant influence on the average character search speed of the subjects. In order to exclude individual differences, the average character search speed was first calculated and then plotted into a table, as shown in Table 3.

Table 3. Average character search speed (character/s)

	0%	30%	60%	80%	100%
50 lx	10.7008	11.3271	11.5958	11.2689	11.5044
300 lx	10.9865	11.3604	11.5206	11.7142	11.8521
500 lx	11.1101	11.3623	11.7119	12.1627	12.6132

Repeated measurement anova results show that the main effect of environmental illumination on average character search speed was not significant,  $F(2, 45) = 0.232$ ,  $p > 0.05$ . The main effect of screen brightness on average character search speed was significant,  $F(4, 180) = 5.893$ ,  $p < 0.05$ . The interaction between ambient illumination and screen brightness was not significant for the average character search speed,  $F(8, 180) = 0.817$ ,  $p > 0.05$ . The influence of screen brightness on average character search speed was shown in Fig. 1.

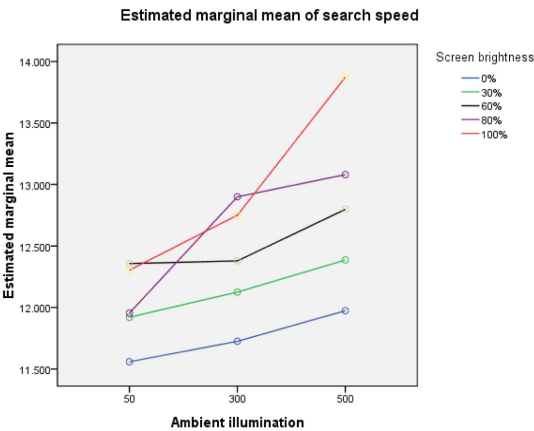


Fig. 1. Estimated marginal mean of average character search speed

As shown in the figure, when the screen brightness was 0%, the average search speed of the subjects was significantly lower than that of other screen brightness levels. When the screen brightness was 100%, the average search speed of the subjects was significantly higher than that of other screen brightness levels. The average search

speed increased with the increase of screen brightness. Among them, when the ambient illumination were 50 lx, 300 lx and 500 lx, the optimal level of screen brightness were about 60%, 80% and 100% respectively.

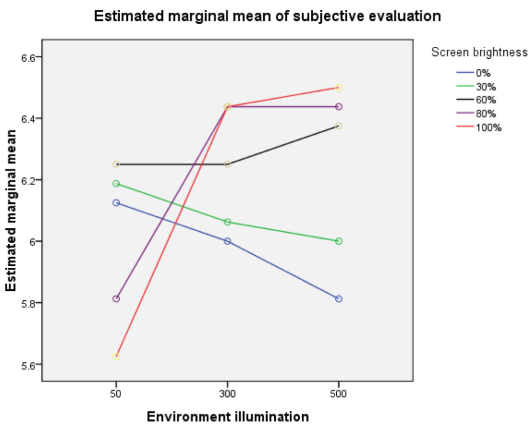
**Average Subjective Evaluation**

In order to analyze whether different ambient illuminations, screen brightness and their interactions have significant impact on the subjective evaluation of the comfort level of the subjects, the average subjective evaluation score of the subjects was calculated, as shown in Table 4.

**Table 4.** Subjective evaluation

	0%	30%	60%	80%	100%
50 lx	6.125	6.313	6.250	5.813	5.625
300 lx	6.000	6.125	6.250	6.438	6.438
500 lx	5.875	6.000	6.375	6.500	6.500

The results of repeated measurement anova showed that the main effect of environmental illumination on subjective evaluation was not significant,  $F(2, 45) = 0.372$ ,  $p > 0.05$ . The main effect of screen brightness on subjective evaluation was not significant,  $F(4,180) = 0.857$ ,  $p > 0.05$ . The interaction between ambient illumination and screen brightness was significant,  $F(2, 45) = 4.631$ ,  $p < 0.05$ . The interaction was shown in Fig. 2.



**Fig. 2.** Marginal estimated mean value of subjective evaluation

As shown in the figure, when the environmental illumination was 50 lx, the optimal screen brightness level was 60%, at which time the subjective evaluation of the subjects was the highest, and the subjective evaluation was the lowest at 100%. When the ambient illumination was 300 lx, the optimal screen brightness level was 80%, which was the highest subjective evaluation and the lowest at 0%, and the value was higher

than the maximum subjective evaluation when the ambient illumination was 50 lx. When the environmental illumination was 500 lx, the optimal screen brightness level was 100%, which was the highest subjective evaluation and the lowest at 0%, and the value exceeds the maximum subjective evaluation when the environmental illumination was 300 lx. Therefore, the optimal screen brightness level increases with the increase of the environmental illumination.

Difference of Mean Flash Fusion Frequency Before and After

Physiological evaluation index refers to the difference before and after the flash fusion frequency of the subjects. Therefore, this section analyzes whether different screen brightness and their interactions have significant influence on the difference before and after the flash fusion frequency of the subjects under different ambient illuminations. First, it sorts out and calculates the difference before and after the average flash fusion frequency of the subjects, as shown in Table 5.

Table 5. Difference before and after flash fusion frequency (Hz)

	0%	30%	60%	80%	100%
50 lx	0.619	0.613	0.550	0.638	0.669
300 lx	0.562	0.488	0.513	0.438	0.450
500 lx	0.588	0.469	0.375	0.444	0.438

The results of repeated measurement anova showed that the main effect of ambient illumination on the difference between before and after the flash fusion frequency was not significant,  $F(2, 45) = 0.901, p > 0.05$ . The main effect of screen brightness on the difference between before and after the flash fusion frequency was not significant,  $F(4,180) = 0.142, p > 0.05$ . The interaction between ambient illumination and screen brightness was also insignificant,  $F(8,180) = 0.106, p > 0.05$ . The results were shown in Fig. 3.

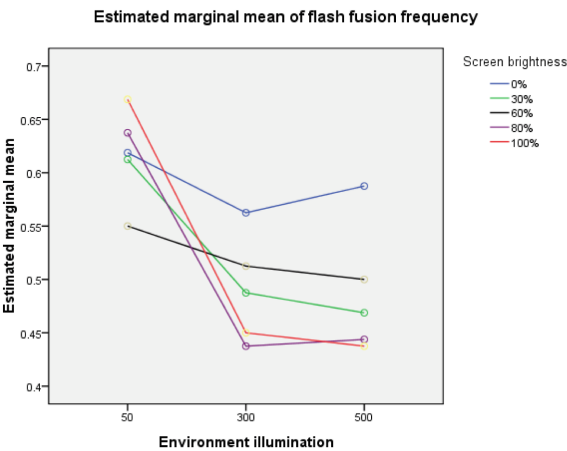


Fig. 3. Marginal estimated mean value of difference before and after flash fusion frequency



As shown in the figure, when the ambient illumination was 50 lx, the optimal screen brightness level was 60%, and the difference between before and after the flash fusion frequency was the lowest, which means the visual comfort of the subjects was the highest. When the ambient illumination was 300 lx, the optimal screen brightness level was 80%, which was obviously lower than the difference before and after the flash fusion frequency when the ambient illumination was 50 lx, which means the visual comfort of the subjects was higher than the optimal visual comfort level when the ambient illumination was 50 lx. When the ambient illumination was 500 lx, the optimal screen brightness level was 100%, slightly higher than the data when the ambient illumination was 300 lx, significantly lower than data when the ambient illumination was 50 lx. And the optimal visual comfort of the subjects was between 50 lx and 300 lx.

### 3.2 Analysis of Each Parameter Under Different Brightness and Contrast

#### Average Character Search Speed

Univariate anova for the average character search speed showed that brightness contrast has no significant influence on the overall average character search speed. In the analysis results,  $F(2, 14) = 3.396$ ,  $p > 0.05$ .

However, the post-mortem test results showed that there was a significant difference in the average character search speed between the brightness of 26–30 and 32–36,  $p < 0.05$ . The average character search speed in the brightness contrast 26–30 was significantly higher than data in the brightness contrast range of 32–36, slightly higher than the average character search speed in the brightness contrast range of 44–47, which was the optimal brightness contrast range.

#### Average Subjective Evaluation

The results of one-way anova with mean subjective evaluation score as the dependent variable showed that brightness contrast had no significant influence on the overall mean subjective evaluation,  $F(2, 14) = 3.194$ ,  $p > 0.05$ .

However, the post-test results showed that the mean subjective evaluation of brightness contrast between 26–30 and 44–47 was significantly different,  $p < 0.05$ . The average subjective evaluation score of subjects with brightness contrast between 26–30 was significantly higher than that of subjects with brightness contrast between 44–47 and slightly higher than that of subjects with brightness contrast between 32–36, which was the optimal brightness contrast range.

#### Difference of Mean Flash Fusion Frequency Before and After

Univariate anova for the difference before and after the mean flash fusion frequency as the dependent variable showed that the brightness contrast had a significant effect on the mean flash fusion frequency. In the analysis results,  $F(2, 14) = 7.693$ ,  $p < 0.05$ .

The post-test results showed that the difference before and after the average flash fusion frequency when the brightness contrast was 26–30 was significantly smaller than the data when the brightness contrast was 32–36 and 44–47. At this time, the visual comfort of the subjects was the highest, which was the optimal brightness contrast range.

## 4 Conclusion

To sum up, for office LED displays when the ambient illumination was 50 lx, the optimal screen brightness level was 60% and the screen brightness was around 128 cd/m<sup>2</sup>. At this time, the average character search speed of people was the fastest, the subjective evaluation score was the highest, and the difference value before and after the flash fusion frequency was the smallest. When the ambient illumination was 300 lx, the optimal screen brightness level was 80%, and the screen brightness was around 178 cd/m<sup>2</sup>. Comparing with 50 lx, the average character search speed was faster, the subjective evaluation score was higher, and the difference before and after the flash fusion frequency was smaller. When the ambient illumination was 500 lx, the optimal screen brightness level was 100%, and the screen brightness was around 214 cd/m<sup>2</sup>. Comparing with 300 lx, the average character search speed was faster and the subjective evaluation score was higher, but the difference value before and after the flash fusion frequency increases slightly.

The brightness contrast range of 26–30 was the optimal brightness and contrast range for office LED displays. In this range, the average character search speed was the fastest and the average subjective evaluation score was the highest, the difference before and after the average flash fusion frequency was the smallest.

**Acknowledgments.** This research is supported by university graduates project in Beijing (2018) and National Key R&D Program of China (2016YFB0401203).

## References

1. Li, H., Zhang, Y., Xu, W., Zhang, L.: Research of optimal parameters of phone screen brightness under different environmental illuminance - take samsung S5660 for example. *J. Psychol. Sci.* **36**(5), 1110–1116 (2013)
2. Fang, W., Guo, B., Zhang, J.: Effect of parameters adjustment of the locomotive LCD on vision efficacy. *J. Railway* **25**, 40–44 (2013)
3. Zhang, Z., Zhu, Z.: Effects of VDT screen brightness and document background illumination on visual core reading. *Psychol. Sci.* **24**(1), 26–28 (2001)
4. Wu, J., Zhu, Z.: Relationship between VDT performance and luminance contrast at different levels of background luminance on screen. *Chin. J. Appl. Psychol.* **3**(1), 17–22 (1988)
5. Lin, C.C.: Effects of screen luminance combination and text-color on visual performance with TFT-LCD. *Int. J. Ind. Ergon.* **35**, 229–235 (2005)
6. Lin, C.C., Huang, K.C.: Effects of ambient illumination and screen luminance combination on character identification performance of desktop TFT-LCD monitors. *Int. J. Ind. Ergon.* **36**, 211–218 (2006)



# Study on the Effect of Key-to-Key Distance on Touch-Sensitive Key Operation

Xiaoli Fan<sup>1,2</sup>, Huimin Hu<sup>1,2(✉)</sup>, Chaoyi Zhao<sup>1,2</sup>, and Wei Zhang<sup>3</sup>

<sup>1</sup> SAMR Key Laboratory of Human Factors and Ergonomics, Beijing 100191, China

<sup>2</sup> China National Institute of Standardization, Beijing 100191, China  
{fanxl, huhm, zhaochy}@cnis.gov.cn

<sup>3</sup> Tsinghua University, Beijing 100084, China  
zhangwei@tsinghua.edu.cn

**Abstract.** The current study investigated the key-to-key distance, which was defined as the distance between the margin points of two adjacent keys transversally and vertically. In view of forefinger operation, the combination of subjective measurement and objective measurement was used in the ergonomics assessment of key-to-key distance effects on the performance. 30 participants are recruited to attend the tests. One-way ANOVA is used to analyze operational performance at different key-to-key distance and then the S-N-K-hoc is conducted for pairwise comparison,  $\alpha = 0.05$ . The results were obtained: when a reasonable key size is decided, key-to-key distance has no effect on the accuracy and efficiency of touch-sensitive key operation. Therefore, considering the user experience satisfaction, the recommended transverse key-to-key distances range for rounded corner key is from 6 mm to 12 mm, while lengthways key-to-key distances range is from 6 mm to 14 mm; the recommended transverse key-to-key distances range for round key is from 6 mm to 12 mm, while lengthways key-to-key distances range is from 6 mm to 16 mm. This research can provide a basis for the design of key size of enterprise electronic products, and has important guiding significance.

**Keywords:** Touch-sensitive key · Key-to-key distance · Human-computer interaction

## 1 Introduction

There are many types of input devices that perform operations in the computing system at present, such as mouse, trackball, mechanical operation key, joystick, touch sensor panel, touch screen and so on [1]. Touch screen is what touched is gained with convenient operation, convenient size adjustment, flexible arrangement and other characteristics, which brings convenience for the man-machine interface optimization matching of all kinds of display and control terminals. The touch screen mainly includes: resistive touch screen, capacitive touch screen and acoustic touch screen, among which capacitive touch screen is the most widely used. With the continuous development and popularity of the Internet and smart phones, capacitive touch screen mobile phones have shown a trend of replacing traditional computers in many fields

such as social networking, shopping, etc., and more applications have been transferred from computers to mobile phones [2]. With the appearance of capacitive touch screen LCD, the human-computer interaction mode in aerospace field has been changed. The task of multi-function touch screen display in aircraft cockpit is becoming more and more complex and diverse. At the same time, capacitive touch screen, as one of the most convenient way of human-computer interaction, is more and more used in the research and development of many intelligent household appliances. There are more and more functions carried by touch screen. The contradiction between rich content and space inevitably leads to new problems of human-computer interaction, such as unreasonable layout of information, mis-touch during operation, low input efficiency and so on [3]. Therefore, it is very important to design the touch screen interface that meets the ergonomic requirements.

In the touch screen, the touch-sensitive key is the device that can transmit the human instruction to the machine and let the machine according to the predetermined target of the human. Whether its design is reasonable or not will directly affect the working efficiency, the safe operation and the comfort of the user. At present, there has been a lot of research on interactive issues such as the impact factors of click operation performance in touch screen. The operation efficiency of touch-sensitive key is affected by many factors, such as key size, key-to-key distance, layout position, movement distance and so on [4]. Parhi et al. [5] had done a systematic study on the optimal target size of touch-sensitive key under one-handed thumb operation in mobile handheld devices. The results showed that the task completion time decreased with the increase of target size, when the target is larger than a certain size (The key size of discrete click operation is 9.6 mm. The key size of continuous click operation is 7.7 mm.), there is no significant difference in click-operation error rate between five target dimensions from small to large. Park and Han [6] studied the effect of key size on one-handed thumb input operation. The results showed that the operation completion time was the shortest at 7 mm and 10 mm key size, while the operation error was the least and the subjective satisfaction was the highest when the key size was 10 mm. Bald-win and Chai [7] explored the feasibility of online adaptive scaling algorithm for key target size, which was different from the above two fixed button-size studies. The results showed that the error rate of click operation could be reduced by 10.4% comparing with the standard key size. ISO9241-9 recommended key sizes equal to at least 95% of the male index finger width at 22.8 mm [8]. In the research of Ye et al. [9], experiment and research were carried out from the aspects of the size and layout of the key plan based on ergonomics principle., with aiming at the design problem of the key type of the mobile phone operated by one hand. The results showed that the larger key was better when the keyboard area was limited and there was no key-to-key distance. The keyboard layout with shorter key width and slight key distance could save the operation time.

Another important design parameter to be considered in the study of key size is key-to-key distance. The distance between two adjacent key edges, as usually indicated by key-to-key distance. Jin et al. [10] showed that old people could obtain the highest input accuracy under the 19.05 mm key size and the 6.35 mm key-to-key distance, while the larger key-to-key distance resulted in a longer response time for the elderly. The research of Wenlin Zhang [11] showed that the effect of key-to-key distance on the operation performance was affected by the key size. When the size was smaller than

6 mm, we should reduce the key-to-key distance as much as possible to improve the operation correctness. On the contrary, relaxed the key-to-key distance as much as possible. Although these characters provide a lot of empirical information, there is no uniform standard for the design of touch screen key-to-key distance, which may indicate that further research is needed to determine the key-to-key distance in a specific situation.

Most of the studies on the effect of key-to-key distance on the performance, accuracy and satisfaction of the whole interaction come from the West currently, but there are few related studies in China. Because there are significant differences in key anthropometric dimensions (such as finger length and width) between Chinese and Western populations in touch screen input, the research results from the West may not be applied to China and the user population. In addition, key shapes can have a significant impact on the usability of touchscreen input operations. This is because different key shapes may affect the touchable area of the key and the user's touch experience, a factor that has rarely received previous attention. This research mainly takes our country user as the research object, simulates the concrete situation which uses the touch cabinet type air conditioning under the family environment, and investigates the effect of the distance between touch-sensitive keys with different shapes on the performance of input operation and user satisfaction to provide reference for the development of touch screens that meet the needs of users and can be easily used.

## 2 Method

### 2.1 Subjects

30 Chinese adults, aged between 22 and 50, with the ratio of men to women 1:1, took part in the experiment. All subjects' visual acuity or corrected visual acuity were above 1.0, and all of them were right-handedness, with no psychological, mental and other cognitive disorders. The subjects were volunteer to take part in the experiment and filled in the informed consent form. After the experiment was completed, they are paid a certain amount of money. All subjects had touch screen using experience, but had not been exposed to similar tasks as in this experiment.

### 2.2 Task Design

**Experimental Software.** Considering the type of touch keys and requirements for key-to-key distance design, the software of touch-sensitive key operation was programmed by C # on Net Framework platform in the study. The key shape, size, and key-to-key distance could be set according to the experimental design. Key styles including font type, size, font color and background color can also be set according to the actual situation. Figure 1 presented the main interface for the task, mainly including the task displaying area and the key operation area. The displaying area would present three randomly generated numbers at regular intervals. The operating area consisted of 9 numeric keys from 1 to 9. The keys were laid according to the parameters that had

been set. After the task was presented, the subject should be as fast and accurate as possible to input the corresponding digital information with the digital key of the operation area. Then the next trial began until the task was finished.

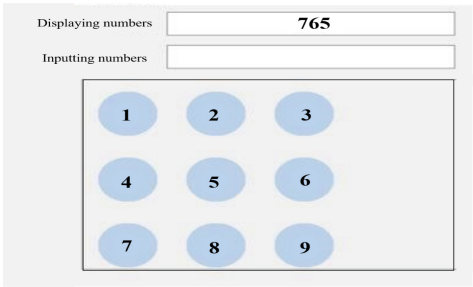


Fig. 1. Task presentation interface

**Experimental Produce.** The experiment adopted the method of within-group design. The key size was 15 mm fixed which was in the range of operating comfort by reference and pre-experiment. Then two groups of experiments were carried out,

- (1) Lengthways key-to-key distance was set as 12 mm. Transverse key-to-key distance was a with-in-group factor. Selecting 12 levels (17 mm, 19 mm, 21 mm, ..., 39 mm) for numeric input task. There were 12 tasks, each including 20 trials.
- (2) Transverse key-to-key distance was set as 12 mm. Lengthways key-to-key distance was a with-in-group factor. Selecting 12 levels (17 mm, 19 mm, 21 mm, ..., 39 mm) for numeric input task. There were 12 tasks, each including 20 trials.

In order to avoid the effect of the fatigue effect on the results of the experiment, in the course of performing the above 24 tasks, the subjects were required to perform 4 tasks and then rested for 5 min. After each task was finished, the subjects were asked to give a satisfaction rating for the operation under the corresponding key-to-key distance. The subjective rating scale was shown in Fig. 2. It was divided into five levels, 1 to 5 pointed correspondingly to most unsatisfactory, more unsatisfactory, general, more satisfactory, and most satisfactory respectively. After each task, the software automatically recorded the error rate and average response time of each task.

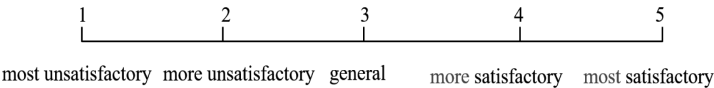


Fig. 2. Subjective rating scale

The experiment was arranged in a relatively quiet environment. Before testing, the actual use of air conditioning touch-sensitive keys should be considered. The final determination of the experimental test posture was a standing posture test. The touch

screen was placed upright. The touch screen laptop was placed on the lift Table. Subjects could adjust their height on the basis of comfort.

### 2.3 Statistical Method

The results of behavioral performance of touch-sensitive key manipulation tasks in 30 subjects with different parameters were collected. At the same time, we also recorded the satisfaction rating of the variables after each operation. Firstly, we used Matlab programming to realize the fast collection and arrangement of reaction time and error rate in the original Table of software record. Then the data was analyzed by using the statistical software SPSS 19.0. One-way ANOVA was used to analyze the performance data (reaction time and error rate) of touch-sensitive keys with different shapes under different transverse and lengthways key-to-key distances in the study. Then S-N-K post hoc test was used to carry on the pairwise comparison. All significant levels were  $\alpha = 0.05$ .

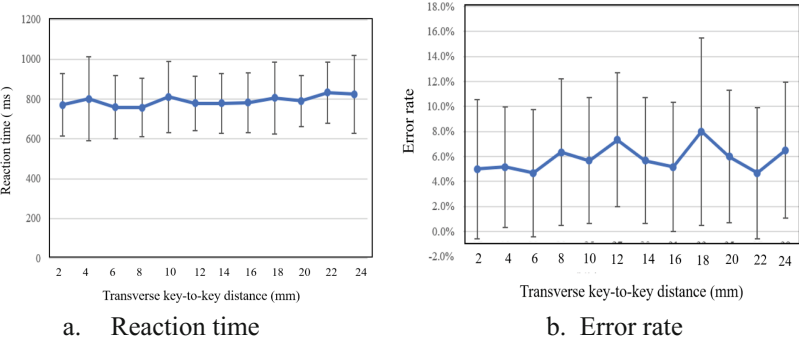
## 3 Result

### 3.1 Rounded Corner Touch-Sensitive Keys

**Results and Analysis of Operation Under Different Transverse Key-to-Key Distances.** Figure 3 showed the changing trend of task performance with transverse key-to-key distances for rounded corner touch-sensitive keys. It can be seen that with the increase of transverse key-to-key distances, the average reaction time and error rate were stable, and there was no obvious variation tendency. One-Way ANOVA was used to study the reaction time and error rate of keys at different transverse key-to-key distances. The results were shown in Tables 1 and 2 respectively. All of them were in  $P > 0.05$ , that was, the main effect of transverse key-to-key distance was not significant. It could be inferred that when the size of the touch-sensitive keys was selected properly, the selection of the transverse key-to-key distance of the keys had little effect on the efficiency and accuracy of the operation of the touch-sensitive keys.

Figure 4 showed the curve of the subjective satisfaction scores varying with the transverse key-to-key distances of the rounded square touch-sensitive keys. It could be seen from the diagram that the subjective satisfaction increased firstly and then decreased with the increase of transverse distance.

In summary, when the size of the touch keys was selected properly, the transverse key-to-key distances of the rounded corner touch-sensitive keys had no effect on the efficiency and accuracy of the task operation. Subjective satisfaction of users was dominant. It could be inferred that the moderate transverse key-to-key distances played an important role in the aesthetics of the key layout, resulting in an inflection point in the trend of the users' satisfaction. Satisfaction score  $> 3.5$  was selected. It was recommended that the transverse key-to-key distance range of rounded corner keys was set between 6–12 mm.



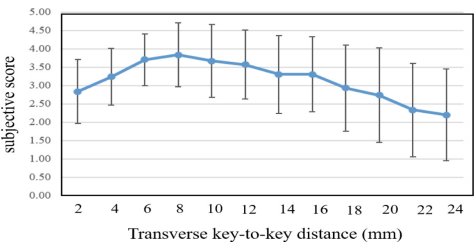
**Fig. 3.** Behavior performance with different transverse key-to-key distances

**Table 1.** One-way ANOVA results of reaction time with different transverse key-to-key distances

	Sum of squares	df	Mean square	F	Sig.
Between group	194307.389	11	17664.308	.657	.779
Within group	9361079.933	348	26899.655		
Total	9555387.322	359			

**Table 2.** One-way ANOVA results of error rate with different transverse key-to-key distances

	Sum of squares	df	Mean square	F	Sig.
Between group	.036	11	.003	1.086	.371
Within group	1.051	348	.003		
Total	1.087	359			

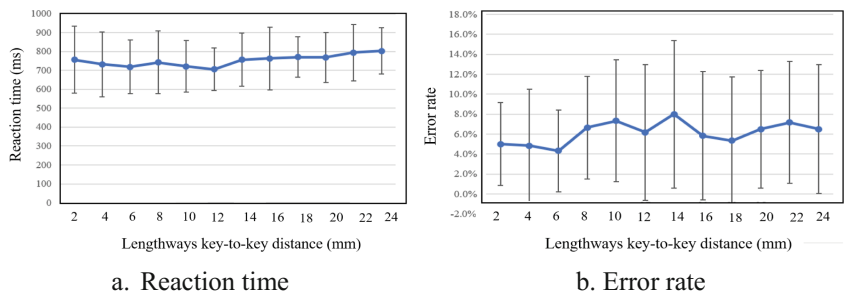


**Fig. 4.** Subjective satisfaction scores with different transverse key-to-key distances

**Results and Analysis of Operation Under Different Lengthways Key-to-Key Distances.** Figure 5 showed the trend of task performance with lengthways key-to-key distance for rounded corner touch-sensitive keys. It could be seen that the average reaction time and error rate were stable with the increase of longitudinal distance, and



there was no obvious variation tendency. One-way ANOVA was used to study the reaction time and error rate of keys at different lengthways key-to-key distance. The results were shown in Tables 3 and 4. All of them were in  $P > 0.05$ , that was, the main effect of lengthways key-to-key distance was not significant. It could be inferred that when the size and size of the touch-sensitive key was suitable, the selection of the longitudinal distance of the key had no effect on the efficiency and accuracy of the touch-sensitive key operation.



**Fig. 5.** Behavior performance with different lengthways key-to-key distances

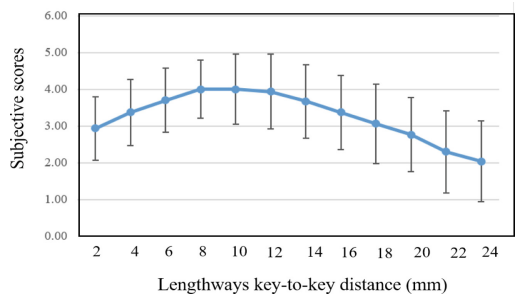
**Table 3.** One-way ANOVA results of reaction time with different lengthways key-to-key distances

	Sum of squares	df	Mean square	F	Sig.
Between group	291036.022	11	26457.820	1.259	.247
Within group	7313350.600	348	21015.375		
Total	7604386.622	359			

**Table 4.** One-way ANOVA results of error rate with different lengthways key-to-key distances

	Sum of squares	df	Mean square	F	Sig.
Between group	.040	11	.004	1.034	.415
Within group	1.238	348	.004		
Total	1.278	359			

Figure 6 showed the curve of the subjective satisfaction scores along with the lengthways key-to-key distance of the rounded corner touch-sensitive keys. It could be seen from the diagram that the subjective satisfaction score increased firstly and then decreased with the increase of lengthways key-to-key distances.

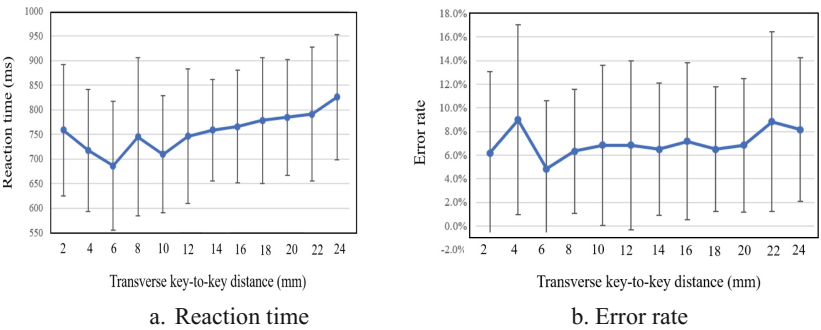


**Fig. 6.** Subjective satisfaction scores with different lengthways key-to-key distances

In summary, when the size of the touch-sensitive keys was selected properly, the lengthways key-to-key distance of the rounded corner touch-sensitive keys had no effect on the efficiency and accuracy of the task operation. Therefore, the subjective satisfaction of the users was dominant, and it could be inferred that moderate lengthways key-to-key distance played an important role in the beauty of the key layout. As a result, there was an inflection point in the variation tendency of user satisfaction. satisfaction scores of more than 3.5 were chose. It was suggested that the lengthways key-to-key distance range of rounded corner keys was 6–14 mm.

**3.2 Round Touch-Sensitive Keys**

**Results and Analysis of Operation Under Different Transverse Key-to-Key Distances.** Figure 7 showed the changing trend of task performance with transverse key-to-key distances for round touch-sensitive keys. One-way ANOVA was used to study the performance of key operation under different transverse key-to-key distances. The results were shown in Tables 5 and 6. For reaction time, the main effect of transverse key-to-key distances was obvious ( $F = 2.788$ ,  $P < 0.05$ ). Further pairwise comparison by S-N-K-hoc test showed that there was a significant difference between the transverse



**Fig. 7.** Behavior performance with different transverse key-to-key distances

**Table 5.** One-way ANOVA results of reaction time with different transverse key-to-key distances

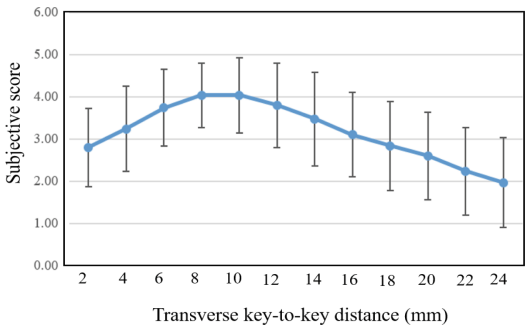
	Sum of squares	df	Mean square	F	Sig.
Between group	505557.164	11	45959.742	2.788	.002
Within group	5737563.700	348	16487.252		
Total	6243120.864	359			

**Table 6.** One-way ANOVA results of error rate with different transverse key-to-key distances

	Sum of squares	df	Mean square	F	Sig.
Between group	.045	11	.004	.992	.453
Within group	1.451	348	.004		
Total	1.496	359			

key-to-key distances of 39 mm and other distances. The rest were in a subset with no significant differences. The main effect on the transverse key-to-key distances of the error rate was not significant ( $F = 0.992$ ,  $P > 0.05$ ). Therefore, it could be inferred that when the size of the touch-sensitive keys was selected properly, the selection of the transverse key-to-key distances of the keys had no effect on the efficiency and accuracy of the operation of the touch-sensitive keys.

Figure 8 showed the curve of the subjective satisfaction scores varying with the transverse key-to-key distances of the round touch-sensitive keys. It could be seen from the diagram that the subjective satisfaction increased firstly and then decreased with the increase of transverse distances.

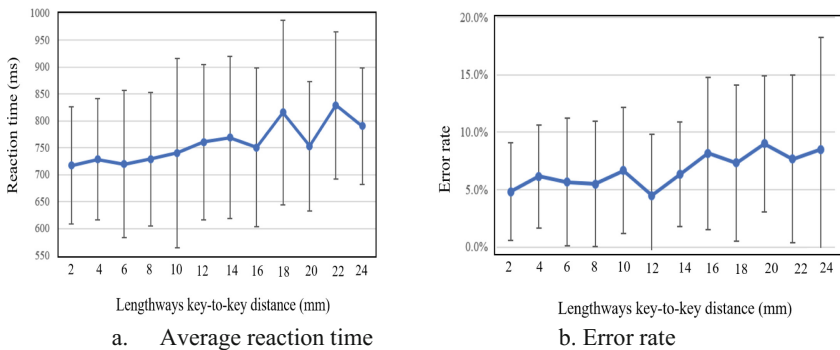


**Fig. 8.** Subjective satisfaction scores with different transverse key-to-key distances

Based on the above analysis, when the size of the touch-sensitive keys were selected properly, the transverse key-to-key distances of the round touch-sensitive keys had no effect on the efficiency and accuracy of the task operation. The subjective satisfaction of the users was dominant, and it could be inferred that moderate transverse key-to-key distances played an important role in the beauty of the key layout.

Therefore, there was an inflection point in the trend of users' satisfaction. scores of more than 3.5 was chose for satisfaction. It was suggested that the transverse key-to-key distance range of round keys should be 6–12 mm.

**Results and Analysis of Operation Under Different Lengthways Key-to-Key Distances.** Figure 9 showed the trend of task performance with lengthways key-to-key distance for round touch-sensitive keys. One-way ANOVA was used to study the performance of key operation under different lengthways key-to-key distance. The results were shown in Tables 7 and 8. For the average reaction time, the main effect of lengthways key-to-key distance was significant ( $F = 2.116$ ,  $P < 0.05$ ). Further pairwise comparison by S-N-K-hoc test showed that the reaction time of keys with different lengthways key-to-key distance was distributed in the same subset, that was, there was no significant difference between them. The main effect on the lengthways key-to-key distance of the operating error rate was not significant ( $F = 1.69$ ,  $P > 0.05$ ). It could be inferred that the selection of the lengthways key-to-key distance had no effect on the efficiency and accuracy of the touch-sensitive key operation when the size of the touch-sensitive key was suitable.



**Fig. 9.** Behavior performance with different lengthways key-to-key distances

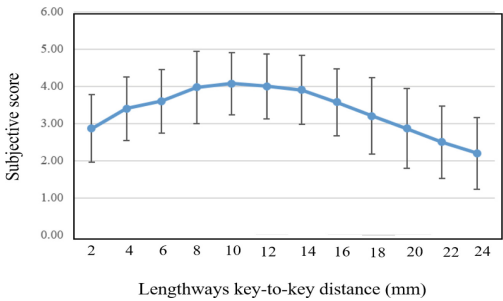
**Table 7.** One-way ANOVA results of reaction time with different lengthways key-to-key distances

	Sum of squares	df	Mean square	F	Sig.
Between group	443929.964	11	26457.820	1.259	.247
Within group	6638447.900	348	21015.375		
Total	7082377.864	359			

**Table 8.** One-way ANOVA results of error rate with different lengthways key-to-key distances

	Sum of squares	df	Mean square	F	Sig.
Between group	.070	11	.006	1.690	.074
Within group	1.307	348	.004		
Total	1.377	359			

Figure 10 showed the curve of the subjective satisfaction scores along with the lengthways key-to-key distances of the round touch-sensitive keys. It could be seen from the diagram that the subjective satisfaction scores increased firstly and then decreased with the increase of lengthways key-to-key distance.



**Fig. 10.** Subjective satisfaction scores with different lengthways key-to-key distances

In summary, the lengthways key-to-key distance of the round touch-sensitive keys had no effect on the efficiency and accuracy of the task operation when the size the touch-sensitive keys was selected properly. Therefore, the subjective satisfaction of the users was dominant, and it could be inferred that moderate lengthways key-to-key distance played an important role in the beauty of the key layout. Therefore, there was an inflection point in the trend of users’ satisfaction.

4 Discussion

The distance layout of touch-sensitive keys was studied by combining subjective and objective methods in the study, and the recommended range of transverse and lengthways key-to-key distance of touch-sensitive keys with different shapes is obtained. In this way, the touch-sensitive key layout design of household appliances electronic products represented by vertical air conditioning can avoid the complicated interface caused by unreasonable key-to-key distance design, and ensure the simplicity and efficiency of interface design. In addition, different shapes of touch-sensitive keys are studied, the results are more accurate and comprehensive. When the size of the touch-sensitive keys is appropriate, the size of the transverse and lengthways key-to-key distance of the keys has little effect on the performance of the key operation. But this does not mean that the key-to-key distance can be designed at will, because the subjective perception of different key-to-key distance is not always at the best level. According to the subjective evaluation results of different key-to-key distance, the subjective satisfaction degree of keys increases firstly and then decreases with the increase of key-to-key distance, that is, they belong to a non-positive correlation trend, which is different from the previous conclusions [11, 14]. Therefore, in the actual design of touch-sensitive key-to-key distance, we should not only consider the performance of the operation of the key-to-key distance in the corresponding task situation, but also take into account the subjective experience of the users at the same time.

## 5 Conclusion

In summary, the method of subjective and objective combination is used to explore the distance between touch-sensitive keys. On the basis of fully ensuring the efficiency and accuracy of the key operation, and taking into account the satisfaction of the user experience, the final result is obtained: when the size of the touch-sensitive keys is appropriate, the size of the transverse and lengthways key-to-key distance of the keys has little effect on the performance of the key operation. Therefore, the main consideration is the subjective satisfaction of the users.

For rounded corner touch-sensitive keys, the recommended range of transverse key-to-key distance is 6 mm–12 mm, meanwhile lengthways key-to-key distance range is 6 mm–14 mm. For round touch-sensitive keys, the recommended range of transverse key-to-key distance is 6 mm–12 mm, meanwhile lengthways key-to-key distance range is 6 mm–16 mm.

**Acknowledgments.** This research was supported by 2017NQI project (2017YFF0206603), General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ) science and technology planning project (2016QK177) and Project of the President's Fund for China National Institute of Standardization (522018Y-5984; 522016Y-4488).

## References

1. Yuishi, K.: Touch Screen Technology and Application. Mechanical Industry Publishing House (2014)
2. Qijun, W., Jin, H., Danxin, L.: A new soft key design parameter for mobile phone touch-screen-the shortest central key-to-key distance. *Chin. J. Ergon.* **23**(2), 1–4 (2017)
3. Haiyan, W.: Interaction Design Research of Touch-Screen Mobile Phone in Mobile Environment. Beijing University of Posts and Telecommunications (2012)
4. Weimin, M.: Ergonomics experimental study on the dimensions, azimuth and spacing of the keys around the cockpit display. *Chin. J. Ergon.* **3**(4), 10–12 (1997)
5. Parhi, P., Karlson A., Bederson, B.: Target size study for one-handed thumb use on small touchscreen devices. In: Proceedings of the 8th Conference on Human-Computer Interaction with Mobile Devices and Services, pp. 203–210. ACM, New York (2006)
6. Park, Y.S., Han, S.: Touch key design for one-handed thumb interaction with a mobile phone: effects of touch key location. *Int. J. Ind. Ergon.* **40**(1), 68–76 (2010)
7. Baldwin, T., Chai, J.: Towards online adaptation and personalization of key-target resizing for mobile devices. In: The 2012 ATM International Conference, Istanbul, Turkey, pp. 34–39 (2012)
8. ISO 9241-9, Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)-Part9: Requirements for Non-keyboard Input Devices, International-Organization for Standardization (2000)
9. Ye, D., Weining, F., Beiyuan, G., Hao, L.: Key design of mobile phone based on ergonomics. In: 2006 International Conference on Industrial Design, Hangzhou, China, pp. 529–533 (2006)

10. Jin, Z., Plocher, T., Kiff, L.: Touch screen user interfaces for older adults: key size and spacing. In: Conference on Universal Access in Human-Computer Interaction, Beijing, China, pp. 933–941 (2007)
11. Parhi, P., Karlson, A., Bederson, B.: Target size study for one-handed thumb use on small touchscreen devices. In: The 8th Conference on Human-Computer Interaction with Mobile Devices and Services, pp. 203–210. ACM, New York (2006)
12. Park, Y.S., Han, S.H.: Touch key design for one-handed thumb interaction with a mobile phone: effects of touch key size and touch key location. *Int. J. Ind. Ergon.* **40**(1), 68–76 (2010)
13. Hwangbo, H., Yoon, S.H., Jin, B.: A study of pointing performance of elderly users on smartphones. *Int. J. Hum.-Comput. Interact.* **29**(9), 604–618 (2013)
14. Park, J., Han, K.H.: Effect of target size and duration of visual feedback on touch screen. In: HCI International, Berlin, Germany, pp. 252–256 (2011)



# Research on Standardization of Public Information Guidance Systems for Railway Stations

Chuan-yu Zou<sup>1(✉)</sup>, Yongquan Chen<sup>2(✉)</sup>, and Ziding Chen<sup>3</sup>

<sup>1</sup> LHFE Key Laboratory of Human Factors and Ergonomics (CNIS),  
Beijing, China

<sup>2</sup> Research Centre of Way Guidance, China National Institute  
of Standardization, Beijing, China  
{zouchy, chen Yongquan}@cnis.gov.cn

<sup>3</sup> Department of Transportation Supervision and Administration,  
National Railway Administration, Beijing, China

**Abstract.** Public information guidance system plays an increasingly important role in the normal operation of railway passenger stations. National Graphical Symbol Standardization Technical Committee has investigated the public information guidance systems of 57 representative railway passenger stations. Nearly 290 main problems are summarized from standardization of guiding elements' design, systemic degree of factor setting, coordination of guidance system planning and architectural design, which provides reference for further optimizing and improving the public information guidance system of railway passenger stations.

**Keywords:** Railway passenger station · Public information guidance system · Wayfinding system

## 1 Introduction

Till the end of 2017, China's railway operating mileage reached 127,000 km, an increase of 2.4% over the previous year. Among them, the high-speed railway operating mileage reached 25,000 km. The national railway network density reached 132.2 km/10,000 km<sup>2</sup>, an increase of 3.0 km/10,000 km<sup>2</sup> compared with the previous year. The number of railway passengers sent was 3.084 billion, an increase of 270 million over the previous year, an increase of 9.6% [1], accounting for 16.6% of the total passenger traffic in the country [2]. Railways play an increasingly important role in passenger transport. As a node of the railway network in the city, the railway passenger station usually forms an integrated transportation hub with other urban transportation systems, and is an important public transportation facility for carrying passengers. The quality and efficiency of public space of railway passenger stations determine the quality and feeling of passengers' railway travel to a certain extent, and the construction level of public information guidance system for railway passenger



stations is one of the important factors determining the efficiency of public space use of railway passenger stations.

In recent years, with the operation and rapid development of high-speed railways, a series of national standards that regulate the public information guidance system for railway passenger stations were issued, laying a foundation for improving the standardization level of railway passenger public information guidance systems, and promoting railway passengers. The public information guidance system became the “standard configuration” when the new railway passenger station was rebuilt.

During 2016–2017 National Graphic Symbol Standardization Technical Committee investigated 57 public information guidance systems in representative railway passenger stations. The purpose was to investigate the current status of railway passenger public information guidance systems and provide suggestions for managers from different railway passenger stations. Those suggestions included the theory and practice of guidance system construction, reference for further optimization. The survey summarized nearly 290 major problems of each station from three aspects, including non-standardization design of guidance elements, poor systemization setting of guidance elements, and disconnection between planning and architectural design.

## 2 Survey Plan

Based on the main technical content stipulated in the relative national standards, combined with the passengers’ demand for the public information guidance system of railway passenger stations, the project team designed a set of survey plans, and conducted survey on the status quo in three aspects: standardization of information elements, standardization of guidance elements, and standardization setting of guidance systems.

### 2.1 Standardization of Information Elements

The information element is an undividable and meaningful component which constitutes each piece of guidance information in the public information guidance system, generally including graphical symbols (including direction symbols), words and colors. The content and usage requirements of those three most basic information elements are standardized in Chinese National Standards on Public Information Guidance Systems. The survey plan includes six aspects, whether to use the graphic symbols in the national standard, whether the new design graphic symbols meet the design standard requirements, whether the color used matches color scheme requirements, whether to use the safety color and safety shape in the national standard, whether to use the standard Chinese and English, etc.

### 2.2 Standardization of Guidance Elements

The guidance elements are carriers that carry wayfinding information of public information guidance systems. It is formed by combining one or several information elements and transmits single or comprehensive wayfinding information. According to the

current national standards, the main guidance elements include: location signs, direction signs, location plans, information index signs, and block guidance map and portable prints. According to the design specifications and key points of each type of guidance elements, the survey plan has compiled survey contents for them. For example, the survey contents for location plan includes whether the design of the single-floor plan is standardized, whether the design of the multi-floor plan is standardized, and whether the location plan with a fixed setting point specifies the current position of the observer, and so on.

### 2.3 Standardization Setting of Guidance Systems

Public information guidance system is a sign system consisting of guidance elements to guide people to move orderly in public places [3]. In accordance with the current national standards, when using various types of guidance elements in combination, it is necessary to ensure it normative, systematic, conspicuous, clear, coordinated and safe [4] to ensure the standardization of the overall system.

## 3 Results and Discussion

More than 12,400 pictures were taken on the scene. And nearly 290 main problems sorted out from each station. Those problems are mainly reflected in the following four aspects, e.g. non-standardized use of information element, non-standardized design of guidance elements, poor systematized setting of guidance elements, and disconnection between guidance system planning and architectural design.

### 3.1 Non-standardized Use of Information Element

**Non-standardized Use of Graphical Symbols.** Formed with graphics, graphical symbol is a kind of visual language that information transmission is not depended on the text languages and affected by cultural background [5]. It has the advantages of easy to understand, easy to remember, beautiful and simple. So it is widely used in the public information guidance system for railway passenger stations. The non-standardized use of graphical symbols found in the survey includes: non-usage of graphical symbols, non-usage of graphical symbols in national standards, distortion of graphical symbols, etc. (See Fig. 1).

**Non-standardized Use of Chinese Language.** Standard Chinese characters are the common language in China. In the public information guidance system of railway passenger stations, Chinese is often used as the auxiliary text of graphical symbols or separately used to transmit passenger-related information. The non-standardized Chinese usage problems found in the survey are non-common Chinese words, lengthy or fuzzy Chinese expressions, and non-match auxiliary texts and graphic symbols (or information) (see Fig. 2).



Non-usage of graphical symbols



Non-usage of graphical symbols in national standards



Distortion of graphical symbols

**Fig. 1.** Non-standardized use of graphical symbols

**Non-standardized Use of English Language.** When two languages are used simultaneously in guidance elements, Chinese is preferred, and the second text should be English [6]. The survey found that the use of non-standard English (see Fig. 3) can be classified into two major categories, e.g. language errors and pragmatic failures [7]. Language errors mainly include spelling mistakes, improper use of words, and inconsistency between Chinese and English. Pragmatic errors include Chin-English and improper occasions.

### 3.2 Non-standardized Design of Guidance Element

**Non-standardized Layout.** The layout of the guiding elements plays a key role in judging the direction of the observer's travel direction and judging the information grouping relationship. The layout of various common information elements is already standardized in the national standard [6]. The survey found that due to the influence of traditional symmetry and aesthetics, the layout is not standardized (see Fig. 4), including: improper layout of direction arrow, improper relation of graphic symbols and texts.

**Missing Important Information Element.** Each type of guidance element is composed of a variety of information elements. In the survey, it is found that the missing



Non-common Chinese words



Lengthy or fuzzy Chinese expressions



Non-match auxiliary texts and graphic symbols

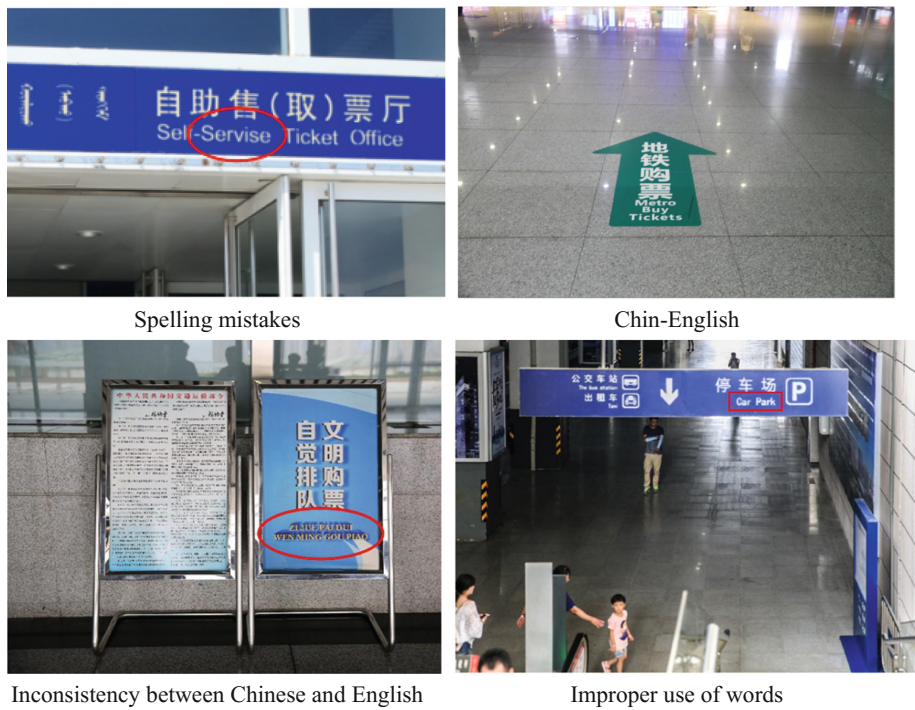
**Fig. 2.** Non-standardized use of Chinese language

important information elements problems mainly include (see Fig. 5): missing direction arrow in the direction signs, missing “observer position” in the location plan, and wrong orientation of location plan.

### 3.3 Poor Systematized Setting of Guidance Elements

**Unreasonable Configuration of Guidance Elements.** A perfect public information guidance system is composed of various guidance elements. There are five types of static guidance elements commonly used [8]: location signs, direction signs, location plans, block maps, and information index signs. Each guidance element has taken an important part in the wayfinding chain.

It is found that among the above five types of guidance elements, only two types can often be seen in the public information guidance system of railway passenger stations, which are location signs and direction signs (see Table 1), while lack of information about the space layout and function distribution of the station which provide by location plans and information index signs. Especially in key locations such as entrances (Fig. 6) and exits, stairs, elevators, escalators, etc., guidance elements are often missing, resulting in passengers unable to quickly form a “mind map” of the station space.



**Fig. 3.** Non-standardized use of English language



**Fig. 4.** Non-standardized layout

**Unreasonable Setting Guidance Elements on Key Point.** Public information guidance system of railway passenger station is composed of three interrelated subsystems such as the station front square wayfinding system, the inbound wayfinding system and the outbound wayfinding system [9]. It was found that problems often occur at places





Missing direction arrow in the direction signs



Missing "observer position" in the location plan



Wrong orientation of location plan

**Fig. 5.** Missing important information element**Table 1.** Configuration ratio of guidance elements

Type of guidance elements	Configuration ratio
Location signs	100%
Direction signs	100%
Location plans	54.5%
Block maps	13.6%
Information index signs	0%

around security inspection, ticket check, stairs, underground or overpass. The unreasonable setting of guidance elements on these nodes (see Fig. 7) greatly affects the effectiveness of passenger flow. Station managers often make up by adding new signs, but the results are unsatisfactory.

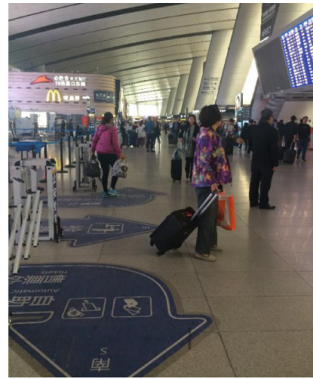
**Insufficient Coordination of Information Elements.** Coordination of information elements is mainly reflected in two aspects: the graphic symbols or characters that represent the same meaning in the same system need to be coordinated, and the design style of similar guidance elements needs to be coordinated. Due to the impact of the



**Fig. 6.** Missing information index sign



Around stairs



Around security inspection

**Fig. 7.** Unreasonable setting guidance elements on key point

maintenance and update of signs, it was found that guidance elements set at the same time had the problems like inconsistent graphic symbols or texts, and various design style (see Fig. 8).

### 3.4 Disconnection Between Guidance System Planning and Architectural Design

It was found the disconnection between construction of the railway passenger station and the planning of the public information guidance system was obvious. Sometimes, during the architectural design of the station, embedded installation points have not been pre-set. Therefore, it is difficult to install the guidance elements at the optimal location. Those elements were install based on existing conditions, which caused many problems. For example, the guidance elements are difficult to install in a position perpendicular to the passenger travel direction; the setting height of the guidance elements is too low to observe (see Fig. 9).



Fig. 8. Insufficient coordination of information elements



Fig. 9. Disconnection between guidance system planning and architectural design

## 4 Optimize Design

According to the main problems of each station, based on the requirements of national standards, representative problems were selected to carry out the optimize design of public information guidance system (see Fig. 10).





Small “Exit” location sign with 4 direction signs



Optimize design



Lots of advertisement, invisible signs at platform



Optimize design



Extra toilet information



Optimize design

Fig. 10. Optimize design

## 5 Conclusion

### 5.1 Improve Top-Level Design

Various undertaking stakeholders involved in the construction of the public information guidance system for railway passenger stations lack effective communication mechanisms in information sharing and cooperation. The various standards and norms used in planning, construction and construction process have made the coordination more difficult. The work targets and responsibilities of those stakeholders are not clear enough. Cooperation between them are not tacit, and there are phenomena such as

avoidance, delay, and unclear responsibilities, which affect the smooth progress of whole project.

## 5.2 Strengthening the Promotion and Implementation of National Standards

It is important to strengthen standardization education and improve the standard application and public information guidance system. It is necessary to organize the study and training of relevant laws and standardized knowledge relative professionals.

## 5.3 Carry Out Standardization Pilot Work

It is necessary to select important projects to carry out pilot work of guidance systems, especially those with huge passenger flow, intensive wayfinding demand and difficult guidance problems.

**Acknowledgments.** This research was supported by National Key R&D Program of China (NQI) (2016YFF0202806).

## References

1. Railway Statistics Bulletin (2017). <http://www.nra.gov.cn/xwzx/zlzx/hytj/>
2. Statistical Communiqué of the People's Republic of China on 2017 National Economic and Social Development. <http://www.stats.gov.cn/tjsj/tjgb/ndtjgb/>
3. GB/T 15565.2 Graphical symbols - Terms - Part 2: Signs and guidance system. Standardization Administration of the People's Republic of China (SAC) (2008)
4. GB/T 15566.1 Guidance systems for public information - Setting principles and requirements - Part 1: General principles. Standardization Administration of the People's Republic of China (SAC) (2007)
5. ISO 7001 Graphical symbols – Public information symbols. International Organization for Standardization (ISO) (2007)
6. GB/T 20501 Public information guidance systems—Design principles and requirements for guidance elements. Standardization Administration of the People's Republic of China (SAC) (2006)
7. Li, Z.: A survey of study in Chinese-English translation of public signs since the late of 1980s. J. Cent. South Univ. **19**(02), 237–242 (2013)
8. ISO 28564 Public information guidance systems. International Organization for Standardization (ISO) (2010)
9. GB/T 15566.3 Guidance systems for public information - Setting principles and requirements - Part 3: Railway passenger station. Standardization Administration of the People's Republic of China (SAC) (2007)



# Methodology of Analysis of Brand Visual Identity of Food Products: Comprehension and Valuation of Graphic Signs

Daniel Raposo<sup>1,2(✉)</sup>, Catarina Laginha<sup>2</sup>, João Neves<sup>1,2</sup>, José Silva<sup>1,2</sup>,  
and Fernando Moreira da Silva<sup>1</sup>

<sup>1</sup> CIAUD, Lisbon School of Architecture, Universidade de Lisboa, Rua Sá Nogueira, 1349-063 Lisbon, Portugal  
fms.fautl@gmail.com

<sup>2</sup> Polytechnic Institute of Castelo Branco, Av. Pedro Álvares Cabral, nº 12, 6000-084 Castelo Branco, Portugal  
{draposo, joaoneves, jose.silva}@ipcb.pt,  
catarinalaginha23@gmail.com

**Abstract.** This study aims to contribute to the knowledge regarding the process of decoding Brand Marks and the perception of the Visual Identity of food products. Specifically, understanding how people understand the styles and connotations of Brand Marks in a given culture. The research is based on the visual identity of Olive Oils and Cheeses with DOP certification from the interior region of Portugal. The investigative process was conducted as Project-grounded Research, using a mixed methodology. The non-interventionist methodology included the review of the literature, the study of descriptive cases and questionnaires, while the active investigation comprised a study of exploratory cases based on the redesign of the visual identity of cheeses and olive oils. The research is organized in a Study 1 (non-interventional research) and Study 2 (active or exploratory research) on 15 brands of olive oil and 15 brands of cheese. The analysis of the data is based on the levels of semiotics of Semantics and Semantics and Pragmatics (through questionnaire) of Brand Marks and labels, using tools that exam the effectiveness of the Visual Identity of the brand, which in itself is one of the results of the research, along with the Brand Marks (re)design guidelines.

**Keywords:** Brand Marks · Connotations · Graphic style · Recognition · Decoding · Comprehension · Agri-food sector

## 1 Introduction

This article refers to an investigative process on the effectiveness of the Visual Identity of food products - Olive Oils and Cheeses - and its purpose is to contribute to the knowledge about how the graphic characteristics contribute to the understanding, valorization and formation of the brand.

In most cases, the sustainability and commercial success of food products also depends on the efficiency of the Visual Identity in making known, positioning,

differentiating the brand and persuading in a given market. Even so, not only is it common to verify the use of amateur practices in the Visual Identity design of food products, as are studies on these projects are almost non-existent. Designers and entrepreneurs have been making empirical decisions about the design of the Visual Identity of food products, based on a limited knowledge of market culture, the communication of competitors, the profile and expectations of the public and without being implemented control measures or brand management.

Particularly in the scenario of the economic crisis of recent years, investment in innovation processes have focused on production, product characteristics and raw materials, contrasting with the lack of commitment to the design of communication.

However, in studies such as that of Oliveira and Alcobia [1], it is reported that the consumer unconsciously formulates a notion of value of the product (cheap, expensive, good, bad, popular, etc.) based on the visual characteristics of the signs associated with it, which is why "(...) if the consumer does not have an idea formed before entering a commercial space they can be influenced by the communication at the point of sale." The study of Oliveira and Alcobia [1] shows the importance of a communication process in this particular sectoral environment, which is crucial in promoting, projecting and positioning a product on the market.

Thus, the effectiveness of communication requires that the design process be developed based on data other than the personal taste of the designer or client, but rather on a set of information about symbolism, perception, culture and social behavior in a given context. This requirement is well expressed by Frascara [2] when they say that the meaning of the message must relate to the interests of the target audience.

Visual identity signs must be selected, designed and articulated with a purpose and in such a way that they constitute a code that corresponds to the personality of the brand in a context [3]. However, many Visual Design projects fail because of lack of brand data in their context and strategic foundation, eventually falling into misallocated formal solutions [4].

The process that we set out to investigate, of understanding and appreciation, shows the dependence that the graphic signs have of the people who give them meaning and value.

Signs make sense through the work of social interaction and gain value when they are appropriated by people, associating itself with secondary meanings, emotions, experiences, values or ideas. For this reason, it is important to study how graphic signs are drawn, communicated and perceived by the public.

The Brand Mark (logo and/or symbol) functions as a "commercial ambassador" and sign of the company, essential in the creation of the first notion of value, but also as the main element of identification and differentiation in the sales space. Over time, Brand Mark carries the secondary meanings and associations of the brand and therefore has a considerable contribution in the transmission of the values of the company, in the representation and identification of the producer or brand notion, as well as in the expression of the quality of the product that contributes to confidence and credibility that can influence purchase. However, Brand Mark must be analyzed in context of use, often on a label or packaging or in the product, where its graphic components relate to others to create a super meaning.

The communication of the brand takes place in several media more or less simultaneous and in a wide interval of time in which diverse messages and different meanings are related by the target public, giving origin to a global perception on the brand. Considering that the first contact with the brand can occur in moments, with different supports and contexts, the Visual Identity fulfills the function of impacting, guaranteeing the recognition, understanding, valuation and persuasion, implying the adoption of graphic codes and contents that agree with the culture and recipient interests [5].

Thus, this study focuses on the analysis of graphic characteristics at the level of anatomy, form, iconicity scale (from iconic representation to the abstract), the expression, color, typography and composition of the Brand Mark and on the label and primary packaging. The label in particular is a complex compound to be analyzed, because of its diversity of elements and the way they relate to each other, however, as Swann said, the effectiveness of the message depends on the correct selection of the graphic elements and the relationship among them.

The processes of analysis and redesign of Visual Identity (Brand Marks and labels in the primary packaging or product) are based on the three levels of semiotics, proposed by Charles Morris in 1946: the semantics; the syntactic and the pragmatic. Semantics refers to the study of the meaning attributed to Brand Mark (which is represented); the syntactic refers to the syntax, that is, to the rules and principles that govern the organization of signs (as represented graphically); and Pragmatics concerns the influence of the context and the culture of the recipient in assigning an overall meaning to the Brand Mark relationship with the communication medium label and packaging.

The selection of the symbolic contents to be associated to the brand (personality, culture, vision and brand values) corresponds to the level of Semantics, while the Syntactic refers to the way in which it is given, to the style and graphic expression to denote and to connote through the graphic signs (Brand Mark and other visual media). The decoding or understanding results from the interpretation of Brand Mark and other visual media, made by the recipient in a context of use, based on their culture and repertoire of experiences. Perception implies that the receiver seeks out, selects, relates, organizes, and establishes connections to understand [2].

## 2 Methodology

This research has the following research question: What graphic characteristics of the Visual Identity (IV) of Food Products, particularly Olive Oil and Cheeses, contribute better to its understanding and appreciation?

From here this hypothesis was defined: the graphic components of Brand Mark and the label condition the understanding and valorization (pragmatic). It is not only about what is represented (semantics), but also about how it is designed, correlated and used visually (syntactically).

The investigative process is divided into two studies. Study 1 corresponds to the non-interventionist research on Brand Marks in the market, while Study 2 refers to Active Interventional Research concerning the redesign and analysis of Brand Marks.

During the noninterventionist phase, a review of the literature was carried out and the research, collection and analysis of thirty Brand Marks and respective labels of Olive Oils and Cheeses from the Central Region of Portugal were carried out. Subsequently, the Brand Marks were analyzed visually for the variables under study and the analysis of their graphic characteristics: shape anatomy, scale of iconicity (from real to abstract), expression, color, typography, composition (symbol, logo, signature). In the same phase, questionnaires were carried out with olive oil and cheese consumers living in mainland Portugal, most of the central region of Portugal (NUTSII), then the Algarve, aged 18–25, 26–35, 36–45, 46–56, 57–65, >66. This first questionnaire aimed to obtain results on the Visual Identity of 15 olive oil brands and the Visual Identity of 15 brands of cheese, available in the market, allowing for the detection of common denominators that contribute to the understanding and type of valuation. Study 1 allowed us to consolidate and redefine the parameters and analysis processes appropriate to Brand Marks.

Study 2 corresponds to Active Intravenous Research, in which an Exemplary Case Study was developed which consisted in the (re)design of four Brand Marks (two Cheese and two Olive Oil) that obtained worse results in the analysis and Study questionnaires 1. After redesigning the Brand Marks and labels, a new questionnaire survey was conducted, using the questionnaire adapted from Study 1.

The results of both questionnaires were compared and challenged with objectives, research questions and hypotheses.

## **2.1 Semantics, Syntactic and Pragmatics in the Analysis and Design Process**

The relationship between the levels of Semantics, Syntactics and Pragmatics is a methodology applicable to the design project - what we call the Triad of the Creation of Meaning during Communication, in which the results of one level condition the following and are interdependent with each other. Its articulation establishes the efficacy level of the brand's Visual Identity and its particular analysis allows us to analyze and define criteria for selection, design and control of graphic signs.

Semantics is relevant in data analysis and diagnosis (characterization of the brand profile in its context, signs and strategy meet the requirements, there are minimal problems, there are serious problems in an appropriate brand strategy, or the concept and strategy are inadequate) of signs and identity values, as well as in the selection of symbols and formulation of concepts associated with the brand according to market premises that include the positioning considering the competitors and expectations of the public, as well as the definition of the personality of the brand.

In this sense, the Syntactic corresponds to the graphic representation or design of the signs or concepts of the brand, how the visual syntax and the rules of use of the signs materialize - shape, color, typography, style and expression, a Brand Mark and a system of Visual Identity of Brand - Correspondence to the meanings of the Brand; visual contrast ability and fascination power; easy identification and memorization; high readability and ease of reproduction; longevity; coherence, articulation and graphic-semantic interdependence within the identity system. Ensuring that signs of identity have the capacity for visual contrast and power of fascination is more important

than ensuring its graphic simplicity [2]. However, according to Harris [5], the important thing is not to generalize, the essence being to adapt the Brand Mark to its time, to its brand personality in a given market and according to the culture and profile of the target audience.

According to Doyle and Bottomley [7], typographical selection stems from its role in the context of visual identity and brand communication, so its origin and context, its shape and graphic characteristics must be taken into account - symbolic in their articulation with the graphic symbols, performance at the level of legibility, readability and possible connotations or secondary associations. In the literature on typographic connotations [8], the typography and type of packaging and product valorization (low, medium, high quality, low, medium, high, etc.) perceived meaning of Brand Mark [5].

Pragmatics refers to the decoding or understanding of the Brand Mark in its context of use, i.e. a label on the packaging or product in a given market and culture. According to Schwarzfischer [8], the pragmatic dimension includes and relates semantics and syntactics, so that in terms of the design process these levels must be pragmatically oriented. Pragmatics increases capacity to differentiate and foster the memorization of a Brand Mark beyond what the Syntactic level allows, since the process of decoding and understanding implies an appropriation and analysis of the recipient [2].

Thus, in the context of this research and considering the Olive Oils and Cheeses' Visual Identity, the analysis focuses on the Brand Marks existing at the level of Semantics (what is represented), Syntactics (as represented) and these in their context of use - label on the packaging at the level of Pragmatics (as they are decoded or understood).

## 2.2 Graphic Elements of Visual Identity of Olive Oil and Cheese' Brand

Considering that small producers of Olive Oil or Cheese tend to limit Brand Identity to Brand Mark, label and packaging, this research focuses on these identity components.

In terms of Brand Mark, it is necessary to analyze the graphical form, including the composition, arrangement of the components, the alignment between symbol and logo or in the case of a logo, the arrangement between the words that compose it.

In the label, the shape refers to the limits and field space with graphic content, to the square, rectangular, round or other format, which in itself can be a sign of identity and differentiation [4].

The categorization process, typographic organization, is not consensual, which is why the classification adopted by the Association Typographique Internationale (ATyPI) was adopted in 1967 based on the Maximilian Vox model of 1954, which will be used in the syntactic analysis of Brand Marks.

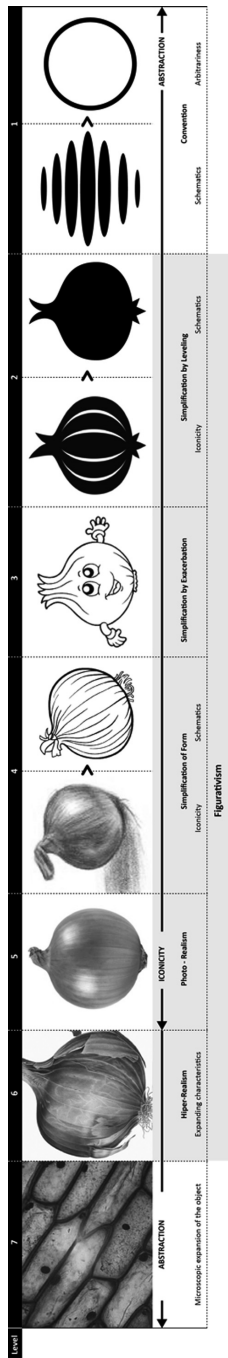


Fig. 1. Iconicity scale (Laginha, Raposo and Neves, 2016).













BRAND MARK					
SEMANTIC	A drop of oil with gold filigree.	Reference to the place of origin through Castelo Branco embroidery.	Olive illustration while raw material.	Reference to the place of origin through Ski at Serra da Estrela (star) and olive leaf crown.	Use of a false coat of arms to create nobility connotations. Inside, are the symbols organized in x: the olive tree, the lion, the eagle and the sun.
SIGN	Icon	Icon	Icon	Icon	Index
ICONICITY SCALE	1	4	4	2	2
SHAPE AND COLOR	 Center alignment. The symbol has higher size and contrast. Gold.	 Left alignment. The symbol has higher size and contrast. Black with yellow parts.	 Center alignment. Logotype superimposed on the symbol. Yellow with black parts.	 Center alignment. The symbol has higher size and contrast. Gold.	 Center alignment. The symbol has higher size and contrast. Gold.
TYPOGRAPHY	Garalde	Garalde	Transitional	Script	Glyphic

Fig. 2. Process of semantic and syntactic analysis (Laginha and Raposo, 2017).

### 3 From Non-interventional Research and to Active Interventional Research









Prior to Study 1 and 2, we performed the Semantic and Synthetic Analysis of the Brand Marks of 15 Olive Oils and 15 Cheeses. Subsequently, the Identity of 15 Olive Oils and 15 Cheeses were evaluated through a questionnaire related to the respective Brand Mark and label, followed by data collection and discussion of results.

In Study 1 the questionnaire technique was used to collect data at the level of Pragmatics, that is, the decoding and understanding of Brand Mark in its context of use, carried out by consumers.

In parallel to the questionnaires, a semantic and syntactic analysis was performed on the same Brand Marks evaluated in a questionnaire to identify and evaluate all the elements that form them individually - the represented content, typography, composition, color and type of expression (from the abstract to the figurative). This study served to relate the graphic characteristics of the brands to the consumers' considerations through the questionnaires.

In order to carry out this analysis, it was necessary to decompose the Brand Marks and individually evaluate their elements. With regard to semantics, it was necessary to describe exactly what is represented and to read the brand name.

The Brand Marks were divided into two groups, those that include a symbol and those that only have a logo, trying to find out if the brands with symbols would have been more positive at the level of decoding and understanding.

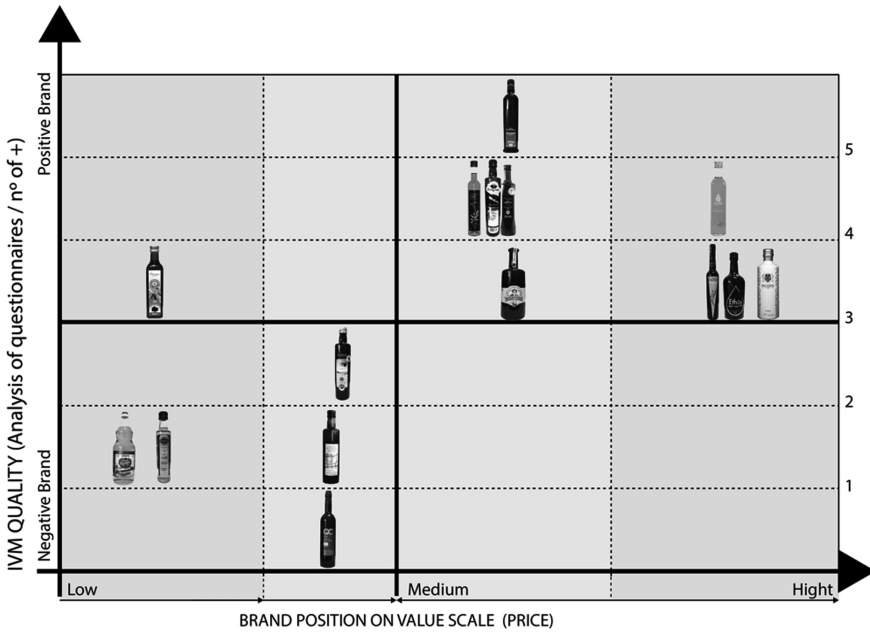
Brand Mark								
Olive oil	62,7%	53,3%	88%	48%	20%	6,7%	72%	93,9%
Wine	13,3%	33,3%	4%	14,7%	72%	88%	18,7%	6,7%
Oil	24%	13,3%	8%	30,7%	6,7%	1,3%	9,3%	----
Juice	----	----	----	6,7%	1,3%	4%	----	----
Buy Intention								
Yes	78,7%	77,3%	41,3%	30,7%	49,3%	44%	81,3%	48%
No	21,3%	22,7%	58,7%	69,3%	50,7%	56%	18,7%	52%
Price Rating								
Low	16%	32%	49,3%	69,3%	25,3%	29,3%	12%	22,7%
Medium	37,3%	60%	34,7%	28%	20%	49,3%	68%	44%
High	46,7%	8%	16%	2,7%	74,7%	21,3%	20%	33,3%
Quality Rating								
Poor	2,7%	8%	17,3%	28%	6,7%	29,3%	2,7%	9,3%
Medium	30,7%	54,7%	56%	58,7%	22,7%	29,3%	44%	33,3%
Good	36%	30,7%	18,7%	12%	29,3%	36%	38,7%	46,7%
Excellent	30,7%	6,7%	8%	1%	41,3%	5,3%	14,7%	10,7%
Classification Concept								
Conservative	9,3%	33,3%	18,7%	21,3%	14,7%	20%	8%	40%
Modern	33,3%	14,7%	10,7%	4%	16%	22,7%	36%	8%
Rustic	4%	13,3%	10,7%	21,3%	5,3%	4%	8%	42,7%
Technology	2,7%	6,7%	8%	2,7%	8%	5,3%	9,3%	----
Luxurious	29,3%	4%	5,3%	----	49,3%	5,3%	5,3%	4%
Banal	21,3%	28%	46,7%	50,7%	6,7%	20%	33,3%	5,3%

**Fig. 3.** Study 1 - results of the Olive Oil brand questionnaires (Laginha and Raposo, 2017).

Brand Mark								
Brand Mark Perception								
	+	+	+	-	-	-	+	+
Buy Intention								
	+	+	-	-	-	-	+	-
Price Rating								
	+	-	-	-	+	-	+	+
Quality Rating								
	+	-	-	-	+	-	+	+
Classification Concept								
	-	-	-	+	+	-	-	-
Results								
	+	-	-	-	+	-	+	+
Label								

**Fig. 4.** Study 1 - analysis table for Olive Oil brands (Laginha and Raposo, 2017).

The analysis of the Brand Marks symbols was based on the type of graphic sign (Fig. 1) (Laginha, Raposo and Neves, 2016) [9] since the proposals by Moles [10] and Villafañe [12] were defined for images, diagrams and diagrams, lacking the Brand Marks.



**Fig. 5.** Study 1 - dispersion chart - Olive Oil brands (Laginha and Raposo, 2017).

The new iconicity scale for Brand Marks allows in the Semantic and Synthetic Analysis of the Brand Marks of 15 Olive Oils and of 15 Cheeses (Fig. 2) the categorization of the symbols of the brands in a more detailed form.

### 3.1 Study 1

Regarding the questionnaires from Study 1 (Fig. 3), these included the Visual Identity of 15 brands of olive oil from 360 respondents, of whom 57% were women and 43% men, consumers of olive oil, resident in mainland Portugal and aged in the following age groups from 18 to 25 years (48%), from 26 to 35 (7%), from 36 to 45 (24%), from 46 to 56 (16%), from 57 to 65 (3%) and over 66 years (2%).

In the same sense, the questionnaire was applied to 360 respondents, of which 65% were women and 35% men, with ages ranging from 18 to 25 years (52%), from 26 to 35 (14%), from 36 to 45 (15%), from 46 to 56 (15%), from 57 to 65 (4%) and greater than 66 years (0%).











LABEL						
	PRICE	Low	Medium	Medium	Medium	
	BRAND QUALITY LEVEL	3	2	4	4	
	SEMANTIC (IMAGE)	Illustration of olive branch with olives and a green field with an olive tree.	Imagem of olive branch with olives. Illustration of wall of a castle.	Illustration of foliage and olive branch with olives.	Illustration of olive branch with olives.	No Image
	ICONICITY SCALE	4(1)	5	2	4(2)	---
SHAPE						
TIPOGRAPHY (Nº/CLASSIFICATION)	1/ Didone	2 / Didone	1 / Lineal	2 / Lineal e Glyphic	3/ Lineal, Mechanistic	

Fig. 6. Study 1 - semantic and synthetic analysis of marks of Olive Oil (Laginha and Raposo, 2017).

The analysis and discussion of results resulted in the transposition of the percentages obtained through a questionnaire into a positive (+) and negative (−) valuation table, which allowed the identification of the dispersion and distribution according to the quality and position of the brand, perceived by the respondents. It also allowed the

PRICE	SEMANTIC (IMAGE)	ICONICITY SCALE	SHAPE	COLOR	TIPOGRAPHY	GM
Medium	Illustration of foliage and olive branch with olives.  or No Image.	4(2)/2	Rectangular	1/2 colors (contrasts between shades of the same color, with white or black)  Main Colors: Green, Yellow	Lineal, Glyphic, Mechanics	Logotype or Symbol + Logotype, in which the symbol is greater or the logotype is inserted in the symbol.
Hight	Abstract Illustration or No Image.	1	1. Custom cutting technique on plain paper; 2. Use of a transparent background sticker in which the info is worked on the color of the bottle itself; 3. Assume the label as a sleeve that wraps around the bottle  Note: In point 1. custom drawing is usually an adaptation of the shape of the graphic mark.	Main Colors: black, gold and white in details (with contrasts shape bottom)  Note: cutting technique letters or figures that assume the color of the bottle.  Graphic finishes in: Gold; Varnish	Lineal, Transitional	Logotype or Symbol + Logotype, in which the symbol is greater than logotype.  This happens for two reasons, because optically the symbol is greater than logotype, because the symbol shape is complex or because the symbol being a fulfilled shape.

Fig. 7. Study 1 - table of guidelines for the design of Olive Oil brand visual identity (Laginha and Raposo, 2017).

correlation between the questionnaire data to the semantic and syntactic analysis grids, to the olive oil and cheese labels, allowing to indicate design principles useful to the Olive Oil and Cheese Brands' Visual Identity. This analysis of the questionnaire data by comparison tables (from Brand Marks with symbol and logo and another one to those that have only logo) and detection of common denominators, goes beyond what the pie charts allow.



**Fig. 8.** Study 2 - redesign of olive oil brands (Laginha and Raposo, 2017).

The organization in positive or negative, considers that less than 50% is negative (–), and more than 50% is positive (+), as it is possible to observe in Fig. 4.

Subsequently, a scatter plot was created that evaluates the quality of the perceived visual identity of the brand, with a vertical scale following the information in the analysis table and with a horizontal scale, which evaluates the brand positioning in a price scale - cheap, medium, expensive, which was related to the price indicated by the questionnaire data (Fig. 5).

In the case of the Visual Identity of the Cheese brands, the same procedures were adopted.

Based on the scatter plots, a semantic and syntactic analysis of the olive and cheese labels was carried out, where data indicate positive results at the level of perception of the Brands' Visual Identity. For the Olive Oils, all the brands that focused on levels 5, 4, 3 and 2 were analyzed, because although the latter is below the positive level, the same would be acquired by the respondents. In the case of Cheeses, levels 4, 3 and 2 were analyzed, with the latter presenting the same exception described for Olive Oils.

In the Olive Oils case, it was considered that three price levels were considered - cheap, medium and expensive, while in the case of Cheeses it was subdivided into medium low, medium high and expensive, only three were studied by the quality factor (those that were above level 2).

The same semiotic analysis based on the levels of semantics and syntactics performed for the Brand Marks was repeated for Olive Oils (Fig. 6) and Cheese labels, adding the image component (illustration and/or photograph) according to the Scale of Iconicity, the shape of the label, the typographic number and category.

From the analysis of the Brand Marks, an information frame was defined (Fig. 7) regarding the visual identity of olive oil and cheese brands, which provides guidelines for brand positioning associated with a notion of value.

### 3.2 Study 2

Taking into account the information obtained in Study 1, two brands of Olive Oil (Probeira and Ouro da Estrela - Fig. 8) and two brands of Cheese (Quinta Serra da Gardunha - DAMAR and Queijo Almeida) were selected for redesigning of their Brand Mark and their label.

The questionnaire data indicated an unclear positioning or lack of clarity on the personality of the brands and problems at the level of labels such as body text, excessive information and data too technical or complex.

After performing the redesign of the Visual Identity of the four brands, they were submitted to evaluation by survey, using the questionnaire adapted from Study 1. The adaptation of the questionnaire passed through the inclusion of new questions that aimed to guarantee greater certainty in the analysis of the data.

After analyzing the data available from Study 1 and during the redesign of the Visual Identity of the four brands (Study 2), it was considered important to include in the questionnaires in Study 1 new questions on the factors that influence the purchase of the product, on the quality relationship of the design and the quality of the product. and we sought to assess the understanding had by the respondents about the concepts presented.

The Visual Identity of the Olive Oil brands, including the redesign of the two brands, were evaluated with 360 Portuguese consumers, of whom 57% were women and 43% men, with ages ranging from 18 to 25 years of age (20%), from 26 to 35 (30%), 36 to 45 (25%), 46 to 56 (17%), 57 to 65 (8%) and 66 years of age (0%). Regarding the Visual Identity of the Cheese brands, including the redesign of the two brands, they were evaluated with 360 Portuguese consumers, of which 64.3% were women and 35.7% were men, with ages ranging from 18 to 25 years of age (28.6%), from 26 to 35 (13.1%), from 36 to 45 (22.6%), from 46 to 56 (27.4%), from 57 to 65 (8.3%) and greater than 66 years of age (0%).

## 4 Discussion of the Results and the Conclusions

In Study 2, in the four brands, the redesign of the Visual Identity of the brands presents clearly positive and contrasting results with those obtained with the brands existing and evaluated in Study 1.

In terms of Olive Oils, Beirã (Probeira) Brand Mark and Ouro da Estrela, respectively in the symbol and logo table, were associated with Olive Oil by 95% of the respondents and of these 93% would buy Beirã and 30.4% would buy the Ouro da Estrela. The Ouro da Estrela has been redesigned as a revival, positioned for a high segment and a niche market that values more traditional products, so the results seem to us in accordance. As for the Cheese brands, the Brand Mark redesign of Almeida Queijo and Quinta Serra da Gardunha - DAMAR were respectively associated with Cheese by 100% and 67.9% and of these 71.4% would buy Almeida Cheese and 84.5% Quinta Serra da Gardunha - DAMAR.

In the four brands, the redesign shows an understanding and appreciation consistent with the objective for the brand and according to the price established in each case. All Brand Marks have been associated with their products by a significant or absolute majority. There are merely differences in cases where there is only a logo.

Then, the results were distributed according to the positive and negative table, used in Study 1, taking into account the perception of value and price. Semantic and Syntactic analysis of the labels was performed on the following factors: content represented, iconicity scale, shape and typography (number and classification), price and positioning. Thus, it was possible to identify the brands where the perception is positive (from grade 3) in the various positions or notions of value and to obtain information to formulate a set of guidelines for the (re)design of the Olive Oil and Cheese Brands' Visual Identity, taking into account a consideration of value.

With the review of the literature, some studies on the perception of the packaging and its impact on the brand image and valorization of the product and others exclusively dedicated to Brand Marks were found. However, packaging studies lack detail with regard to graphical components and studies on Brand Marks tend to evaluate them out of context of use. On the other hand, all these studies fall on the level of Pragmatics without confronting these data with the levels of Semantics and Syntactics, that is, what was selected and how it was designed.

Study 1 served to obtain data on the efficiency of the Visual Identity of the Brands being studied, allowing to consolidate the vectors in analysis and to launch the hypothesis. Study 2 served to validate this hypothesis and formulate considerations. The homogeneity between the data obtained in Study 1 and 2 for the same brands is indicative of the reliability of the questionnaire and the adequacy of the variables being studied.

Although the Semantic and Syntactic analyzes are performed empirically and by direct observation, an objective analysis grid based on design principles and classifications with the highest convention or agreement, applicable to Brand Marks, has been defined. In the case of labels, data analysis included the positioning and price associated with Brand Visual Identity.

The analysis of the questionnaire data (part of the Pragmatics) from the dispersion graphs was essential in order to be able to relate this information to the Semantic and

Syntactic analysis tables. In the same sense, for the accuracy of the data, it was essential to validate the understanding of the concepts used in the questionnaires by the interviewed consumers, instead of doing it with only one sample.

By the correlation between the scatter plots and the semantic and syntactic analysis tables, it was possible to arrive at two tables with design guidelines, respectively for Olive Oils (Fig. 9) and Cheeses.

PRICE	SEMANTIC (IMAGE)	ICONICITY SCALE	SHAPE	COLOR	MATERIAIS E ACABAMENTOS	TIPOGRAPHY	BRAND MARK	CONCEPT
<b>LOW</b>	Illustration of olive branch with olives or olive tree.	4(1)	100% Rectangular (vertical direction)	More than 3 colors (contrasts with light background) Main colors: green, brown, maroon, yellow	Materials: Plain paper sticker.	Didone	Logotype	Banal
<b>LOW MEDIUM</b>	Photo of olive branch with olives or olive oil. or Abstract illustration	5-1	100% Rectangular (vertical direction)	3 or + colors (contrasts with white/light background)	Materials: Plain paper sticker.	Didonas, Mecanichs, Lineal	Logotype	Banal, Conservative
<b>HIGH MEDIUM</b>	Illustration of olive branch with olives or No image.	4/2	100% rectangular; 80% Rectangular + 20% custom; 100% custom or the label wraps around the bottle. (horizontal or vertical direction)	2 colors	Materials: Plain paper sticker or paper stick with transparent background.	Lineal, Humanist, Glyphic	Logotype or Symbol + Logotype: Symbol pically greater than logotype.	Banal, Modern
<b>HIGH</b>	Abstract illustration or No image.	1	1. Custom cutting technique on plain paper and stick with transparent background in which the info is worked on the color of the bottle itself; 2. The label wraps around the bottle.  Note: In point 1, the custom cutting is usually an adaptation of the shape of the brand mark.	Main Colors: black, golden, white Brightness: too dark or too white	Materials: Plain paper sticker or paper stick with transparent background.  Graphic Finishes: Metal Pantones - especially, gold is associated with the color of oil; Use of Varnish.	Lineal	Logotype or Symbol + Logotype	Modern, Luxury, innovative

**Fig. 9.** Study 2 - table of guidelines for the design of Olive Oil brand visual identity (Laginha and Raposo, 2017).

By comparing data obtained between the current Visual Identity and its redesign, it is considered that the investigative process has been validated and is adequate for the definition of design guidelines and as an evaluation process.

Thus, it was possible to identify common denominators between Brand Visual Identity with the same valuation and graphical-symbolic elements, associating them with a price and positioning.

For example, among other data, Olive Oils' brand VI color indicates that those with a high or high average price have in common 1 or 2 colors, often special colors like Gold, Metallic, UV coating, etc.

Regarding the style or expression of the graphics, the data show that perception changes from average Olive Oil to expensive when there is a simplification of image expression, according to the Iconicity Scale, from level 2 (simplification by leveling) to level 1 (total abstraction).

Regarding the label, the data indicate that Olive Oils considered expensive have an opaque label that covers the entire bottle to protect olive oil when it is dark or transparent glass, medium size with a custom cut. Olive Oils considered medium-priced



tend to have a more vertical rectangular shape, with cases of small clipping areas under the bottle.

Regarding cheeses, the data indicate that those that are perceived as cheap (although with quality), tend to present round labels with a simplified expression by leveling (level 2 of the Iconicity Scale). While the average prices are round and more often associated with images between levels 5 (photorealism, i.e. photography or drawing at a high level of detail that represents reality) and levels 2 and 3. Those who have a lower or medium price tend to represent shepherds, sheep in pasture or craft-making scenarios, whereas medium-priced ones choose to portray sites of origin or production and those associated with the highest price tend to have unusual formats (rectangular, triangular, irregular and round shapes) and abstract graphics (level 1 in the Iconicity Scale) or ornaments, and use a back label to accommodate the amount of information required.

Low- and medium-priced products tend to use Neo-grotesque and Grotesque, while those that are perceived as having high prices are associated with Classics.

Overall, the data indicate that it is advisable to organize the information by levels of importance without neglecting detail and comply with the applicable legislation, in order to avoid giving little information (which generates mistrust) or too much (the label is not appealing or difficult to read).

According to the data obtained, the investigative process was adequate in that it allowed to answer the question of investigation and to fully prove the hypothesis, since a correction between the Semantic and the Syntactic was verified with the Pragmatic of the Visual Identity of the brands of Olive Oils and Cheeses. In addition, it was possible to identify correlations between graphic characteristics of the Visual Identity of brands with the same positioning and that determine their decoding and understanding.

The results of this research make a valid contribution to academia and research and are useful in the practice of the Communication Design profession, namely by the design and redesign guidelines, as a process of observation, analysis and evaluation of the efficiency of the Olive Oils and Cheeses' brand Visual Identity including support in decision making during a branding or rebranding process.

## References

1. Oliveira, P., Alcobia, P.: Influência da Cor, Materiais e Morfologia das Embalagens na Presunção de Qualidade dos Produtos. In: 3ª CIDAG - Conferencia Internacional em Design e Artes Gráficas, Lisboa (2014)
2. Frascara, J.: EL diseño de comunicación. Ediciones Infinito, Buenos Aires (2006). ISBN 987-9393-42-2
3. Costa, J.: Imagen global. In: Enciclopedia del diseño, vol. 1. CEAC, Barcelona (1994)
4. Swann, A.: Diseño y Marketing. Editorial Gustavo Gili, S.A., Barcelona (1991). ISBN 84-252-1489-0
5. Harris, M.: Why logos are going retro update, [em linha], 21 de novembro de 2016. <https://www.digitalartsonline.co.uk/features/graphic-design/why-logos-are-going-retro-update/>
6. Doyle, J.R., Bottomley, P.A.: Dressed for the occasion: font-product congruity in the perception of logotype. J. Consum. Psychol. **16**, 112–123 (2006)

7. Ampuero, O., Vila, N.: Consumer perceptions of product packaging. *J. Consum. Mark.* **23** (2), 102–114 (2006)
8. Schwarzfischer, K.: The aesthetic meaning of syntactic, semantic and pragmatic gestalt integrations in integrative aesthetics. *Gestalt Theor.* **33**(3–4), 345–362 (2011)
9. Laginha, C., Raposo, D., Neves, J. : The scale of iconicity in the field of graphic brands. In: Fernández, L., Herrera, E. (eds.) *Graphic Brands of Corporate Identity*, 2016, Donostia-San Sebastián: Book of Minutes. UPV/EHU, Editorial Service, Bilbao, pp. 153–160 (2016)
10. Moles, A., Janiszewski, L.: *Grafismo funcional*. In: *Enciclopedia del diseño*. Ediciones CEAC, Barcelona (1990)
11. Raposo, D.: *La letra como signo de Identidad Visual Corporativa: Codificación y Decoficación del Sistema de Identidad*. Faculdade de Arquitetura da Universidade de Lisboa, Lisboa (2012)
12. Villafañe, J.: *Introducción a la teoría de la imagen*. Pirámide, Madrid (2006)

# **Design and User Involvement**



# Evaluation of the Concept of a Smart City Gamification from a User Centered Design Perspective

Francisco Rebelo<sup>(✉)</sup>, Paulo Noriega, and Tiago Oliveira

CIAUD, Lisbon School of Architecture, Universidade de Lisboa, Rua Sá  
Nogueira, Pólo Universitário, Alto da Ajuda, 1349-063 Lisbon, Portugal  
fsrebelo@gmail.com

**Abstract.** Galvanize the citizen to be engaged with a smart city project projects are not an easy task, normally they feel that their voice cannot make the difference and leaves the project. Gamification can change this, by engaging the citizen with challenges and rewards, they will be involved creating “critical mass” to influence the makers and change the city. In this context, this paper presents the evaluation of a gamification strategy concept for the Smart City Sense Project implemented in a mobile application. The evaluation was done by a questionnaire with 41 questions, filled by a group of 23 citizens that was already involves in city civic activities related with security. In general, this special population has a positive reaction to our different proposals, but there is no unanimity in the aspects related to the gamification strategies associated with the rewards and the give challenges for their community. The user-centered design methodology proved to be robust to evaluate the proposed gamification strategy, allowing ergonomics to play a fundamental role in the development of an information system, that can prevent the occurrence of problems of acceptance in the future.

**Keywords:** Smart city · Engagement · Gamification · Mobile application · Ergonomics design

## 1 Introduction

New technologies, gives the opportunity to citizens to increase their live style and efficiency, creating smart cities and smart citizens. This is particularly important nowadays, considering the rapid urbanization rate the challenges related with socio-economic, environmental and governance challenges [1].

There are various definitions about what a smart city is, one of the most integrated definition was made by Angelidou [2] including four important cardinal forces for smart cities: advanced human capital (citizen empowerment, intellectual capital and knowledge creation); social capital (social and digital inclusion), behavioral change (sense of ownership and meaning) and a humane approach to change, where technology responds to the needs and interests of the user. Recently, Tan Yigitcanlar et al. [3] in a systematic review of the literature on smart cities, suggested three types of drivers: community, technology and policy, which are linked to five desired outcomes:

productivity, sustainability, accessibility, wellbeing, liveability and governance. The authors suggested that these drivers and outcomes together create a framework to better understand a smart city.

Sensors are essential for developing a smart city, they can take measures from the environment (i.e. temperature, noise, contaminants) and process images in real time in an efficient way. They can have some limitations related with subjective data, that depends from the citizen profiles. For example, safety perception and human emotion and feelings related with events that occurs in the city is not measure by a sensor. Also, some events like holes in the streets and the danger that they can represent cannot be easy to be identified automatically by sensors. In this context, the citizen can be a sensor with a lot of advantages compared to physical sensors. By have the opportunity to share information about good and bad events in the city, the citizen will be engaged and take more responsibility for their individual situation, being involved to contribute to society. Several researchers connect this participation is an important way of enhancing democracy [4–6]. Engage the citizen is not an easy task, they need to spend energy and an amount of time to participate. A way to engage the citizen is through the use of devices that allows the introduction and consultation of information with a good usability. Another complementary way to increase the citizen engagement is the gamification, with incentives to became participant. Smartphones with adequate software provides a way to get data from the citizen, by adding elements of gamification [7]. Gamification was defined in the first time in 2011 from Zichermann and Cunningham [8] as “the process of game-thinking and game mechanics to engage users and solve problems”. In this context, they connect gamification with the possibility to involve the consumers in loyalty programs and generate behavior change. A complementary perspective as proposed by Werbach et al. that propose a definition for gamification as a way to bringing fun to obligatory activities. Another perspective as done by Schoech et al. [9] that associate gamification to engage and motivate to a behavior change strategy. Grossman et al. [10] define gamification as the use of elements of video games in non-game situations, to enhance user experience and engagement.

The mixt of the previous perspectives give us the following definition. Gamification is a process that use game mechanics to engage people to accomplish a task to solve a problem, or change a behavior, with pleasure, in a non-game context. This means that gamification might be used in situations where a person needed to accomplish an objective, after developing a set of tasks, but also to change a bad behavior that can affect, for example, the health or safety of a person.

Gamification use renewals (points, rankings, levels, badges, money) and challenges (complete activities and achievements) to motivate the users inside a storytelling to give an objective to interact. Those game mechanics are supported by the human needs related with hedonism (senses stimulation and discovery), prestige (privileges and leadership), achievement (through tasks completion), socializing (cooperation, collecting support) and expression (customization to be different).

According to Marache-Francisco and Brangier [11] the implementation of a gamification strategy needed to be supported by two main requirements: an analysis of the context to identify the main aspects to be considered in the gamification experience

and by an interactive design process, that allow the evolution of the gamification solution by user tests.

Taking this framework as a reference, this study presents a gamification proposal for an ongoing research to develop an online platform for the project smart city sense.

Taking this framework as a reference, this study presents a gamification proposal for an ongoing research to develop an online platform for the project Smart City Sense, financed by the Portugal 2020 program. This project involves the conceptualization, design and implementation of an information technology platform where the wealth of data collected by citizens (volume, variety and detail), is aggregated with data collected by a variety of other existing sensors in the city, giving in real time, a clearer and more vivid vision of the global “pulse” of the city. The platform will also create an adequate environment (physical and virtual) for cooperation between citizens and city authorities enabling that the information added by one part to be available to all stakeholders. This objective proposes an approach to the concept of Smart Cities that puts the citizen as the focal point of the data collection and information sharing process [12].

The first users of this platform will be the security community leaders that live in the various regions of Lisbon. These persons are civil persons that dedicate some of their time to improve the quality of life of the persons that live in their Lisbon region, particularly in relation to security. Because they are special people, we had many doubts about various characteristics of the platform to be implemented. Being people who are more involved in the security aspects of people, we were interested in knowing if they would also be interested in having a comprehensive intervention, also being involved in the conditions of the city that can affect people’s health and accessibility and efficiency. Engaging those people in a gamification process was another challenge, we did not know what kind of challenges and rewards (intrinsic or extrinsic) would be most appropriate to motivate them to use the Smart City Sense platform.

## 2 Methodology

A methodology was based on participants’ opinions, through a questionnaire, to be used to evaluate a gamification proposal for a smart city.

### 2.1 Sample

As explained before, the participants of this study were security leaders of the Lisbon city, that collaborated voluntarily in this study. A sample of twenty-three persons, aged between 32 and 66 years (mean age = 45, SD = 6,33), 14 female and 9 males from different zones of Lisbon participated in this study.

### 2.2 Methodology

A questionnaire was designed to extract the information from the Lisbon city security leaders to propose a gamification strategy for the platform. According to literature review and meetings with the project team, composed by a multidisciplinary group of: ergonomists, psychologists, designers, engineering and sociologists, we elaborate 41

questions in a five-point Likert scale ranging from 1 to 5, where 1 was (completely disagree) and 5 (completely agree), plus demographic data (gender, age and residence). The first question was aimed to confirm the interest to collaborate in a smart city project. The same question occurs in final of questionnaire, to verify if the respondents changed their opinion after answered all questions.

1. I want to be able to use an application that contributes to the efficiency and well-being of the citizen.

The following three questions aimed to verify the interested of the security leaders to report different kind of problems in the city. Considering that they are more involve with city security, we need to verify if they could be interested to be involved to report problems related with health and accessibility.

2. I would like to be able to use an application to report situations that may affect the security of the citizen.
3. I would like to be able to use an application to report situations that may affect the health of the citizen.
4. I would like to be able to use an application to report accessibility situations that may hamper citizen mobility.

Considering a situation where the user cannot report an event in-loco, but have the possibility to report later, for example in home, with the following question we want to verify if they agree with this possibility.

5. To report a situation, I want to be able to check the location at the time it happens, but I want to be able to report later at another location.

Normally, the solutions for a smart city project is dependent of negative events, in this project we want to know if the potential users, agree about the idea to report positive events, related with good things, like those in the following four questions.

6. I would like to be able to use an application to report good things in the city, such as safe streets to drive at night.
7. I would like to be able to use an application to report good city situations, such as clean streets.
8. I would like to be able to use an application to report good city situations, such as beautiful gardens and urban art.
9. I would like to be able to use an application to report cultural events that will occur in my community.

When the potential user is busy, the motivation to suggest an improvement, after report a problem, could not be the best. But if they are not able to suggest an improvement, they probably will feel less engage to report a problem in the city. The following question access whether the potential user would interest in suggesting improvements solutions for a problem.

10. After reporting a situation, I would like to suggest improvement suggestions through an application.

The notifications sent to users is good provide feedback about the events and occurrences in the city. That information can contribute to engage the citizen in the platform. However, this information could not be intrusive in the life of the citizen. In the next four questions we want to know when and here the potential user want to receive feedback notifications of the platform.

11. I would like to receive notifications about the city in the morning.
12. I would like to receive notifications about the city in the afternoon.
13. I would like to receive notifications about the city at night.
14. I would like to receive notifications when I am away from home.

Considering that the potential users are more involved in security issues we don't know if they are interested to consult other aspects of the city, particularly related with health and accessibility. The following three questions are related with this subject.

15. I would like to consult to security-related situations in the application.
16. I would like to consult to health-related situations in the application.
17. I would like to consult accessibility issues in the application.

How long is acceptable for the user to report in the application a situation in the city? The answer of this question is very important to decide the number of item's that must be filled in the application. If the user needs to enter a lot of information to report an event, he may not feel motivated to post, however, if little information is requested about an event, it will not be possible to understand the situation and determine the best intervention strategy. After a discussion inside the multidisciplinary team work, we decide that two minutes is the time needed to enter the most important information to characterize an event situation in the city. The next question wants to capture the level of agree about this decision.

18. It is acceptable for me to spend 2 min to report a situation in the city.

When the user wants to report an event in a mobile application in the urban context, he needs to play attention to the environment, to avoid safety problems due to a loss of attention to the traffic, for example. In this context, writing text in a mobile application could not be a good idea. However, allowing the user to write a text to explain better the event can be an important information to better understand the event. The next question wants to capture the level interest of the user about their willingness to write a text and/or take a photography.

19. I would like a text area to describe the situation I want to report.
20. It is acceptable for me to photograph with the application a situation to illustrate a report.

In the next question, we want to check the user's opinion, about the time of two minutes to report an event on the platform, would be well accepted by others. The objective is to verify if there are differences between the opinion of him, collected in the question 18 and others, but now in relation to the others.

21. It is acceptable for other people to spend 2 min reporting a situation in the city.



Enter personal information in an application is very important to characterize the user, to send to him the adequate information in function of their needs and preferences. However, this can be critical, as you usually the user do not want to put personal information in the application, due to confidentiality issues. Next two questions collect the level of acceptance that users would be available to provide personal information and preferences.

22. It is acceptable for me to customize my area in an application, according to the following personal characteristics: Name; Age; Profession; Genre; Place where I live; Telephone; Email.
23. It is acceptable for me to customize my area in an application according to the following personal characteristics: Food preferences; How to get to work; Difficulties of mobility.

Next question collects the level of the user acceptance to share theirs reports in the application.

24. It is acceptable to me that other users of the application should consult the situations I have reported.

Normally, the security leaders are only involved in activities their region and don't care about the other regions of the city. In our proposal we are interested to involve those persons not only in their region, but in all other zones of the Lisbon city, through gamification strategies. In the following questions we want to know the motivation of the potential users to report information in their neighborhood and in other communities.

25. Whenever I share situations in my neighborhood, I receive rewards.
26. Whenever I share situations in other communities in the city, I receive rewards.

A good leader must challenge the community members and have the curiosity to know and control the behavior of the other community members. In the following questions we want to know if the security leaders are motivated to use an application to do it.

27. I want to be able to challenge other users.
28. Whenever I share situations, I would like to know how many people have reported this situation.

Extrinsic rewards, such as relating to receiving points or stamps for reporting events, is a way to create user engagement mechanisms. In the next question, we are interested in hearing the opinion of the community safety leaders on this aspect.

29. When I share information in a community for the first time: I would like to receive a virtual stamp (with graphic elements of the community) in a virtual carnet until I complete the 24 parishes of Lisbon.

The visual identity of an application is very important to be easy recognized and accepted by the potential users. In our application to the smart city sense platform we want to know if the landmarks and traditional parties in the city could be used to accepted by the security leaders.

30. It makes sense for me that the application has for the city of Lisbon have graphic elements of identity allusive to: popular parties and monuments, for example, Lisbon castle.

The balance between intensity of the challenges and the rewards types, are very important to engage the potential users to post and consult information in a smart city. In the next two first questions, we want to know: when and the feedback type for the security leaders. We also developed a set of questions to evaluate the relative importance that the security leaders give in relation to different of rewards (personalized information, feedback, status, credibility and distinction, be able to give challenges).

31. When I share a situation in a community for the first time: I want to receive personalized information about this parish.
32. When reporting a situation, about a city problem that has a possible resolution: I would like to be informed about updating my report.
33. Based on my use of an application, I would like to be able to evolve my status in the city, as follows: 1st level: Discovering the city; 2nd level: Attentive; 3rd level: Active; 4th level: Proactive; 5th level: Recognized; 6th level: Caretaker; 7th level: Exemplary.
34. In view of the veracity of the shared information, I would like to be able to develop credibility, in order to distinguish myself from other users, as follows: Negative level: Speculator; 1st level- Dedicated; 2nd level- Integral; 3rd level- Consistent; 4th level- Sincere; 5th level- Reliable; 6th level- Issue
35. When I report situations in a community, I would like to be able to evolve within the parish, distinguishing me from who contributes more or less, as follows: 1st level has 1 star ... 5th level has 5 stars

Who can challenge other citizens? The status of a person is a very important factor, so that the citizens of a community can accept and implement the challenges posed. The next question is intended to assess the opinion of potential users if a high individual status in the program can pose challenges to other community members.

36. At 5th Level (5 stars) I can challenge other members of the parish group using the application.

In the following two questions we want to know if the security leaders want to receive rewards, related to other activities that are not directly connected to report or consult information using the application.

37. With my use, I want to receive mini-games where I can earn more points for my status.
38. When I walk next to an emblematic site, I want to receive information on this site in an application.

The possibility to have links to share the personal performance in the networks could be a good feature to improve the application engagement, but some people don't want to be exposed online. The next question evaluates the degree that the security leaders want to share their performance in internet.

39. I would like to be able to share my performance using the application on social networks.

The penalties are part of the gamification process and aim to keep people in the application. In this context, we were interested to know the reaction of the user when he loses status if do not use the application for a period of one month.

40. If I do not use the application for a month, I agree to lower my cumulative status.

The last question, which is the same as the first question, seeks to verify whether people have changed their minds about the use of application after completing the questionnaire.

41. I want to be able to use an application that contributes to the efficiency and well-being of the citizen.

### 2.3 Procedures

The participants (security members leaders) were invited to a meeting with the objective to collaborate, as potential user in the development of the concept of an application do share and consult information about Lisbon city.

In the first part of the meeting, we explained the importance of the project Smart City Sense and the need to involve then in a user centered design perspective in the development of an application where they can share and consult information of the city.

Next, we show an example of completing the questionnaire with a question and asking if there were any questions, before fill the questionnaire.

## 3 Results and Discussion

The results will be presented for each question and discussed its suitability to the application gamification project that supports the platform.

Questions 1 and 41: I want to be able to use an application that contributes to the efficiency and well-being of the citizen (mean 4,65: max. 5, min. 3, for the first question) and (mean 4,7: max. 5, min. 3, in the last question).

These results show that the potential users accept to use an application to report and consult information to contribute to the citizen efficiency and well-being. It is also verified that after completing the questionnaire, where they knew of some characteristics of this application, the results were not altered.

In conclusion, in general the potentials user accepts the possibility to use an application.

Questions 2, 3 and 4 – report respectively, problems with security (mean 4,7: max. 5, min. 3), health (mean 4,67: max. 5, min. 3) and accessibility (mean 4,74: max. 5, min. 3).

During the questionnaire preparation meetings, doubts were raised as to whether security community leaders would also be interested in reporting health and accessibility issues. The results showed that they are very interested in reporting, without

distinction, situations that could compromise the level of security, health and accessibility of the citizen.

Those features will be implemented in the application.

Question 5 – report a situation later in another location (mean 4,43: max. 5, min. 3). The potential user doesn't see any problem to have the possibility to report a situation in the application in another location. This feature will be implemented in the application, georeferencing the location and later, asking if the user wants to report this situation.

Questions 6 to 9 – Use the application to report positive events: safe streets (mean 4,52: max. 5, min. 3); clean streets (mean 4,30: max. 5, min. 2); beautiful gardens (mean 4,13: max. 5, min. 2) and cultural events (mean 4,26: max. 5, min. 1).

In general, users accept this idea, however, in a less intense way, compared to the one used in the application to report problems. Particularly, the aspects related to beautiful gardens and cultural events, had some answers less than 3.

Although there is not a very strong consensus in all these aspects, we think that these characteristics should be implemented in the application.

Question 10 – report suggestions through an application (mean 4,35: max. 5, min. 3).

Although not very strong, the big trend is to be able to use the application to suggest solutions for a given problem. Knowing that in urban space, after reporting an event, it may be difficult to type a solution in a smartphone, we will propose an option that allows the user to fix the solution later, at a more appropriate time and space.

Questions 11 to 14 – receive notifications about the city in the morning (mean 4,17: max. 5, min. 3), afternoon (mean 3,9: max. 5, min. 2), at night (mean 3,78: max. 5, min. 1) and away from home (mean 3,70: max. 5, min. 1).

While most of the potential users accept receiving notifications at any time of the day and even away from home, the big trend is to receive these notifications in the morning. Regarding the location where they can receive the notifications, particularly, out of the house, some users expressed discomfort referring that they feel controlled by the application. In conclusion, it is important to inform users that for this application function, it is necessary to know their location to send notifications and that all information collected is confidential. The user will also be allowed not to allow the application to know her location.

Questions 15 to 17 – like to consult: security-related situations (mean 4,61: max. 5, min. 3); health-related situations (mean 4,26: max. 5, min. 2); and accessibility issues (mean 4,43: max. 5, min. 2).

Potential users prefer to consult information related to security aspects, however, they have also shown interest in consulting information related to health and accessibility. In this case, the doubts that arose during the development of the questionnaire that the community security leaders would not be interested in consulting problems other than the safety aspects is not true.

Question 18 – Two minutes, as the acceptable time to report a problem (mean 4,3: max. 5, min. 1).

Although most users accept as appropriate two minutes, as the acceptable time to report an event, two people have stated that it is a very high time. This problem will be discussed later in question number 21.

Questions 19 and 20 – Need an area to describe the situation (mean 4,43: max. 5, min. 3) and take a photography (mean 4,61: max. 5, min. 3).

Either of these situations are acceptable to potential users, although they are more likely to illustrate the event with a photograph than with a description of a text. In this case, regarding the text and considering the difficulties in entering text on a smartphone in the urban space, as well as the situation of danger to the user that this situation entails, our proposal will be that the text entry can be done later, in another space and time.

Question 21 - Acceptable for other people to spend 2 min reporting a situation (mean 3,7: max. 5, min. 1).

Compared with question number 18, where potential users are asked if two minutes would be adequate time to report an event in the city, this question was referred to a lower value (mean 4,3–3,7), this mean that they are not sure that two minutes is an appropriate time to report an event in the city.

We think that despite this trend, more studies need to be done to know the appropriate time to report an event with a smartphone in urban space.

Questions 22 and 23 – Customize the application with personal demographic characteristics (mean 2,70: max. 5, min 1) and personal characteristics (mean 3,09: max. 5, min 1).

In general, potential users are unwilling to provide personal data that allows customization of the application. Knowing that this information is very important for the stratification of people and in particular for sending personalized information. Our opinion is that this information should only be requested later, when the user relies on the application and can be comfortable at ease. Whatever the situation, this information should never be considered mandatory.

Question 24 – Consult the user reported situations (mean 3,78: max. 5, min 1).

This situation has not met the consensus of all potential users of the application, two participants refer their complete disagreement in allowing others to consult their reported situations. In this context, our proposal is that, by default, the information relating to the events reported is confidential, allowing however that at the user's choice, this information may be public.

Questions 25 and 26 – receive rewards to post events in neighborhood (mean 3,22: max. 5, min 1) and in other communities (mean 2,87: max. 5, min 1).

In general, potential users are not interested in getting rewards, to report events in the city, particularly if they are in regions other than their own. We think that this reaction is due to the fact that they think that the rewards are always extrinsic, receiving money, for example. As citizens, who voluntarily dedicate themselves to preserving the security of their region, the financial aspects are not the reason to report events in the city.

Questions 27 and 28 – challenge the others (mean 3,23: max. 5, min 1) and control the citizen reports (mean 4,42: max. 5, min 2).

The results show that community safety leaders are not interested in challenging community members. This result can be a problem for the application, because without users motivated to challenge citizens and thus involve more users, the application may not succeed in the future. In this context, it will be necessary to try to quickly find good strategies that motivate leaders to introduce challenges to the citizen to create

mechanisms of engagement and with that, to retain users and to increase the user community.

Question 29 – after report an event receive a visual stamp (mean 2,61: max. 5, min. 1).

The result showed once again that community safety leaders are not interested in receiving extrinsic rewards, so this will not be the best strategy to motivate them to the application.

Question 30 – application using graphic elements allusive Lisbon parties and monuments (mean 3,78: max. 5, min. 1).

Despite being well accepted by the majority, some potential users express the displeasure in associating the application with elements of the identity of Lisbon. We think that this opinion may be related to the fact that the people who answered the questionnaire are only concerned about their region and not interested in mixing other regions. This should merit further investigation.

Questions 31 to 35 – after report an information in the application, receive renewals: personalized information about the community (mean 3,65: max. 5, min. 1); be informed about updates of the report (mean 4,65: max. 5, min. 1); increase status (mean 3,78: max. 5, min. 1); increase credibility (mean 3,57: max. 5, min. 1); distinguishing (mean 3,61: max. 5, min. 1).

Although the results are positive, there is not a very strong agreement on these rewards, some users reported negative opinions regarding this strategy. The highest result is related to receiving updates on the events reported, however, rewards related to status, credibility and distinction were not highly valued by those who answered the questionnaire.

More studies should be done on this topic to see if these users are more interested in other types of rewards given their special community security leader profile.

Question 36 – Challenge the other members of the community using the application (mean 2,96: max. 5, min. 1).

This result shows that the five-star status in the application is not well accepted to allow the launching of challenges to other members of the community. It is recalled that in question number 27 in which potential users have expressed no interest in challenging other members of the community. More research is needed to find the best way to engage leaders to challenge other members of the community.

Questions 37 and 38 – play a game to get more status in the application (mean 2,61: max. 5, min. 1) and receive information personalize information in the city (mean 3,48: max. 5, min. 1).

Users of this application, who responded to this questionnaire, do not want to use an gaming entertainment application, even if it is to increase the status. Regarding the personalized information in the city, there was also no response from the people who answered this questionnaire (community security leaders) a great interest in receiving personalized information about the regions of the city.

Question 39 – share personalized performance in social networks (mean 2,57: max. 5, min. 1).

People who answered the questionnaire are not interested in sharing the events they reported in the application on the platform.

This view is consistent with previous responses, where respondents did not demonstrate the need for their information to be disseminated to others in the application.

Question 40 – lower the cumulative status if not use the application (mean 2,70: max. 5, min. 1).

Although they consider that status is not very important in this application, people who answered the questionnaire do not want to lose status.

## 4 Conclusions

This study uses a user-centered design approach to evaluate a gamification strategy for a Smart City Sense platform application. The study was developed with the first population which will use this application, citizens who voluntarily are leaders their local community, with tasks related to people security. In general, this special population has a positive reaction to our different proposals, but there is no unanimity in the aspects related to the gamification strategies associated with the rewards and the give challenges for their community.

In general, the user-centered design methodology proved to be robust to evaluate the proposed gamification strategy, allowing ergonomics to play a fundamental role in the development of an information system, that can prevent the occurrence of problems of acceptance in the future.

Other studies should be developed to evaluate whether the same strategies can be applied to the general population, which have different characteristics from the one that participated in this study.

**Acknowledgments.** This work is co-financed by the project LISBOA-01-0247-FEDER-017906: Smart City Sense, FEDER, in the scope of the Program Portugal 2020, through LISBOA2020.

## References

1. Belanche, D., Casaló, L.V., Orús, C.: City attachment and use of urban services: benefits for smart cities. *Cities* **50**, 75–81 (2016)
2. Angelidou, M.: Smart: cities: a conjuncture of four forces. *Cities* **47**, 95–106 (2015)
3. Yigitcanlar, T., Kamruzzamanf, Md., Buysb, L., Ioppolo, G., Sabatini-Marques, J., Costada, E.M., Yun, J.J.: Understanding ‘smart cities’: intertwining development drivers with desired outcomes in a multidimensional framework. *Cities* **81**, 145–160 (2018)
4. Sæbø, Ø., Rose, J., Flak, L.S.: The shape of eParticipation: characterizing an emerging research area. *Gov. Inf. Q.* **25**(3), 400–428 (2008)
5. Kolsaker, A., Kelly, L.L.: Citizens’ attitudes towards e-government and e-governance: a UK study. *Int. J. Public Sect. Manag.* **21**(7), 723–738 (2008)
6. Amnå, E., Ekman, J.: Standby citizens: diverse faces of political passivity. *Eur. Polit. Sci. Rev.* **2**, 261–281 (2014)
7. Hollands, R.G.: Will the real smart city please stand up? *City* **12**(3), 303–320 (2008)

8. Zichermann, G., Cunningham, C.: *Gamification by Design. Implementing Game Mechanics in Web and Mobile Apps*. O'Reilly Media Inc., Sebastopol (2011)
9. Schoech, D., Boyas, J.F., Black, B.M., Elias-Lambert, N.: Gamification for behavior change: lessons from developing a social, multiuser, web-tablet based prevention game for youths. *J. Technol. Hum. Serv.* **31**(3), 197–217 (2013)
10. Li, W., Grossman, T., Fitzmaurice, G.: GamiCAD a gamified tutorial system for first time AutoCAD users. In: Miller, R., Benko, H., Latulipe, C. (eds.), *UIST 2012 Proceedings of the 25th Annual ACM Symposium on User Interface Software and Technology*, pp. 103–112. ACM, New-York (2012)
11. Marache-Francisco, C., Brangier, E.: Process for gamification: from the decision of gamification to its practical implementation. In: Berntzen, L., Böhm, S. (eds.), *Proceedings of CENTRIC 2013: The Sixth International Conference on Advances in Human-Oriented and Personalized Mechanisms, Technologies, and Services*, pp. 126–131. XPS, Wilmington, DE, USA (2013)
12. Rebelo, F., Noriega, P., Oliveira, T., Santos, D., Oliveira, S.: Expected user acceptance of an augmented reality service for a smart city. In: Marcus, A., Wang, W. (eds.) *Design, User Experience, and Usability: Users, Contexts and Case Studies, DUXU 2018. LNCS*, vol. 10920, pp. 703–714. Springer, Cham (2018)





# Natural Human-Computer Interfaces' Paradigm and Cognitive Ergonomics

Victor M. Almeida<sup>1</sup>(✉), Sónia Rafael<sup>1</sup>, and Marco Neves<sup>2</sup>

<sup>1</sup> Faculdade de Belas-Artes, Centro de Investigação e de Estudos em Belas-Artes (CIEBA), Universidade de Lisboa, Largo da Academia Nacional de Belas-Artes, 1249-058 Lisbon, Portugal

{v.almeida, s.rafael}@belasartes.ulisboa.pt

<sup>2</sup> CIAUD – Research Center for Architecture, Urbanism and Design, Lisbon School of Architecture, University of Lisbon, Rua Sá Nogueira, Pólo Universitário, Alto da Ajuda, 1349-055 Lisbon, Portugal  
mneves@fa.ulisboa.pt

**Abstract.** Digital device ubiquity increased the need for HCI's analysis, but academic research is frequently supported in week frameworks. The establishment of a structured body of knowledge is essential for the development of more efficient interfaces and interaction experiences.

Contemporary interface design is grounded in the natural ways that humans interact with each other and/or interact with the environment, fostering the development of transparent interactions through the use of increasingly more natural modalities in HCI. Modalities and dimensions of information are at the centre of UX/UI and, as such, are at the core of the analysis hereby presented. Its naturality is the basis for the establishment of effective cognitive ergonomics in HCI. This paper proposes a *natural human-centred system design* paradigm, expanding the *user centred system design* paradigm towards an effective human-machine interaction centred in natural communication.

**Keywords:** Human-computer interfaces · Cognitive Ergonomics · User interface design · Natural interaction paradigm

## 1 Introduction

Though not a recent issue, production processes' modernization promotes the constant contact between humans and machines, as they increasingly occupy our daily routines. Ergonomics mediates this Human-Machine relationship, with an emphasis on Cognitive Ergonomics, which focus on individuals' memory, attention and perception, as well as other cognitive processes.

The etymological origin of the word Ergonomics derives from the Greek, *ergon* - whose meaning is work – and *nomos* – whose meaning is norms. Ergonomics emerged as a science that sought to determine norms for the use of machines in the workplace, and the interaction of humans with machines. In this context, to interact can be defined as “the set of strategies carried out by the human with the elements of a certain system. The quality of the development of these interactions develop is dependent on the

adequacy that may exist between the human being, who has certain needs, characteristics, capacities, competences and limitations, and the demands of the tasks that he must perform to use a product in a given System" [1].

Cognitive Ergonomics is a discipline self-limitation within ergonomics and the "cognitive" label denotes a focus on human's knowledge and comprehension. E.g., it acknowledges the connections between ergonomics and interface design as a determining discipline in the design of HCI's with a focus on experience and utilization framed by the natural interaction's paradigm.

## 2 Cognitive Ergonomics: A Reading

Cognitive Ergonomics departs from user engagement centred approaches and from the application of methodologies and interface design development tools with a focus on human-machine relation, towards a cognitive approach directly related to humans' cognitive skills and needs, in order to better embroil the will of individuals. The vastness of this field encompasses information systems and information technology, nowadays materialized in a plethora of technological artefacts.

The paradigm shift occurred when interface development turned its focus on "*end-user programming*" [2], taking advantage of spreadsheet software *ease of use* in data representation and in the user's immediate response by facilitating tasks to people with no programming skills. I.e., the advantage of spreadsheets was more motivational than cognitive given the ease with which users could meet their organization and information upsurge needs. Thus emerged interactive user-based systems, which Gerrit van der Veer [3] historically structures in *participatory design* (first presented by Enid Mumford in the work developed by the *Quality of Working Life Group*), *user-centred design* [pioneered by Michael Tauber and the *User Virtual Machine* (UVM) as well as the creation of the *Extended Task-Action Grammar* (ETAG) language applied by Geert de Haan, in what he termed *ETAG-based design*], and *contextual design* (initially proposed by Hugh Beyer and Karen Holtzblatt as an approach centred on a *mainstream* design vision).

### 2.1 Participatory Design: A Contextual Approach

*Participatory design* (PD) established itself as an attitude in the 1970s, originally in the Nordics, with a special emphasis on Norway [4]. Cooperation between unions and researchers enabled the creation of a methodology that brought employees into the computer-aided definition of design and control systems. The approach consisted in integrating the knowledge of employees and their effective participation in a set of diverse activities that included meetings to discuss problems and find work related solutions. Researchers were involved in lectures of clarification and support to the development of the project. This Scandinavian "model" was based on a strong union's influence that encouraged the participation of employees but, although it promoted effective achievements, it was restricted to local contexts and it would have to be subject to review before local solutions could be generalized to wider contexts [5].

Researchers began to look at the possibility of developing tools and techniques for design cooperation. A user-centred contextual approach, with a diverse and less expected context analysis, was thus promoted in order to overcome the previous functional perspective. In practical terms, this PD variation implied the development of tools, techniques and theories that allowed some users to effectively collaborate with designers in what is considered to be *cooperative design* [6].

The Seattle *Participatory Design Conference* (PDC '90) and the book *Design at Work: Cooperative Design of Computer Systems* [7], were landmarks for the systematization of sets of ideas and configurations in the *participatory design* process, with the assumption in mind that teams of designers and collaborators were to create computer applications that could improve working conditions, be under the control of users and facilitate their activity, and focus on solving organizational problems, towards an increase in the quality of the results and a disregard of productivity increases as the sole goal [6].

As such, a change in the design process was envisioned. Instead of developing designers or analyst perspective's centred proposals, *cooperative prototyping* emerged as a possibility that recognized the importance of users and sought the benefits that creative and systematic creation of collaborative mock-ups could provide.

Nonetheless, Stahl [9] sustains that, despite the generous principles behind Mumford's ETHICS [8] (effective technical and human implementation of computer systems) *participatory design* methodology, this was a very difficult and confounding process. Its application burdened heavily innovation projects that for economical and development reasons needed that all parts would be familiarized with the specific technology [9]. So, balances between ethical design premises and the requirements of contemporary research and industry development.

## 2.2 User-Centred Design: The Third Paradigm

Harrison, Tatar and Sengers [10] contemplate the existence of three paradigms that stem from the understanding of human factors and engineering relationship in the development of human-computer interfaces. On two poles, they ponder the first paradigm to be the focus on the concrete problems of human-machine interaction, recognizing that these are their essence, while the second paradigm has its focus on the information that is processed by humans and machines. Thus, arise variations in the ways data rationalization occur and how data is understood by users and computers. The third paradigm shifts both from the pragmatism of the former and the primordial attention to the flows of information of the latter, towards the meaning and implications of that information. Therefore, a perspective centred on the construction of meaning [8] is established in a broader and more interactive way.

*User-centred design* (UCD) is one of the most valuable practices for the integration of human factors into HCI projects and contrasts with performance-structured practices outlined by engineering goals. On the other hand, task-based systems are characterized by the development of user-centred software/hardware and their mental and physical requirements, without favouring the functional capabilities of the system [11]. This is a significant step towards enhancing the user experience (UX) and meeting cognitive needs with simplicity.

### 2.3 Contextual Design

Human-Centred Design (HCD) expands the narrower view of UCD. Its relevance emerged on the assertion that information systems and humans must be acknowledged and understood by designers and researchers in a plural context of peoples' interactions with technologies [12]. As such, it is considered that the changes generated by the introduction of a new system affect not only those who work directly with the devices but also by all the people that somehow are affected by the change.

The above judgement signals the multiplicity of situations that should be considered by the technicians and that are not limited to the simple response of requests of the users whose description is increasingly undefined. UCD should not only focus its methodology on interface interaction analysis but also on the contextual set user/technology. Ritter et al. propose the term "user-centred system design", in line with the SIGCHI 1996's definition of the activity associated with Computer-Human Interaction: "*We enable our members to create and shape how people interact with technology and understand how technologies have an impact in people's lives*" [13].

## 3 Natural Human-Computer Interfaces: The Fourth Paradigm

An interface acts as the bidirectional mediator of communication between user and computer, requiring from both an active engagement at two different levels: they must try to comprehend the processes and mechanisms of communication between the parties, which are intrinsic to the interface at hand; and they must try to comprehend the information that the interface mediates and was emitted by the counterpart [14]. To do this, the interface must position itself as an entity capable of acting as an intermediary between the two agents, since each has incomplete information about the other and its congenital forms of communication.

In this regard, Maybury and Wahlster stress the need for the development of increasingly intelligent interfaces, defining them as those that promote the efficiency and the naturality of the interaction by adding the benefits of adaptability, suitability to the context and support to the development of tasks [15].

There is also the growing desire for the disappearance of the interface, with the cognitive vanishing of the mediator of interactions in order to make them more authentic and closer to reality. In this context, Bolter and Grusin, present the concept of transparency as a characteristic of immediacy; i.e., the absence of mediation or representation. Transparency occurs when the user forgets or even ignores the medium through which it is being transmitted information, thus feeling itself in direct contact with the content [16].

Bolter and Grusin argue that, together, virtual reality, three-dimensional graphics, and interface design are making digital technology transparent [16] so that users feel as if they are part of the system.

In addition to the ease of learning, use and transparency objectives, intelligent interfaces should have the ability to improve interaction by understanding ambiguous,

inaccurate or partial multimodal data, in addition to being able to present such data in a coherent and cohesive way.

### 3.1 Natural Human-Centred System Design

In natural human-to-human communication man selects the medium or set of mediums that he sees as the best fit for the message at hand (e.g., in terms of ease or speed) [17], and that flexibility should also exist in HCI. Hence, the furthering of naturalness in HCI is a relevant goal.

In this regard, we evoke Wiener's premise that human-machine interaction should be modelled with human-to-human communication in mind (as it should, one might add, for machine-to-machine interaction), arguing that communication between humans and machines should not be distinguish from the natural communication that humans engage in [18]. It should be considered irrelevant that the communicative signal is acquired and processed by a machine and not by a human.

Rather than just an element of the dichotomy *natural versus artificial*, naturalness is the fundamental concept of an HCI paradigm that has been around since its inception. In fact, the paradigm of natural interaction is transversal and mostly pursued at academic and engineering levels. It stands on the assumption that not all interaction modalities are equally performant and that those more related to the natural communications and interactions that humans engage in are more suitable and efficient. The natural character of an HCI finds, as such, parallelism to human-to-human or human-to-environment interactions.

The hypothesis that natural interactions have functional relevance is based on the cognitive and perceptual analysis of human communication processes.

Ferri and Paolozzi's stand for the need of human-centred system's architectures with which users can interact through modalities common to human-to-human communication and in a close to natural way so that no adaptation to the computer system or learning is necessary [19]. Therefore, both communicative efficiency and accessibility are promoted, limiting or reducing the need for specific training in the use of the interface.

Natural interfaces are, as per Hansson, Wallberg, and Simsarian, those that appeal to the user's intuition, supporting the transfer of knowledge and skills that he brings from the known environments and contexts he experienced previously [20].

Nonetheless, naturality in HCI should not be considered as a goal in itself but rather as a means to achieve a goal (the efficiency and ease of use), and that's something that one should keep in mind during the selection of the output and input channels at use, either by the human agent or by the computer agent of a given interaction.

Sharma presents a different approach to the concept of natural communication, arguing that the design of more natural communication interfaces must go through the selection of the sensory modalities that more effectively fulfil the task. Additionally, argues that traditional computer systems present sensory modalities that have, in some cases, greater usability than those currently used in ordinary human-to-human communication. Therefore, the naturalness of an interaction is defined from the perspective of enhanced ease of interaction and superior usability, rather than from a strict parallelism with the interactions that humans engage in [21].

### 3.2 Classifying the Natural Nature of Sensory Modalities

Rafael states that HCI input and output channels should be classified in three different classes: natural modalities, artificialized natural modalities and artificial modalities [22].

Rafael defines natural modalities as those that use the sensory channels that are natural for the communication of the specific information's content and are used in an equivalent fashion to the one that humans would use in a human-to-human context (e.g., playing a golf computer game with an haptic interface, while holding the equivalent of a golf stick and executing similar movements), and defines artificial modalities as those that use sensory channels that are different from the former (e.g., playing the same game with text-based commands).

Artificial modalities are, per Rafael, those that use the sensory channels that are natural for the communication of the specific information's content but are used in a dissimilar fashion to the one that humans would use in a human-to-human context (e.g., playing a golf computer game with a haptic interface, but with a different set of movements that in no way resemble the use of a golf stick).

It is a distinction that positions the three classes of modalities in the same level of hierarchical importance, rather than establishing only two classes (natural modalities versus artificial modalities) that would see the artificialization of natural channels as a sub-class of natural modalities (genuinely natural modalities versus artificialized natural modalities) or as a sub-class of artificial modalities (authentic artificial modalities versus artificialized natural modalities).

It's a class organization that builds on Sharma's concept that all modalities are equally important if they adequately fulfil the goal of providing ease of use and efficiency.

## 4 Conclusion

The development of interfaces with a user-centred contextual approach with the focus on both user and technology is a significant step towards enhancing user experience as well as meeting its cognitive needs.

Technological advances progressively promoted the emergence of interfaces more focused on user usability and accessibility, as well as on ubiquity and naturality of use of the digital artefacts.

Historically, the development of interfaces has favoured greater flows of information in the communicative processes between humans and computers, as it has the increase in usability and the decrease of the interaction processes' difficulty [23].

The *natural versus artificial* dichotomy has been at the centre of the development of *proof of concept* interfaces since the emergence of human-computer interfaces development.

The available sensory modalities in human-computer interaction can promote interaction through communicative processes equivalent to those occurring in natural contexts. Although not a requirement, the use of interaction modalities that support themselves on the sensorial channels that are natural in equivalent human-to-human

contexts has been favoured. When they are not available or its use is not possible, artificial modalities are the option and, in some cases, are more efficient.

The *natural human-centred system design* paradigm pursues naturalness in human-computer interfaces and its relationship with the cognitive ergonomics. This paradigm expands the *user-centred system design* and humanizes HCI with its focus on naturalness.

It is relevant in several key areas, with an emphasis on the following: augmented environments, computer-based learning, and information visualization. Intelligent systems and agents, interaction design, interaction through wireless communication networks, interfaces for shared environments, multimedia design, non-verbal interfaces, speech and natural language interfaces, support for creativity, and user support systems are specific fields of application.

## References

1. Rebelo, F.: *Ergonomia no Dia a Dia (Day-to-Day Ergonomics)*. Edições Silabo, Lisboa (2017)
2. Nardi, B.A., Miller, J.R.: The spreadsheet interface: a basis for end-user programming. In: Diaper, D., et al. (eds.) *Human-Computer Interaction, INTERACT 1990*, Amsterdam, North-Holland (1990)
3. Veer, G.C.: Cognitive ergonomics in interface design – discussion of a moving science. *J. Univ. Comput. Sci.* **14**(16), 2614–2629 (2008)
4. Velden, M., Mörtberg, C.: Participatory design and design for values (2012). [https://www.researchgate.net/publication/278713757\\_Participatory\\_Design\\_and\\_Design\\_for\\_Values](https://www.researchgate.net/publication/278713757_Participatory_Design_and_Design_for_Values). Accessed 18 Jan 2019
5. Kyng, M.: Users and computers a contextual approach to design of computer artifacts (1995). <https://pdfs.semanticscholar.org/204e/9c481b6f97fd38feb0d7801b6f03189a9c84.pdf>. Accessed 18 Jan 2019
6. Bødker, S., Grønbaek, K., Kyng, M.: Cooperative design: techniques and experiences from the Scandinavian scene (1995). [https://www.researchgate.net/publication/236877738\\_Cooperative\\_Design\\_Techniques\\_and\\_Experiences\\_From\\_the\\_Scandinavian\\_Scene](https://www.researchgate.net/publication/236877738_Cooperative_Design_Techniques_and_Experiences_From_the_Scandinavian_Scene). Accessed 19 Jan 2019
7. Greenbaum, J., Kyng, M. (eds.): *Design at Work: Cooperative Design of Computer Systems*. Lawrence Erlbaum Associates, Hillsdale (1991)
8. Mumford, E.: *Effective Systems Design and Requirements Analysis: The ETHICS Approach*. Palgrave Macmillan, Basingstoke (1995)
9. Stahl, B.C.: Participatory design as ethical practice – concepts, reality and conditions. *J. Inf. Commun. Ethics Soc.* **12**(1), 10–13 (2014)
10. Harrison, S., Tatar, D., Sengers, P.: The three paradigms of HCI (2007). [https://www.researchgate.net/publication/215835951\\_The\\_three\\_paradigms\\_of\\_HCI](https://www.researchgate.net/publication/215835951_The_three_paradigms_of_HCI). Accessed 20 Jan 2019
11. Cowen, M., Lemon, A., Gill-Hesselgrave, D.: User-centered design (UCD) process description (2014). [https://www.researchgate.net/publication/280051399\\_User-Centered\\_Design\\_UCD\\_Process\\_Description](https://www.researchgate.net/publication/280051399_User-Centered_Design_UCD_Process_Description). Accessed 20 Jan 2019
12. Ritter, F.E., Churchill, E.F., Baxter, G.D.: *Foundations for Designing User-Centered Systems*. Springer, London (2014)
13. <https://sigchi.org/cdg/index.html>

14. Chignell, M.H., Hancock, P.A.: Intelligent interface design. In: Helander, M. (ed.) *Handbook of Human-Computer Interaction*, pp. 969–991. North-Holland, Elsevier (1988)
15. Maybury, M., Wahlster, W.: Intelligent user interfaces: an introduction. In: Maybury, M., Wahlster, W. (eds.) *Readings in Intelligent User Interfaces*. Morgan Kaufmann Publishers (1998)
16. Bolter, J.D., Grusin, R.: *Remediation. Understanding New Media*. The MIT Press, Cambridge (2000)
17. Clark, H., Brennan, S.: Grounding in communication. In: Resnick, L.B., Levine, J., Sag, S. (eds.) *Perspective on Socially Shared Cognition*, pp. 127–149. American Psychological Association, Washington, DC, USA (1991)
18. Wiener, N.: *The Human Use of Human Beings: Cybernetics and Society*, pp. 127–149. Houghton Mifflin, Boston (1954)
19. Ferri, F., Paolozzi, S.: Analyzing multimodal interaction. In: Grifoni, P. (ed.) *Multimodal Human Computer Interaction and Pervasive Services*, pp. 19–33. IGI Global, Hershey, New York (2009)
20. Hansson, P., Wallberg, A., Simsarian, K.: Techniques for “natural” interaction in multi-user CAVE-like environments, In: *Proceedings of the European Conference on Computer Supported Cooperative Work, ECSCW 1997* (1997)
21. Sharma, R., Pavlovic, V.I., Huang, T.S.: Toward multimodal human-computer interface. *Proc. IEEE Multimedia Sig. Process.* **86**(5), 853–869 (1998). Special Issue
22. Rafael, S.: *Para uma Taxonomia da Multimodalidade na Interação Homem-Computador. Proposta Aberta de Classificação Pluridimensional. (Towards a Taxonomy of Multimodality in Human-Computer Interaction. An Open and Pluridimensional Classification Proposal)*. Ph.D. thesis. Lisbon University of Lisbon, Portugal (2015)
23. Abascal, J., Moriyón, R.: Tendencias en interacción persona computador. *Revista Iberoamericana de Inteligencia Artif.* **16**, 9–24 (2002)





# Grains of Memory: User Experience in the SandBox Interactive Installation

Adriana Moreno<sup>1(✉)</sup>, Arminda Guerra Lopes<sup>2</sup>, and Mónica Mendes<sup>3</sup>

<sup>1</sup> ITI/LARSYS, Faculdade de Belas-Artes da Universidade de Lisboa,  
Lisbon, Portugal

adriana.moreno@campus.ul.pt

<sup>2</sup> ITI/LARSYS, Instituto Politécnico de Castelo Branco,  
Castelo Branco, Portugal

<sup>3</sup> ITI/LARSYS, Faculdade de Belas-Artes da Universidade de Lisboa,  
Lisbon, Portugal

**Abstract.** Departing from oral recollections we performed about the sea, we have developed the Sea Grains interactive installation series “SandBox” as a poetic instrument to research how a corpus of memories can be contextualized through digital art to illustrate the identity, emotional and social practices of people with the sea. The installation plays back the collected oral recordings to the participants as they playfully interact with a sandbox, stimulating multiple senses to evoke memories. The conceptualization involved cultural studies, oral history, and neuroscience. Through a series of public exhibitions, we have field-tested and iterated the installation, which progressively became more immersive<sup>4</sup> to better achieve the proposed goals. Our account can help inform artists and User Experience (UI) practitioners exploring and integrating memory into digital media artifacts.

**Keywords:** Immersive technology · Multimedia · Poetics · Identity practices · Memory · Interactive installations · User experience

## 1 Introduction

Studying the sea as a place of memory and identity emerges from the personal experience in the region of Algarve, in Portugal, and also from emotional reports experienced by the people of the Algarve and immigrants that reported the presence of “saudade” (feeling of nostalgia) on different levels – some recalled the games from the time of youth, others from their land of origin. The sea was recurrent in their narratives. This was, fundamentally, the motivation to further study these narratives as an identity process. In a subsequent phase, field records were explored in the Algarve in 2014 and 2015. It was denoted that the narratives were initially verbalized by the people who were contacted, according to the perception of the authors, in relation to the identity expression that the sea involved in that emotional context. As such, the potential to develop a theoretical and practical study was comprehended. This study would raise questions about the sea, its memories and possible modes to feel and explore this place. The experiences collected in the Algarve and the emotional reports

where the sea was present, not only as place of memory [15] but also as metaphorical space capable of enabling and gathering different experiences, identities and relations, led to the creation of this work.

The artistic experience series – SandBox – presented in this article intends through poetic immersion to (re) present life stories, scenarios or simply moments lived from the representation of that place: the sea. To better understand the representational universe in which the sea was inserted, different knowledge areas were explored to help develop those experiences. Subsequently, activities were done, in a collaborative network, with the aim of potentializing the initial concepts and the adequate methods to implement interactivity.

This artistic practice was then developed from a corpus of memories of people who contextualize the sea as an important component of the identity of their emotional relationships and social practices.

## 2 The Theoretical Context

In this section, we introduce the concepts of immersive technology and the experience of the user in a way that we can contextualize our interactive installation. We will also address the concepts of human-computer interaction (HCI) and user experience (UX).

Immersive technology permits to dissipate the line between the physical world and the digital or simulated world, creating a sensation of immersion. This allows to feel present in an immersive environment. The term is used quite often to describe the immersive virtual reality, art installations and videogames, but it is not clear if the use of the term is the same for every user. Torchia et al. [25] refer to immersive technologies as being virtual reality and augmented reality. To the authors, immersive technology refers to all perceptual forms and interactive technologies that establish a link between the physical world and the digital world. This is the ideal form to transform the people and the closest places. Humans make use of various methods to feel the environment through the senses and the installation that we are presenting is an example of this theme; however, it is out of scope from the authors' analysis to get into details about theoretical aspects on this theme.

The area of HCI has been treated in different manners, which allows us to interpret the theories, methods and practices according to the chosen approach [7, 8, 20, 25]. Generally, it concerns the relations between people and machines and the purpose of the practical contributions of research is to reveal unknown information on human behavior and its relation with technology. The practical research methods generally used in HCI include formal experiences, field experiences, field studies, interviews, focus groups, research, usability tests, case studies, daily studies, ethnography, contextual survey and sampling of experiences. The field of HCI has several strategies for evaluating a digital system. But these strategies do not always map well to interactive art installations, as it is not necessarily easy to combine HCI and art. The HCI methods may not measure aspects in interactive art that is of huge importance for the artist [10], for instance emotions and experiences. In this paper, we present the use of the evaluation methods – questionnaires, observation and interviews – in the collection and analysis of data as the basis for the creation and development of the artistic installation SandBox.

Interaction design refers to the functions necessary for interaction between the user and the artifact – also in this area there are several definitions [12, 17, 20]. Trifonova et al. [26] discuss various types of interactions that can be found in interactive art installations, varying from static and dynamic to evolutionary. They collect and group the forms of interaction and how they influence the installation into three perspectives: interaction rules, triggering parameters and content origin. In this case, interactivity depends greatly on what effect the artist want to achieve with the installation and what message she wants to share with the audience. Since the SandBox interactive installation was developed for and with users, we also recurred to user experience, as it refers to the set of elements and factors related to the user's interaction with a particular product, system or service, the result of the interaction being a positive or negative experience. It refers, therefore, to the emotions and attitudes about the use of the product or service and includes practical, experiential, affective and meaningful aspects.

UX “encompasses all aspects of the end-user's interaction with the company, its services, and its products.” (Nielsen-Norman Group 2005). A sample of definitions about user experience is presented as follows. Alben [1]: All the aspects of how people use an interactive product: the way it feels in their hands, how well they understand how it works, how they feel about it while they're using it, how well it serves their purposes, and how well it fits into the entire context in which they are using it. Mäkelä and Fulton Suri [8]: A result of motivated action in a certain context. Hassenzahl and Tractinsky [5]: A consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.) and the context (or the environment) within which the interaction occurs (e.g. organizational/social setting, meaningfulness of the activity, voluntariness of use, etc.).

Sample statements about UX found in different sources and people's opinions include the following: UX is an emergent field without a formal body of knowledge; UX is a term that is elusive to grasp; UX is a momentary feeling a user has while interacting with a system; UX is an attitude towards a system; UX is an emotional bonding with a system; Expectations determine user experience; UX is a value; We cannot design user experience, but we can design for user experience; UX is best viewed in terms of marketing. In this paper several and different user experiences, as described, contributed to improve the feeling of immersiveness of the installation.

### 3 Related Work

This section presents three main examples, one for each core concept: the sandbox practice, the use of sand as a tool for experience interaction and an example from Sánchez [23] addressing the concept of memory on an artistic installation. The SandBox approach is not completely new. Woods et al. [27] described a project which combines 3D visualization applications with a hands-on sandbox exhibit to teach earth science concepts. The augmented reality (AR) sandbox allowed users to create topography models by shaping real sand, which was then augmented in real time by an elevation color map, topographic contour lines, and simulated water. The system

teaches geographic, geologic, and hydrologic concepts such as how to read a topographical map, the meaning of contour lines, watersheds, catchment areas, levees, etc. [27]. The main idea of the AR SandBox comes from an implementation of an open source project at University of California, Davis supported by the National Science Foundation.

KAZI et al. [11] used sand on artistic installations. Sand animation is a performance art technique in which an artist tells stories by creating animated images with sand. Inspired by this medium, Kazi et al. [11] developed a new multi-touch digital artistic medium named SandCanvas that simplifies the creation of sand animations. “The elegance of sand animation lies in the seamless flow of expressive hand gestures that cause images to fluidly evolve, surprising and delighting audiences.”

There are also other art installations, which address concepts like memory and reminiscence [23]. Prey explores digital storytelling and the de/composition of memory and experience. Accordingly to the authors, Prey is a reinvention of lucid childhood dreamscapes and a recreation of imaginary entities made incarnate in the form of three vintage interactive novels. Prey utilizes simple and intimate forms of interactivity.

The presented installation is a novel concept since it uses piezoelectric sensors to generate sounds by moving the participant fingers through sand. Conversely, the exploration of the sea as an audio source can be an interesting opportunity for research.

## 4 Research Methods

HCI focuses on the investigation about relationships between computer technology, human activity and society. It is a multidisciplinary field, which justifies the use of all the social sciences evaluation methods and some engineering research methods.

Qualitative methods of research permitted to get data related with user’s motivations, expectations, and behaviors. Questions are asked, notes registered: “we tend to project our own rationalizations and beliefs onto the actions and beliefs of others” [16].

Methods of collection and analysis depend on the challenge at hand. In this work we used a combination of several qualitative methods: questionnaires, interviews and observation. The questionnaires and interviews were used before the prototype development process and throughout the interaction process. The questions were centered on the functioning of SandBox. Researchers were also interested to collect as much information as possible from the users perspective. The goal was to understand how they felt using an artistic installation and what they expected when using it. The interviews allowed, through the questions asked, to explore a wide range on the problem that we had in hand and to collect information that allowed us to make improvements in our installation.

Observation was done while users interacted with the SandBox installation. There are two main ways in which researchers observe – direct observation and participant observation. Dawson argues that “direct involves the observation of a ‘subject’ in a certain situation” [5]. Denzin participant observation is “a field strategy that simultaneously combines document analysis, interviewing of respondents and informants, direct participation and observation, and introspection [6]”.

In this research participant observation was applied, which is a special mode of observation where the observer is not merely a passive observer. According to Dawson “In participant observation, the researcher immerses herself into a community, culture or context: the action is deliberate and intended to add to knowledge” [5]. It combined participation in the lives of the people under study whilst maintaining a professional distance that allows adequate observation and recording of data.

Users were observed in different physical spaces with venues from Lisbon to Porto, Faro, Guimarães and Coimbra and in different moments between 2016 and 2018. Their behaviors were recorded and listed. Face expressions were very important to add and to complete the data from conversations. The data obtained contributed to improve the physical installation and the interaction elements as well as the database of the memories collected.

#### 4.1 Participants

There were two type of participants: those who were interviewed at Culatra Island (15 people) and those who interacted with the SandBox at exhibitions (around 150 user experience questionnaires were done, from which 87 were fully accomplished). The first type were people that lived in the Portuguese region of Algarve and immigrants who contributed to the installation development with their narratives about the sea, the emotional experiences and life stories that they had with this subject. The second type of participants were exhibition visitors who interacted with the SandBox in different events. The interactions were observed and they were asked to answer a questionnaire, which focused on the usability and user experience of the installation. The goal was to fit their desires and to further develop the prototype improvement.

### 5 The Interactive Installation

SandBox is an interactive installation created in the scope of the Sea Grains research project. It is based on sound memories – oral narratives and sound fragments – collected during two years, 2015 and 2016, in different places of Portugal in order to understand the personal relationships affected by the sea place as a symbolic element of belonging. These memories are records of stories, scenarios, identity relationships and lived moments that discuss the sea place and its context [9].

The following two fragments from the interviews done in the scope of the research underlying this installation present the relation with the sea in a biographical way:

“I wasn’t born here! I was brought by the waves. (...) if I am here it is because this is my destiny. The sea is part of me and I am part of all this. I arrived here I was still a baby, and Culatra was waiting for me. There was a party and everyone came to see me.” (Cláudia Conceição)

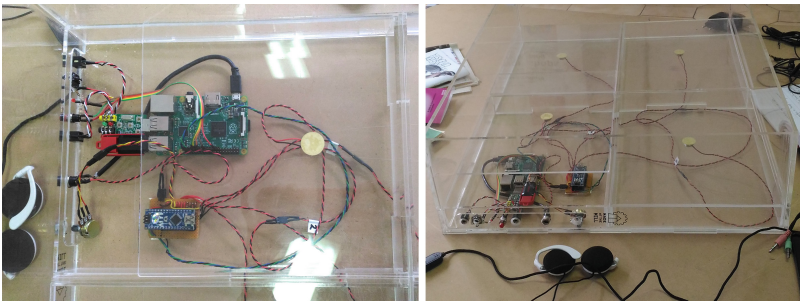
“Whether we live by the sea or we only travel on vacation, whether we grew up near a beach or we only have lived in one occasionally, most of us tend to run our fingers through the sand, examine from close-up the little grains or just watch them slide between our fingers.” (Dolores Steinman)

The first fragment was collected in an interview at Culatra Island and the second was collected by the SandBox interactive installation during an exhibition at #16. ART International Meeting of Art and Technology.

SandBox is an artistic experience immersed in complex and peculiar dimensions - such as nature, human, science and technology - that overlapping enable an immersive poetics capable of operating discussions about this sea place and its relationships in different contexts: emotional, ecological, political and even institutionalized when it relates to the social and essentially economic aspects. For the conceptual and methodological development of this work a continuous dialogue was necessary between different fields of knowledge of art and technology. We also considered issues inherent to the user experience. It was not intended to find concrete answers, but to provoke discussions that permeate the art from the human quotidian with the use of technology, and thus allow to broaden participatory actions that can promote and potentiate developments in the fields of art, as well as to extend this study.

### 5.1 SandBox Technical Rider

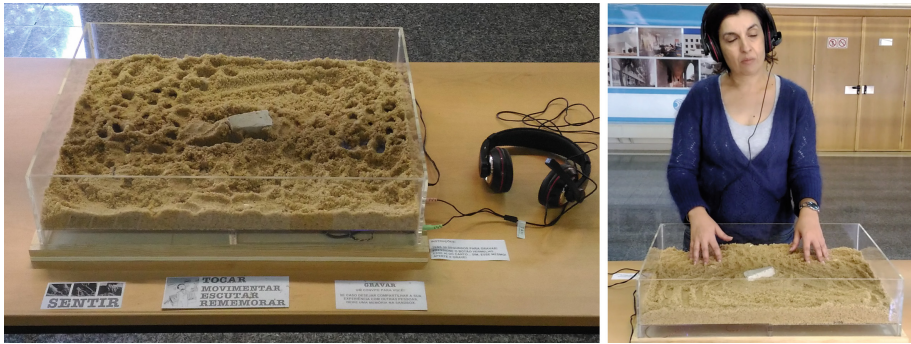
The installation is flexible and can be mounted in different spaces, either indoor or outdoor. It consists of an acrylic box (0.6 mm thick, 60 cm length  $\times$  45 cm width 15 cm height), divided into two compartments: on the inner base it has integrated an Arduino nano, a Raspberry Pi and four sensors; on the external part of the base it has five devices (input and output) – audio output, power on/off, recording, power supply, sensor calibration. In the upper part, a platform is divided into four mobile trays (each with one sensor) that sustain the sand and the movement of the users, and also a pen drive for storage. For listening, either loudspeakers or headphones have been used, depending on the context of the exhibition. In addition, to accommodate the acrylic box, a table with compatible dimensions is used and to connect the power source the requirement is two power outlets (Fig. 1).



**Fig. 1.** Detail of the hardware setup inside the SandBox

All hardware that allows interaction with SandBox, including audio recording and playback, is located at the bottom of the box. The vibrations created by the users when moving the sand are detected by four piezoelectric elements that are measured by an

Arduino microcontroller. If there is enough vibration (as calibrated within an adjustable threshold), a signal is sent from the Arduino to a Linux Raspberry pi computer, which randomly selects and plays a stored audio recording (sonic fragment) on a USB flash drive using OMXplayer. During playback, other recordings are not played back; only when the user stops moving the sand, the sound fragment stops playing and instead continues to hear the background sound fragments of the installation. An additional button on the outside of the box, when pressed, signals the Raspberry Pi to make a new recording of 30 s (see Fig. 2) through the connected microphone, which is then added to the collection of recordings on the flash drive, adding new compositions.



**Fig. 2.** SandBox after an interaction experience at Universidade do Algarve, Faro. At left, the image shows the illustrated caption for recording and, at right, the moment of interaction

## 5.2 SandBox Interaction Experience

The main interactions and experiences that SandBox permits are listed as follows:

1. Interaction Design, as the user interacts with the SandBox through headphones (which allows hearing and reproducing sound fragments such as voices, natural sounds, noises, whistles, and melodies), putting the hands inside the box, moving hands immersed in the sand of the sea that is humid, and when the user stops moving their hands on the sand he/she continues to listen to the sound fragments;
2. The user experiences are the emotional multiple interactions, the user participation as author and narrator of different sound sources, diverse stimulus and perceptions about the sea, and a dialogue space with different sensory scenarios (Fig. 3).

## 6 Results and Discussion

In this section we present the interaction immersed in the universe of sound and suggestions that can be inserted in SandBox resulting from the analysis of this artistic installation by the authors and the participants. SandBox is a listening box “that invites the other to concentrate the whole body in the voice” [2], or in the different sound sources - conventional and nonconventional - that when previously manipulated





**Fig. 3.** Detail of the sea sand and of the underlying microcomputers at the base and users interacting with the SandBox at the SynaïsThesis exhibition.

generate different narrative paths, that is, an appropriation of the memory which was previously revealed.

Sound as an immersive and interactive element simultaneously challenges the memory, since it requires from the user a constant search of its sonic repertoire so that one can understand the compositions that have been constructed. The interaction requested by SandBox suggests listening, and sound (in this context) is

“directed and easily affected by other sounds and materialities that it crosses (...), the sound brings us closer to the source and its identity (...); listening tuns the plural into singular, the multiple into individual, and the body becomes an integral part of that sound” [19].

The user is also a narrator, (co) author and producer of different sound sources, where each one has the power to (re) build its own sonorous territory and not only from “an experience that is submerged in sound” [2] but also in multisensory experiments. This interactive trigger has differentiated parameters with respect to the interactive modalities and, consequently, to the behavior of the user:

“It is common to recognize among the users of the same work, possessing interactive multi-modality, differences of attention about its elements” [13].

In this regard, we emphasize that the SandBox artistic language understands different modalities of stimuli, deepening of experiences and perceptions in relation to the sea. Therefore, the interactive experiences mentioned are formed from the immersion with the box and, later, from the intimate interpretations that each user establishes with the narratives and/or sound fragments. In this sense, we seek from this lived (affective) environment conditions to trigger specific sensors that are able to understand and provide a more intuitive interaction.



The territory is thus signified and introduced in SandBox, but not restricted, because its poetry is constantly redrawn by different sensations and sound effects – cuts of moments experienced or impressions perceived by the users, that is, the identity content manifests from this scenario capable of eliciting a catch of fragmented meaning, which depends on interpretation and reading belonging to each individual [3]. This way, SandBox is always unique and individual, because the user is triggered to be part of the poetics, participating with its own identity. Based on the foregoing, it is perceived that sound plays a key role in the installation. Its ability to evoke emotions, especially through memory, makes the SandBox a space for dialogue that involves and integrates the interaction in multiple sensory scenarios of interaction, that is, the sound beyond its emotional domain – argument to activate dynamic events [4, 18] and feel, enabling the user to create trajectories personified with the medium - in this case, with the sea and its representations.

This way, the sound source allows the user to emerge and connect sensations of the place “sea”, such as: waves crashing on rocks, seagulls, wind blowing, whistling of a person, diving; to extend in its own way an intimate connection with what is heard, felt, remembered, silenced, understood, and so on. In short, the sound source contains countless readings and meanings of the place “sea”.

We now present some aspects that have arisen from using the SandBox. It was observed that some behaviors of interaction with the SandBox undergo situations of overlapping of instants [1], which mark the path of action of (re)territorialization of the constructed experience (personal) through the sound source of the place “sea”. In this particular case, sounds can (re) configure space, memory and emotion through ruptures between the now and something before (time X space) [22].

Still in this sense, the appropriation of the place “sea” made by the user is accomplished by means of its constant readings and interpretations, being able to trigger possible pauses – or another open space for different appropriations.

The understanding of the narratives in the Sandbox is also beyond its physical space. Some of the players were immersed in the box, but they did not record their impressions, as they felt intimidated by the use of the microphone at the time of recording; however, they expressed what they felt by talking aloud or demonstrating their emotion. From this observation, the way of listening was changed as well as of recording. Instead of the use of columns, a headset is now attached to a microphone so that the speakers can listen and record their memories and feelings with more privacy (Fig. 4).

In any case, the involvement of the user in appropriating the SandBox extends access paths to very particular readings, and for this reason it was necessary to reconfigure the prototypes of the SandBox to better enable the interaction of the users, as described below.

1st modification: the form of listening was altered – a headset coupled to a microphone and the addition of a new sensor (in the form of a stone) that can interrupt the listening, being the triggering of the narratives at the discretion of the user. It was hoped that with the adjustments, SandBox would obtain engagement through the recordings and not only in a visual and/or verbal way (Fig. 5).

2nd modification: the removal of the central sensor – when the trajectories of the hands of the users were observed, we noticed that the stone prevented a more



**Fig. 4.** First version of SandBox at the informal art show Noc Noc Guimarães, October 2016



**Fig. 5.** SandBox version with central sensor

spontaneous movement, because it was in the center of the box delimiting the space of interaction. In addition, the touch on the stone became constant, which could indicate that the user was not comfortable with the listening and when touching the stone knew that something new could arise. Before this doubt was asked (through a questionnaire) to some users how they would describe their experience and specifically about the presence of the stone in the middle of the installation box. The result was interesting because the initial suspicions about the discomfort did not proceed, but we had the curiosity as a determining action for the behaviour of the user: (A) an element in the center of the box instigated the users to touch, that is, they wanted to pick up the stone to observe what happened; (B) for the curiosity to hear a new sound fragment (Fig. 6).



**Fig. 6.** Left: the SandBox with the central sensor in stone form in the exhibition at Museu do Chiado during XcoAx. Right: the version of the installation without the stone exhibited at the Fine Ars School of the University of Lisbon gallery, 2017.

After alterations in the box, new questions arose: could SandBox present the sea as a place of possibilities of synesthetic production capable of influencing human sensory perception? SandBox could conduct a synesthetic experience, that is, conditions to trigger the various senses of the person who experienced it. From a first prototype we realized that the SandBox provided a multisensory experience to the users – tactile, olfactory and auditory. Initially, the tactile immersion of the user is requested to activate the sensors at the submerged acrylic surface of sea sand, evoked by memories, which reveal (randomly) different identity engagements and, consequently, diverse cultural displacement contexts, even in case of apparently “common” places.

The (re) constructions and deconstructions of the sound expressions, previously stored in the SandBox, allowed the user to (re) compose the SandBox through their own sonorous landscapes. In this way, the narratives become either intermittent or continuous, since the process of (re) composition produced by the user, like the SandBox, is not a linear path, but a construct of different sound fragments and memories that it has experienced or their identity practices with the theme. In this sense, the sea is a place of subjectivity, often linked to the memory and identity of subjects, which make this place a place of sensations, capable of producing or revealing visuals and meanings in a dynamic process.

In this light, various forms of symbolic representations present in this place can be extracted and susceptible to new readings. Thus, we believe that this interactive installation, as well as the study that surrounds it, bring possibilities of contribution in the artistic and social field with regard to the themes of a community or personal nature that show the forms of interaction between human and nature and their social identity links presented through multimedia art, which allowed to confront the different ways of seeing the context – sometimes particular, others representing plural feelings and also reciprocal.

## 7 Conclusions

We consider that the interactive installation SandBox – Grains of Memory is an active and continuous poetic process, capable of individually apprehending new soundscapes and, thus, expanding other ways of experiencing the identity relations with the place “sea”. In this sense, we describe some results and experiences, both about the technical production of the installation and the immersive experiences of the users in the exhibitions. In the immersive experiences, we observed that the use of time (duration of experience) and space (area covered by the box) influenced the activity of SandBox. Each user established their immersion levels with the box, resulting in different multisensory experiences, that is, according to the tactile path established by the user. The box was, therefore, adjusted to the rhythm imposed by the movements.

Many users fixed their hands only to one part of the box, giving more action to the sensors located on that surface, while the other sensors entered a kind of inertia. Following this behaviour, the next users, when manipulating the sand in these inactive areas, found it more difficult to interact with the whole installation, intuitively forcing the central sensor (positioned by a rock) to restart the box. On the technical construction, we made some adjustments to have more flow between the user and the box. We noticed, for example, that the use of headphones changed the way the users reacted by listening to the sound fragments, making them more sensitive to listening – sound details that perhaps transmitted by speakers would not give the necessary intimacy. In the face of this change, SandBox has made more recordings than it did the first time it was exhibited. SandBox is therefore fulfilling its objectives as an experimental work, changing to each new experiential context and technical challenge.

In the recent SandBox version (prototype 3), presented at the In Shadow 2017 Festival, the user had the entire surface of the box to go through. As they moved the sand, they listened to the fragments that were allowed, and as the movement stopped, they listened. In this case, it was noticed that there was more interaction of the hands in the sand because the process is more intuitive than in the first versions. With the SandBox artistic experience, important discoveries have been made regarding the theme of the sea and its contexts, especially when revealing different ways of interacting with this place and different practices of belonging presented in narratives recorded over a year of exhibitions. As a result, we believe that its objectives are fulfilled whilst experimental work, changing to each new experiential context and technical challenge. In the next stage, we intend to broaden previous experiences with SandBox in order to embrace new identity references in the search for intimate narratives and different soundscapes.

**Acknowledgments.** The authors would like to thank: all the users who participated in the SandBox; CAPES research funding; Tiago Rorke, who collaborated developing the code for the installation. This research was partially funded by ITI, through LARSYS, Projeto Estratégico LA9-UID/UID/EEA/50009/2019.

## References

1. Bachelard, G.: A intuição do instante. Verus editora, Campinas (2007)
2. Barthes, R.: A preparação do romance II. A obra como Vontade. Notas de curso no Collège de France 1978–1980. Tradução de Leyla Perrone-Moisés. Martins Fontes, São Paulo (2005)
3. Barthes, R.: O Óbvio e o Obtuso. (Trad. Isabel Pascoal). Edições 70, Lisboa (2009)
4. Blesser, B., Salter, L.R.: Spaces Speak, are You Listening?: Experiencing Aural Architecture. The MIT Press, Cambridge (2007)
5. Dawson, C.: A Practical Guide to Research Methods, 3rd edn. How to Books Ltd., Oxford (2007)
6. Denzin, N.: Interpretive Biography. Sage, Newbury Park (1989)
7. Dix, A.J., Finlay, J., Abowd, G., Beale, R.: Human-Computer Interaction, 2nd edn. Prentice Hall, Englewood Cliffs (1998)
8. Hakansson, M.: Lecture on Human-Computer Interaction. Archives of the Intelligent System Design. IT University, Denmark, Copenhagen (2005)
9. Hall, S.: A identidade cultural na pós-modernidade, 11ª ed. DP&A, Rio de Janeiro (2006)
10. Höök, K., Sengers, P., Andersson, G.: Sense and sensibility: evaluation and interactive art, no. 5, pp. 241–248, New Horizons (2003)
11. Kazi, R.H., Chua, K.C., Zhao, S., Davis, R., Low, K.-L.: SandCanvas: new possibilities in sand animation. In: CHI 2011 Extended Abstracts on Human Factors in Computing Systems (CHI EA 2011) (2011)
12. Kolko, J.: Thoughts on Interaction Design (2009). ISBN 978-0-12-378624-1
13. Leote, R.: Multisensorialidade e sinestesia: poéticas possíveis? ARS (São Paulo) **12**(24) 42–61 (2014). <http://dx.doi.org/10.11606/issn.2178-0447.ars.2014.96737>. ISSN 1678-5320
14. Lowgren, J.: Interaction design - brief intro. In: Soegaard, M., Dam, R.F. (eds.). The Encyclopedia of Human-Computer Interaction, 2nd edn. The Interaction Design Foundation, Aarhus, Denmark (2014). [https://www.interaction-design.org/encyclopedia/interaction\\_design.html](https://www.interaction-design.org/encyclopedia/interaction_design.html). Accessed 10 Jan 15
15. McGaugh, J.L.: Memory and Emotion: The Making of Lasting Memories. Weidenfeld & Nicolson, London (2003)
16. Norman, D.: The Design of Everyday Things. Basic Books, New York (2013). Revised Edition
17. Norman, D.: Emotion and design: attractive things work better. Interact. Mag. **ix**(4), 36–42 (2002)
18. Pallasmaa, J.: The Eyes of the Skin: Architecture and the Senses, 2ª ed. Wiley, Hoboken (2005)
19. Pinto, J.G., Ribeiro, L.C.: O Som e o Evento. Universidade do Porto. VII Congresso SOPCOM (2011)
20. Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S., Carey, T.: Human-Computer Interaction. Addison-Wesley Longman Ltd., Bosto (1994)
21. Preece, J., Sharp, H., Rogers, Y.: Interaction Design: Beyond Human-Computer Interaction. Wiley, Hoboken (2015)
22. Ricoeur, P.: A memória, a história, o esquecimento. UNICAMP, Campinas (2007)
23. Sánchez, T.R., Seo, J.H.: Prey: De/composing memory and experience. In: Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA 2017) (2017)
24. Te'eni, D., Carey, J., Zhang, P.: Human Computer Interaction: Developing Effective Organizational Information Systems. Wiley, Hoboken (2007)

25. Torchia, Kalal, C.S., Iwamoto, M., Roberto, M., Merchant, K., Siviero, A., Mainelli, T., Ahuja, Y.: IDC's worldwide semiannual augmented reality and virtual reality spending guide taxonomy (2017)
26. Trifonova, A., Jaccheri, L., Bergaust, K.: Software engineering issues in interactive installation art. *Int. J. Arts Technol.* **1**(1), 43–65 (2008)
27. Woods, T.L., Reed, S., Hsi, S., Woods, J.A., Woods, M.R.: Pilot study using the augmented reality sandbox to teach topographic maps and surficial processes in introductory geology labs. *J. Geosci. Educ.* **64**, 199–214 (2016)



# Measure of the Lived and Functional Effects of Gamification: An Experimental Study in a Professional Context

Eric Brangier<sup>1</sup>(✉) and Cathie Marache-Francisco<sup>2</sup>

<sup>1</sup> Université de Lorraine – Metz, PErSEUs EA 7312,  
Psychologie Ergonomique et Sociale pour l'Expérience Utilisateurs,  
BP 30309 Île du Saulcy, 57006 Metz, France  
Eric.Brangier@univ-lorraine.fr

<sup>2</sup> Amadeus, 485 Route Pin Montard, 06560 Sophia Antipolis, France

**Abstract.** The aim of this research is to study the effects of gamification on end users. Several points of attention have already been highlighted in various research studies (e.g., motivational problems, corporate culture issues, ambiguous social relationships, cultural literacy and gamification paradox). The focus of our experimental study is the evaluation of the impact of a gamified system compared to a non-gamified system on the direct perception of its users. 20 employees tested two versions of the same application: one was gamified and the other one was not-gamified. Then, they responded to different scale-based questions, followed by an interview. It appears that gamification leads to a modification of the lived aspects of user experience without having any effect on the functional aspects. Thus, the application is perceived as being more playful, more engaging, more moving, more symbiotic. This research underlines that, in a work environment, gamification must be applied with an acute knowledge of its impacts.

**Keywords:** User experience · Gamification · Hedonism · Productivity · Impact

## 1 Introduction

Computer and mobile applications increasingly use gamification to enhance user engagement and motivation and to support behavioral change. Gamification is “the use of game design elements in non-game contexts” [6, 7]. More specifically, gamification is “the use of game elements in non-game systems - usually digital system -, adapted to user profiles to motivate and engage them, with an emphasis on pleasant or even playful participation. Gamification is therefore a new type of use of certain game principles, which (1) consists of a process seeking to increase user engagement and motivation and lead the user to carry out a task which they wouldn't have carried out spontaneously with the same efficiency, and, (2) a form of presentation of human-machine interactions according to criteria relating to the game world” [14]. The recipes that have made video games so successful are transferred into the professional field, without often having any precise feedback on the impacts of gamification on employees.

Although the amount of gamified systems has increased in recent years, it appears that their evaluations remain rare. The purpose of our research is to present a gamification measurement process of the operators of a computer company, in order to identify the positive and negative aspects of this technique.

First of all, we will define the main orientations in the field of gamification and user experience and then describe the problematic points of this study. Then, we will describe our methodology that seeks to compare a gamified and a non-gamified version of the same application. The results will finally be discussed in the light of the theory of technosymbiosis [1, 3, 5].

## 2 User Experience and Gamification

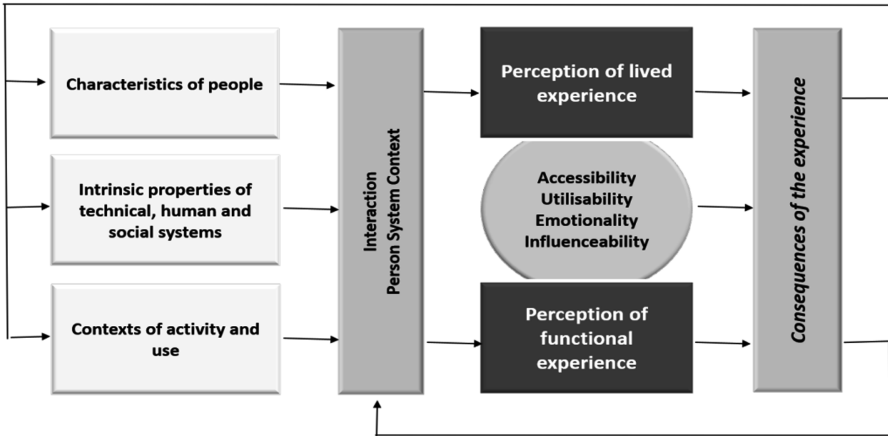
The development of ergonomics is partly linked to the development of new technologies, as the latter have raised the question of their adaptation to human capacities. Recently, the notion of HCI (Human Computer Interaction) ergonomics has been overtaken by “user experience”. The user experience (UX, User eXperience) is both a disciplinary crossroads and a key concept to understand the entirety of human-machine interaction. UX analyses, corrects and designs the functional and lived interactions of all types of users in all types of work and/or social life situations, with all types of human or technological products, services and systems. The goal is to guarantee (1) a high level of user satisfaction before, during and after use, (2) a high quality of interaction, as well as (3) a high technical performance. UX is increasingly seen as a system consisting of (Fig. 1):

- inputs in relation to each other (characteristics of individuals; intrinsic properties of human, technical and social systems; context of activity and use);
- the interaction itself, which has structuring properties;
- experienced and functional perception of technology (access, convenience, emotion, persuasion);
- outputs that are the consequences of the experience, which in turn have effects on inputs and person-system-context interaction.

Thus, UX includes two important poles: the functional dimension and the lived dimension. It may refer to a strict functional need, just as it may relate to intellectual or emotional motivations or social experiences. With UX, human-machine interaction is encapsulated in a more general activity where social roles take place, skills are developed, and social players are built. UX comprises [4]:

- A functional (interactive) experience that emphasizes the utilitarian purpose. To ensure this function, the HCI has adopted practical criteria that simplifies access to the function. From a functional point of view, the user interface should therefore be seen as a means for the human being to master the technique and the functions related to its implementation. It leads to the accessibility and usability criteria.
- A lived (experiential) experience that corresponds to the increased search for emotions and memorable sensations where we will interact as much for the setting





**Fig. 1.** Elements of the user experience.

and atmosphere as for the product or service [9]. The interaction is very often attractive - we obviously think of video games - where the user is caught in a spiral of engaging interactions, where s/he has the opportunity to live an unprecedented experience of spectacular emotions, individual commitments or clandestine persuasions. Here, the user interface is therefore to be seen as a means for the human being to live a poignant, emotional and engaging experience. It leads to the criteria of emotion and persuasion.

Gamified systems offer new human-technology interfaces that combine playful graphic presentations with new types of professional constraints [2, 19]. The aim is to get inspiration from games and extract principles and techniques that could lead to improved digital systems and greater appeal to the professional audience. When, for example, the financial tracking tables are austere but usable, gamification proposes to make them just as usable, but this time presented with more humor, attractiveness, social value, competition or even pleasure in use [10, 12, 14]. Thus, gamification would represent the ideal of the employee who knows what to do and how to do it, and who gives himself entirely, as described by [11]: “so-called game-like behavior: focus on the task at hand, multitasking under pressure, work overtime without discontented attitude, always keep retrying when fails, etc.”. Consequently, these gamification techniques question ergonomics in the sense that they should affect the functional and/or lived aspects of UX. If so, how?

### 3 Problem and Method

#### 3.1 Problematic

Our main problem is to identify the effects of gamification, especially when it is applied in a professional setting. The premise is that it generates two types of impacts: lived and functional.

First, gamification is an enrichment of the lived experience at two levels: (1) increase of the playful functions of the interface and (2) increase of the creative functions of the interface (i.e., the ability of the user to be more creative) through greater involvement and motivation to explore the system. In addition, the emotional aspect which is core to gamification is also central. It often involves relying on users' motivations and adding an attractive overlay to generate positive emotions, and a positive attitude towards the system. Gamification could also be related to the notion of tech-nosymbiosis [1, 3, 5, 8] which underlines a strong correlation, a kind of fusion between man and technology. Hybridized, the human being becomes a user to be involved, to be seduced and to whom we will propose a personalized interaction, through on the one hand solicitations that will resonate with his/her own motivations and on the other hand a guiding interactivity that will support and optimize his cognitive efforts. The notion of symbiosis describes technology as an extension of the human with whom it lives in a relationship of co-dependence. The question is no longer to accept or reject technology but to consider that humans shape technology, which in turn shapes humans.

Secondly, gamification relates to functional effects that would be negative. If some elements are intended to support the user's task, they inadvertently add an overlay that can have several negative consequences, including:

- Diverting users from the primary purpose of the system and leading them to lose sight of the business context in which the interaction takes place through quick reward loops and a loss of the sense of effort at work;
- Leading to a rejection of the system, in particular through the perception of an intent to infantilize and/or manipulate as in the case of the previous study;
- Undermining the perception of the system's utility, insofar as the previous study revealed that this notion was not present in the context of gamification;
- Decreasing perceived efficiency by being complex and time-consuming.

This leads to two general assumptions:

- H1: Gamification is a source of added value for the lived experience (increase in playful, emotional dimensions, attitude, creativity, symbiosis);
- H2: Gamification undermines the experience through its functional impact (decreased perception of utility, ambiguous perception of the system).

### 3.2 Methodology

20 employees of a professional software company were surveyed for this study: 11 men and 9 women of an average age 34.65 years (standard deviation: 9.26). Of these, 18 subjects analyze data as part of their employment. 11 subjects reported playing video games. 5 subjects are familiar with gamification, 7 by name and 8 not at all. Subjects were recruited directly by electronic means as well as by posting within the company.

The hardware consists of a habituation scenario with the use of iPad Clock and Maps applications. It is conducted through a PowerPoint. A scenario for using the professional mobile application is available in two versions: gamified and non-gamified screens. Functional equivalence is ensured (Fig. 2). The system was gamified using methods [12, 13, 15–17]. The hardware also includes the Morae recording software, an

instruction sheet, data collection, and finally questionnaires: satisfaction during the handover (Schmitt 2012), items emotions and attitudes [18], creativity, individual and system symbiosis [8], and of course a profile characterization (Fig. 2).



**Fig. 2.** Examples of screens from the gamified version placed in parallel with the non-gamified version.

The subjects carry out a first phase of habituation with the conduct of the study on traditional iPad applications. They observe the use of Clock and Maps applications according to a predefined scenario. They then carry out the two phases of the experiment: they are first confronted with one of the two versions of the professional mobile application and then with another (counterbalancing between the subjects, with a random choice). The “contentment” item is surveyed throughout the study at key moments in the scenario, and the user indicates his/her position aloud. The same questionnaire is presented at the end of each phase and a questionnaire providing information on the user’s profile is displayed at the end of the experiment. In all cases, the subjects scroll through the PowerPoint themselves in order to be able to observe the details of the interface at their own pace. The following are measured:

- Video and audio recording of the handover via the Morae system;
- Questionnaires on 7-points Likert scales: contentment during the handover (Schmitt 2012), emotional items and attitude [18], creativity, individual and system symbiosis [8], user profile.

The test of the two hypotheses is based on several indicators.

**Hypothesis 1: Regarding the lived impact, higher “lived measures” scores are expected for the gamified system than for the non-gamified system.**

- H1a: increase in the playful score.
- H1b: increase in the contentment score.
- H1c: increase in the positive emotions score.
- H1d: increase in the attitude score.
- H1e: increase in the creativity score.
- H1f: increase in the individual symbiosis score.
- H1g: increase in the system symbiosis score.

**Hypothesis 2: Regarding functional impact, higher “functional measures” scores are expected for the non-gamified system than for the gamified system.**

- H2a: A gamified system induces a lower utility perception score than a normal system.
- Thus, the verbalizations of the subjects will present positive and negative arguments according to the gamified version compared to the non-gamified version. These verbalizations are also indicators of the user experience (lived and functional).

## 4 Results

All the results are statistically analyzed using mean comparison tests (tests of normality and homogeneity of variances) led to the choice of the type of test (parametric: Student's t; non-parametric: Wilcoxon).

### 4.1 Results: Impacts on the Lived Experience

**H1a: A gamified system induces a higher score on the playful item than a normal system.** The hypothesis is validated. The average on the play item of the gamified version is significantly higher than that of the non-gamified version at  $p < 0.02$  ( $N = 8$ ;  $T = 0$ ;  $Z = 2.52$ ). Thus, it is ( $mg = \text{mean gamified}$ )  $mg = 6.15$  ( $sg = 0.99$ ,  $sg = \text{standard deviation gamified}$ ) while that of the non-gamified version is ( $mn = \text{mean non-gamified}$ )  $mn = 5.50$  ( $sn = 1.15$ ;  $sn = \text{standard deviation non-gamified}$ ). By analyzing the scores distribution, it appears that if the medians and extremes are identical, there is a real difference in score at the playful item in terms of the interquartile range. The score assigned to the gamified system extends to a high score, that of the non-gamified system to a lower score.

**H1b: A gamified system induces a higher contentment score than a normal system.** The hypothesis is validated. The average regarding the contentment item of the gamified version is significantly higher than that of the non-gamified version at  $p < 0.01$  ( $t [19] = 3.66$ ). It is in fact  $mg = 2.18$  ( $sg = 0.62$ ) while that of the non-gamified version is  $mn = 1.75$  ( $sn = 0.66$ ). By analyzing the scores, it can be seen that the median is higher for the score assigned to the gamified system compared to the non-gamified system, with more narrow extremes and a substantially similar interquartile range.

**H1c: A gamified system induces a higher positive emotion score than a normal system.** The hypothesis is validated. The mean positive emotions (score calculated: mean of responses to positive emotion items) of the gamified version is significantly higher than that of the non-game version at  $p < 0.01$  ( $t [19] = 2.99$ ). Indeed, it is  $mg = 5.07$  ( $sg = 0.76$ ) while that of the non-gamified version is  $mn = 4.40$  ( $sn = 1.10$ ). It is interesting to note that the median is higher for the score assigned to the gamified system compared to the non-gamified system, with more narrowly defined extremes and interquartile range.

**H1d: A gamified system induces a higher attitude score than a normal system.** The hypothesis cannot be validated. The mean attitude (score calculated: average of responses to attitude items) of the gamified version is  $mg = 6.13$  ( $sg = 0.65$ ) while that of the non-gamified version is  $mn = 5.63$  ( $sn = 1$ ). However, the difference is not significant at  $p = 0.052$  ( $t [19] = 2.07$ ).

**H1e: A gamified system induces a higher creativity score than a normal system.** The hypothesis cannot be validated. The average creativity of the gamified version is  $mg = 5.6$  ( $sg = 1.23$ ) while that of the non-gamified version is  $mn = 5$  ( $sn = 1.65$ ). The difference is not significant at  $p = 0.09$  ( $N = 12$ ;  $T = 18$ ;  $Z = 1.65$ ).

**H1f: A gamified system induces a higher individual symbiosis score than a normal system.** The hypothesis is validated. The mean individual symbiosis (calculated score: mean of responses to individual symbiosis items) of the gamified version is significantly higher than that of the non-gamified version at  $p < 0.01$  ( $t [19] = 3.75$ ). It is indeed  $mg = 5.46$  ( $sg = 0.74$ ) while the non-gamified version is  $mn = 4.95$  ( $sn = 0.70$ ). Regarding the distribution of responses, the median is higher for the score assigned to the gamified system compared to the non-gamified system, with narrower extremes.

**H1g: A gamified system induces a higher system symbiosis score than a normal system.** The hypothesis is validated. The system symbiosis mean (calculated score: average of responses to system symbiosis items) of the gamified version is significantly higher than that of the non-gamified version at  $p < 0.01$  ( $t [19] = 3.08$ ). It is indeed  $mg = 5.38$  ( $sg = 0.76$ ) while that of the non-gamified version is  $mn = 4.76$  ( $sn = 0.93$ ). Regarding the distribution of responses, the median is higher for the score assigned to the gamified system compared to the non-gamified system, with narrower extremes. The interquartile range is also higher in the case of the non-gamified system, with a wider distribution below the median.

## 4.2 Results: Impacts on Functional Experience (Experiment)

**H2a: A gamified system induces a lower utility perception score than a normal system.** The average utility perception of the gamified version is  $mg = 5.95$  ( $sg = 0.90$ ) while that of the non-gamified version is  $mn = 5.40$  ( $sn = 1.34$ ). However, the difference is not significant at  $p = 0.052$  ( $N = 14$ ;  $T = 21.5$ ;  $Z = 1.95$ ). Despite a downward trend in the utility perception, the hypothesis cannot be validated.

### Qualitative Results: Study of Verbalizations

The qualitative analysis of post-experimental verbalizations reveals that different themes appear repeatedly between subjects, and that the latter refer to both positive and negative aspects of gamification, thus revealing a certain ambiguity regarding the notion. The hypothesis is therefore validated.

#### Positive Criticisms

First, the subjects expressed positive opinions regarding the gamified version, and in particular regarding its playful aspect, more present than in the standard version.

- I3: *“well, it has a little game side in a way, a little Foursquare side, a little playful side (...) I prefer the first in terms of IU and the second in terms of spirit (...) The 2nd version I find it uh the playful side uh the side I learn by having fun, I win badges uh, I measure myself against my colleagues (...) I found it nice.”*
- I7: [badges] *“Okay, it’s like in the games”*
- I9: *“it’s like in a game, it’s good when you’re bored”*
- I10: *“[the non-gamified version] it’s usable but less playful”*
- I16: *“It’s funny, isn’t it?”*

In addition, subjects sometimes smiled or laughed when viewing the gamified version. Far from being a mockery, it seems to be indicator of their surprise and appreciation. For example, one of them laughed while he had asked for a visualization to be deleted and it was falling apart. Then, users reported more pleasure in the interaction, with a description of a system that would be «nice», «sexy», friendly and dynamic

- I5: *“easy navigation capacity, the information is immediately analyzed, sorted, etc. in a very user-friendly way, very simple (...) visually it is very pleasant (...) more dynamic, with more conviviality, it’s just that it had more relief”.*
- I9: *“it was like more colorful, more interactive, with like pictures of the people, more personal. And it was less serious (...) and it would like grab more your attention»*
- I12: *“Before it was more fun, more encouraging, now [non-gamified version] we don’t want to look for or understand (...) now it’s corporate software, the other one was cooler (...) It’s classic but then it does its job (...) It’s like you took a grenadine and after a mineral water.... the mineral water can be very good on its own”.*
- I14: *“It was certainly the first[gamification] that gave me more inspiration. I think it was much more... I imagine it was much more interactive, much more enjoyable (...) a little less straightforward (...) it made me a little more enthusiastic (...) I wonder why people would prefer the soberer version, maybe it seems more serious to them, maybe, though if I think we can be serious with a colorful atmosphere”.*

The subjects also commented on the innovative aspect of gamification. Thus, the gamified version would be more inspiring, more modern and less classic.

- I10: *“[non-gamified version] it’s a basic application, it’s a little more classic, there’s less surprise and novelty”.*

- I11: *“more modern”*
- I13: *“it’s more human, it’s more modern and it’s easier”*.

Finally, it should be noted that the subjects also mentioned the guiding aspect of the gamified version. It was perceived as more intuitive, and as more easily drawing attention to the relevant.

- I12: *“it’s not like the old Excel all ugly, you don’t know where to look for the data all that, here it’s more highlighted, it’s more intuitive (...) we’re less into looking for to see the info of being on your graph to say s\*\* where is the data you need to see”*.
- I13: *“there is this help which actually is very useful (...) it is generally well done”*.
- I18: *“that’s really nice, I feel much more confident now (...) and secure (...) The application is creating a relationship with me (...) I am encouraged, it increases adoption and confidence”*.

#### *Negative Criticisms*

Although the subjects showed a preference for the gamified version, this does not mean that they fully agree with it. One criticism is that gamification constitutes noise in relation to the primary purpose of the application. The users spoke of distraction, pollution, complexity, lack of usefulness or even lack of professionalism.

- I13: *“it’s visual pollution insofar as it doesn’t bring anything, it’s just a graph”*.
- I20: *“it’s always to use animations in moderation in general because, there are sides, um, it’s a little fun but after that, it’s not a gadget either, it’s still a product used for professional purposes”*.

The subjects also spoke, in the continuity of the notion of noise, of diversion of purpose.

- I12: *“these badges stories and all that for me it’s useless (...) it diverts the objective, it’s a thing that instead of focusing on data, on dashboards, on all that, we do... what must be a tool we make it a purpose (...) you’re in a company, your employees, well they’re there, they have badges, they’re all happy... yeah, ok, for the company what is it for? It’s no use, it’s just hot air. And don’t tell me it’s like motivation, bloody stuff, that’s not how you motivate people (...) and then the competition goes on for the one who does the most dashboards?”*.
- I17: *“Now we’re on the social side, and now it’s not too much my delirium (...) and in the professional world even less (...) the goal is laudable you see, but I think that in the end it can deviate from the original goal (...) finally you will maybe use it for something else you see (...) the like, the feed”*.

Finally, different subjects reported negative emotions during interaction with the gamified system.

- I6: *“the image that will break down like that finally it’s very, very negative in fact”*.
- I10: *“[badges] I know I did well, but it makes me feel like we’re rewarding something difficult”*.

## 5 Discussion and Conclusion

The objective of this study was to determine the effect of gamification on the perception of functional and lived experience. Two theoretical hypotheses have been formulated in this context:

- H1: Gamification increases the lived aspects of the experience (more playful perception, positive emotions, attitude, creativity, symbiosis),
- H2: Gamification undermines the functional aspects of the experience (decreased perception of utility, ambiguous perception of the system).

In order to test them, a gamified and a non-gamified version of the same professional mobile application were presented to users. Questionnaires were used, and verbalizations were recorded to enrich the information collected.

Both operational assumptions have been partially validated. There is no influence of gamification on the attitude or creativity score. However, it impacts playfulness perception, contentment, positive emotions, individual symbiosis and system symbiosis. It is positively affected by the use of gamification compared to a neutral system. Concerning the functional impact of gamification, while no difference in terms of perceived utility was observed, positive and negative arguments were found in the verbalizations, revealing an ambiguous experience. If the gamified version generates positive criticism (playful, pleasant, innovative, guiding) and if more than 75% of subjects say they prefer it, there is no difference in terms of attitude and perception of usefulness with the non-gamified version. Both systems therefore lead to a favorable state of mind and are perceived as useful. The same applies to the question of creativity with the data: both systems are identified as allowing equivalent analytical work to be carried out. Thus, the difference operates on the relationship that is established through gamification: a relationship that is more emotional, more playful, more guiding and finally more symbiotic. This allows us to validate the idea of a new mode of interaction that involves more emotions, more symbiosis through, in particular, increased feelings of control and adaptation, and the presence of an emotional balance. Finally, gamification seems to achieve its parallel goals of seduction and pleasure while implicitly pushing for productivity, since a dependence is established with this symbiotic relationship, and users are/will probably be more controlled and standardized.

In addition, as the verbalizations reveal, the gamified system has raised negative criticism. Some elements, whether visual or functional, were perceived as useless and disturbing (some subjects even talked about diversion from the initial professional goal), or even as inducers of negative emotions (e.g., excessive reward giving an impression of difficulty when the task is simple, or even stressful metaphors). This reflects the ambiguity of gamification [17]. Thus, it seems that we are in the context of interactions aiming at stimulating and generating pleasure even if it means sinking into «too much», especially in the case of subjects who have a clear vision of their objective and who do not wish to interfere with its resolution. The subjects thus highlighted the distance from the professional goal and, by extension, the meaning of work. With this and the notion of symbiosis and control, the whole paradox of gamification emerges through this study.



This study also raises the question of the relative effectiveness of gamification. Some users have shown a clear preference for the non-gamified version. If gamification generates a priori an incentive relationship for action, it is therefore not enough to predict its effects. It is the user who will decide whether this mode of interaction is appropriate for his/her activity and whether this object is an instrument. Thus, some subjects stated that elements of the gamified version provided added value on the playful, hedonic and guiding dimensions because it fit positively into their work context and would allow them to achieve it in a more pleasant way and with more guidance and confidence (especially for the most inexperienced persons). On the other hand, elements were perceived as noise generators, potential goal diverters and finally inducers of negative emotions. In these situations, gamification elements were rejected or ignored because they did not appear to be consistent with the expectations of the work context.

Are we moving towards a kind of productive hedonism that seeks to mix professional motivation and gambling pleasure, and thus induces reactive behaviors from some users who feel trapped? Probably... and this obviously implies further research in this area, to measure the effects of gamification in real work situations.

## References

1. Sonia, A., Eric, B.: Evolutions in human technology relationship model: rejection, acceptance and technosymbiosis. *IADIS Int. J. WWW/Internet* **11**(3), 46–60 (2013)
2. Botra, A., Herselman, M., Ford, M.: Gamification beyond badges. In: *IST-Africa Conference and Exhibition, IST-Africa* (2014)
3. Brangier, E., Bastien, J.M.C.: L'évolution de l'ergonomie des produits informatiques: accessibilité, utilisabilité, émotionnalité et persuasivité. In: Valléry, G., Le Port, M.C., Zouinar, M. (eds.) *Ergonomie des produits et des services médiatisés: nouveaux territoires, nouveaux enjeux*, pp. 307–328. Presses Universitaires France, Paris (2010)
4. Brangier, E., Desmarais, M., Nemery, A., Prom Tep, S.: Évolution de l'inspection heuristique: intégration de l'accessibilité, de la praticité, de l'émotion et de la persuasion. *J. d'Interaction Personne-Système (JIPS)* **4**(1), 69–84 (2015)
5. Brangier, E., Dufresne, A., Hammes-Adélé, S.: Approche symbiotique de la relation humain-technologie: perspectives pour l'ergonomie informatique. *Le Travail Humain* **72**(4), 333–353 (2009)
6. Deterding, S., Khaled, R., Nacke, L., Dixon, D.: Gamification: toward a definition. In: *Proceedings of the CHI 2011 Workshop: Gamification: Using Game Design Elements in Non-Game Contexts*, pp. 6–9. ACM, Vancouver (2011). [http://gamification-research.org/wp-content/uploads/2011/04/CHI\\_2011\\_Gamification\\_Workshop.pdf](http://gamification-research.org/wp-content/uploads/2011/04/CHI_2011_Gamification_Workshop.pdf)
7. Deterding, S., Dixon, D., Khaled, R., Nacke, L.: From game design elements to gamefulness: defining «gamification». In: *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*. ACM, Tampere (2011)
8. Hammes-Adélé, S.: Traduction temporelle de la relation humain-technologie-organisation Validation et perspectives autour de la symbiose. Thèse de doctorat, Université de Lorraine, France (2011)
9. Hassenzahl, M.: Emotions can be quite ephemeral: we cannot design them. *Interactions* **11**(5), 46–48 (2004)

10. Heffernan, A., Fogarty, R., Sharplin, E.: G'aim'ing to be a rural teacher?: improving preservice teachers' learning experiences in an online rural and remote teacher preparation course. *Aust. Int. J. Rural Educ.* **26**(2), 49–61 (2016)
11. Liu, Y., Alexandrova, T., Nakajima, T.: Gamifying intelligent environments. In: *Proceedings of the 2011 International ACM Workshop on Ubiquitous Meta User Interfaces, Ubi-MUI 2011*. ACM, Scottsdale, Décembre 2011
12. Marache-Francisco, C., Brangier, E.: Gamification experience: UXD with gamification background. In: Blashki, K., Isaias, P. (eds.) *Emerging Research and Trends in Interactivity and the Human-Computer Interface*, pp. 205–223. IGI-Global (2013)
13. Marache-Francisco, C., Brangier, E.: Process of gamification: from the decision of gamification to its practical implementation. In: *CENTRIC 2013: The Sixth International Conference on Advances in Human-Oriented and Personalized Mechanisms, Technologies, and Services*, 27 October–1 November, pp. 126–131 (2013)
14. Marache-Francisco, C., Brangier, E.: Gamification and human-computer interaction: a synthesis. *Le Travail Humain* **78**(2), 165–189 (2015)
15. Marache-Francisco, C., Brangier, E.: Validation of a gamification design guide: does a gamification booklet help UX designers to be more creative? In: Marcus, A. (ed.) *Design, User Experience and Usability, HCII 2017*, pp. 284–293. Springer, Toronto (2016)
16. Mora, A., Riera, D., Gonzalez, C., Arnedo-Moreno, J.A.: Literature review of gamification design frameworks. In: *7th International Conference on Games and Virtual Worlds for Serious Applications (VS-Games)*, Skövde, Sweden, pp. 1–8 (2015)
17. Raftopoulos, M.: Towards gamification transparency: a conceptual framework for the development of responsible gamified enterprise systems. *J. Gaming Virtual Worlds* **6**(2), 159–178 (2014)
18. Sbai, N.: The influence of specific emotions on consumer judgment and behavioural intention with respect to innovations. *Thèse de doctorat, Université de Grenoble* (2013)
19. Schuldt, J., Friedemann, S.: The challenges of gamification in the age of Industry 4.0: focusing on man in future machine-driven working environments. In: *IEEE Global Engineering Education Conference (EDUCON)* (2017)



# Comparative Analysis of Body Measurement and Morphology Between Subjects with Different Body Mass Index

Caelen Teger da Silva<sup>(✉)</sup>, Maria Lúcia Leite Ribeiro Okimoto,  
Dominique Leite Adam, and Kelli C. A. S. Smythe

Federal University of Paraná, Curitiba, Brazil  
caelenteger@gmail.com, lucia.demec@ufpr.br,  
domiadam@gmail.com, kellycas@gmail.com

**Abstract.** The aim of this paper is to understand the effects of the interaction between clothes, body shape and measurements and how it affects 3 subjects with different body mass index. Also, it wishes to observe the application of a mixed, qualitative/quantitative scientific methodology. The plus size public, despite being already majority in many countries is still seen as a niche market. This is a promising and lucrative market and many companies are looking to embrace it. The increase in the quality of the clothing products depends on the knowledge development in several areas among which the ergonomics and anthropometry. The results indicate the statistical and morphological variation between the groups and within the groups, and in the visual analysis.

**Keywords:** Body morphology · Plus size · Body mass ·  
3D body scan measurements · Methodology

## 1 Introduction

Obesity has almost tripled worldwide since 1975. By 2016, when latest World Health Organization (WHO) survey has done, more than 1.9 billion adults, people over 18, were overweight, considered healthy World Health Organization (WHO) directions [1, 2]. Nowadays, considering all the countries in the world, there are more obese or overweight people than underweight, this occurs in all regions, except for some sub-Saharan Africa and Asia areas [1]. The epidemic of overweight and obesity has also spread throughout Latin America and the Caribbean, with a greater impact on women according to the United Nations Food and Agriculture Organization (FAO) and the Pan American Health Organization (PAHO) [3]. The latest joint report from these organizations indicates that 58% of the Latin American and Caribbean population are overweight totaling 360 million people [3]. In Brazil, the scenario does not deviate from the global. Overweight in Brazilian population grew 26.3% in the last decade [4]. Currently, more than 50% of Brazilians are in a higher weight than the World Health Organization (WHO) recommend [4].

The overweight's physical alterations at individuals generate specific demands from the public to the textile and fashion industry [5–7]. Industries do not offer products in

enough quality and quantity to reach the needs of plus size public [5]. Thus, the offer of fashion items decreases as the measurements grow at sizes charts. Overweight people's needs and aesthetic values are placed in the background. It is difficult and even impossible to find appropriate clothes for those people [8], in this way, the market moves in the opposite direction to the consumer's desire. Plus size people, despite being already majority in many countries are still seen as a niche market [9, 10].

Regardless of whether it is a niche or not, the fact is that this is a promising and lucrative market and many companies are looking to embrace it. In order to companies to grow, the path usually goes through price reduction or increase in product quality [10]. The enhancement in the quality of clothing products depends on the knowledge development in several areas, among which ergonomics and anthropometry [2]. Despite the numerical superiority of obese and overweight individuals, few studies have investigated anthropometric and morphological characteristics of these types of bodies [2]. Although the morphology of the human body is presumably not homogeneous [10], the study of 3D aspects of the body can provide information for a more current biotype characterization, which accurately represents populations.

Most anthropometric research methods are based on the statistical analysis of measurements collected manually or with 3D scanners, but these data are analyzed and applied in the development of clothing following a 1D rationale [12]. The reasoning of the traditional method of development and alterations of patterns is no longer enough to provide clothing with good fit and comfort or attend to the morphological differences in population [10]. Using linear measures in basic pattern foundations is the accepted method and recognized as useful for the industry, its importance is evident. However, changes in dietary pattern, physical inactivity, and lifestyle have now re-designated morphotypes, and it is a fact that people of similar weight and size may have different types of bodies [10, 12].

In this way, mass customization seems to be a good direction. For the growth and implantation at the industrial level, mass customization necessarily requires the understanding of the morphology and interaction of the bodies with the clothes. In this scenario, this experiment aims to understand the effects of the interaction between clothes and body shape and measurements and how it affects 3 subjects with different body mass index (BMI). Also, it wishes to observe the application of a mixed, qualitative/quantitative scientific methodology.

To achieve this goal, 3 individuals with different body masses were selected, mathematically classified in the same biotype. One of the subjects is considered normal weight within the World Health Organization (WHO) and body mass index (BMI). These individuals wore 5 different bottoms designs sewn with different fabrics. Comparisons between the three individuals were made.

## 2 Method

### 2.1 Sample Selection

The scanning was conducted in three women in the aged 19 – 45 years and three different body mass index (BMI). According to the World Health Organization (WHO),

healthy = 18,6–24.9; excess weight = 25–29.9; and obesity grade I = 30–34.9 [1]. They represent the most recurrent body type in the southern region of Brazil, which is rectangular body type [1]. The choice of a healthy subject is due to the interest in doing a comparison with excess weight's people. These three people were named *Subject 1, 2 and 3* in a crescent IBM order.

## 2.2 Data Acquisition

The 3D scans were obtained from a Microsoft Kinect 360 and RecFusion Pro 1.4.5. Pre-processing steps (fill holes, remove noise, smoothing and optimizing the mesh) are obtained with Autodesk Meshmixer 3.5.474, measurements were achieved com 3D measure UP 2.2.18360.165 by ProtoTech solutions and finally analyzed statistically using Paste 2.17c e Microsoft excel.

In order to generate 3D objects which are rigorously comparable between each other, we only take into account the torso of the body scan [13, 14]. Arms and legs are not relevant for the morphology comparison in this study, as the main measurements of a garment are related to the torso fitting waist and hip girth as variables to analyze. Participants were scanned wearing five different kind of pants. The bottoms were sewed with different fabrics of varying composition and weight in five different designs (Table 1).

**Table 1.** Fabric's composition and weight.

Clothes	Composition/weight	Fabric
A <i>Control/underwear</i>	97% PA 2% CO 1% PUE	Lupo Underwear
B <i>Fold over waistband</i>	92% PA 8% PUE 265G/M2	Aradeffe Fitness
C <i>Elastic waistband</i>	92% PA 8% PUE 265G/M2	Aradeffe Fitness
D <i>Low waist</i>	11,5 OZ/YD2 390 G/M2 99% CO/1% EL	Santista Denim
E <i>High waist</i>	11,5 OZ/YD2 390 G/M2 99% CO/1% EL	Santista Denim

The fabrics and designs were chosen because of they are common and widely used in southern region of Brazil. Bottoms were cut from pattern blocks drafted with size chart and diagram from MIB method [15]. The top was selected so not interfere in the experiment and remained constant. Girth waist and hip were the choose measurements (Table 2). The obtained images were evaluated from two perspectives: the morphology and the measurements of the bodies. *One-way ANOVA*, *Tukey test* and *t-test* identifying the differences and significance levels between the measured circumferences.

Comparison were made between the morphological and statistics results in everyone, according to the different trousers, and between three participants. The method of analysis used was mixed, qualitative/quantitative, because the combination

**Table 2.** Body dimensions selected for body shape analyses.

Variables	Measurement procedure
Waist girth	Horizontal circumference around the waist, taken parallel to the floor at the smallest point of back waist as seen from the side
Hip girth	Horizontal circumference around the hip, taken parallel to the floor at the greatest prominent point of the buttocks as seen from the side

of methods offers an alternative for the investigation of complex phenomena, which is the case of anthropomorphic and morphological investigations.

### 3 Results and Discussion

The measurements obtained are presented in the following Tables 3 and 4, all measures are in centimeters. Table 3 shows the measurements of the three subjects wearing the 5 different types of bottom. It can be observed that the waist and hip girths, obtained with the subjects wearing only the underwear (control), do not match with Brazilian measures tables. It is important to note that until the publication of this article, a complete and official anthropometric study was not published in Brazil.

**Table 3.** Waist measurements.

Waist	Subject 1	Subject 2	Subject 3
A	63	82	110
B	63	83	107
C	63	85	114
D	63	86	118
E	67	88	112
Mean	<b>63,8</b>	<b>84,8</b>	<b>112,2</b>

In a brief comparison between different tables of published measurements, it was observed that in the MIB [15] and AUDACES [17] size chart, subject 1 would be considered a size 38 while Subject 2 would be between sizes 46 and 48 and Subject 3 does not fit in this chart. The same occurs with the SENAI [16] chart, in which Subject 3 also does not find any size, Subject 1 would enter sizes 36 and 38, Subject 2 between 46 and 48. Despite the confusion of sizes Subjects 1 and 2 find a representativeness of their mathematical measures in these charts, which does not occur with Subject 3, which does not have representative measures in any of them. From the measurements (Tables 3 and 4), the statistical analysis was performed.

For the statistical analysis, it was established:

- Variance de 0,05 (5%)
- $H_0: \mu A = \mu B = \mu C = \mu D = \mu E$  or  $H_1$ : at least one inequality

**Table 4.** Hip measurements.

Hip	Subject 1	Subject 2	Subject 3
A	88	103	124
B	87,5	106	125
C	89,5	104,5	125
D	90	106	124
E	94	106	125
Average	<b>89,8</b>	<b>105,1</b>	<b>124,6</b>

- Groups: A, B, C, D, E
- Participants: Subject 1, subject 2, subject 3

The first statistical test applied was a *one-way ANOVA*. The summary of the results is in Tables 5 (waist) and 7 (hip). The comparison between groups and within groups is presented. Among the sources of variation, the one of most interest is the *p-value* that is below the established level of significance, 0.05 (5%), then indicates that there is at least one significant difference between two groups.

**Table 5.** Analysis of variance (ANOVA) – Waist

ANOVA: one way						
	SQ	gl	MQ	F	Valor-P	F crítico
Between groups	57,6	4	14,4	0,024253	0,99865	3,47805
Inside groups	5937,33	10	593,7333			
Total	<b>5994,933</b>	<b>14</b>				

Observing *p-value* for analysis of waist means, we have that  $0.998 > 0.05$  being so we failed to refute  $H_0$ , since there is difference between waist means for the use of different pants indicating that the difference between means between groups is statistically significant to the waist. This is visually evident when one observes the difference in curvature of the three waists and hips. Although the three subjects belong to the same biotype, it is possible to notice that the waists and hips do not necessarily have equal variations.

It is natural to conclude that this may be one of the factors that makes so difficult to use tables of measures satisfactorily. Another consequence for this variation will be the difficulty in obtaining a satisfactory fit on the clothes. In this case, we applied the *Tukey test* to identify in which interaction there is a statistically significant difference (Table 6).

**A** - Control/underwear, **B** - Fold over waistband, **C** - Elastic waistband, **D** - Low waist, **E** - High waist.

The result of this test indicates that only **B** (Fold over waistband) to **A** (under-wear) presents similar averages, that is, the means of the waist measurement samples wearing

**Table 6.** Tukey's pairwise comparisons.

	A	B	C	D	E
A		1	1	0,9996	0,9996
B	0,04739		0,9990	0,9992	0,9992
C	0,1659	0,2132		1	1
D	0,2843	0,3317	0,1185		1
E	0,2843	0,3317	0,1185	0	

pants **A** and **B** are statistically similar. It is evident that the pant **B** in relation to the control/underwear shows very little change in morphology of the body.

The *ANOVA* for the hip (Table 7) shows the *p-value*  $0.999 > 0.05$ , and we also failed to refute  $H_0$ , since there is a difference between the means of hip in the different groups.

**Table 7.** Analysis of variance (ANOVA) – Hip

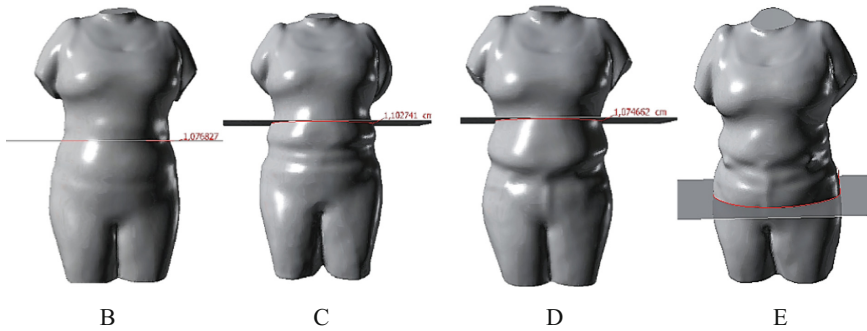
ANOVA: one way						
Fonte de variação	SQ	gl	MQ	F	Valor-P	F crítico
Between groups	-17,3333333	4	4,33333333	0,014162763	0,999531112	-3,47805
Inside groups	3059,66667	10	305,966667			3059,66667
Total	<b>3077</b>	<b>14</b>				

A *T-test* was performed comparing the measures of everyone. The three subjects presented the  $P (T \leq t) < 0.05$  indicating that waist and hip presented at least one significant statistical difference.

Thus, the mean change in measurements in terms of different models and tissues is statistically significant. In this case, looking at the Fig. 2, in which we see the Subject 3 wearing the models **B**, **C**, **D** and **E**, it is possible to verify the relationship between the statistical analysis and the morphology of the subjects.

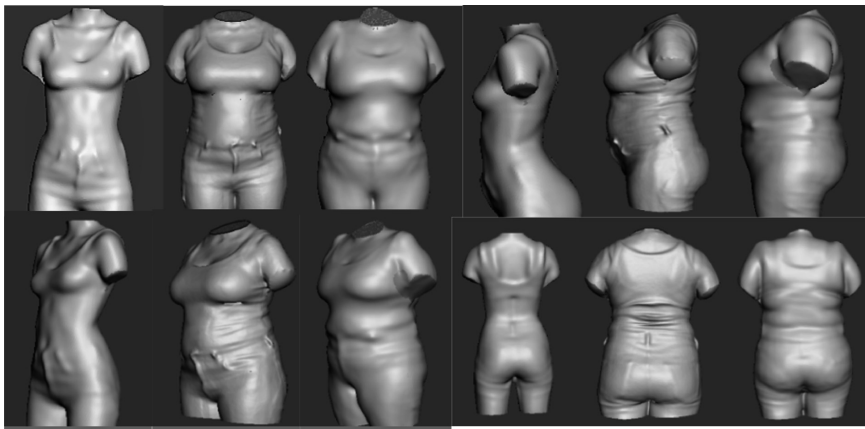
It is important to qualitatively analyze visually significant differences in subject's morphology and between groups. We select Subject 3 for this analysis. When wearing design **B**, the contour of the body is softened presenting an organic line with almost no interruption or abrupt change of direction. Dressed in design **C**, although the pants have been sewn in the same fabric as the **B**, the waist has an elastic, which generates a slight break in the waist and hip line. The **D** and **E** designs cause a very visible deformation in the waist, stomach and hip area. In **D** it is observed that the waistband forms a containment strip by wrapping the waist. In this case the belly lies above this waistband falling and hanging out of the pants. The **E** design has a high waistband, decreasing the belly pending effect, however, the stomach becomes compressed and moves down. The break in the silhouette line in **D** and **E** occurs mainly by the type of fabric (jeans) and the double waistband in a rigid fabric (Fig. 1).





**Fig. 1.** Subject 3 wearing 4 different bottoms

Figure 2 shows the three subjects in order 1, 2 and 3 in frontal, lateral, diagonal and back views. As a matter of space, only the images referents to E (high waist jeans) were addressed here.



**Fig. 2.** Subjects 1, 2 and 3 in frontal, lateral, diagonal and back views

Morphological variations between the subjects spots the differences in body mass index (BMI). We could say that within this sample, significant statistical variation is related to morphological variation, but it is not possible to associate statistics with body mass index (BMI), because it is not a variable, but only a sample selection factor in this experiment.

Qualitatively, it is evident that plus size bodies are more affected by different pants than the lean body. Back skinfolds in Subject 1 are non-visible, in Subject 2 a fold is seen on the side but does not extend to the back, this occurs in Subject 3. Clothing to body relation does not offer a linear result in relation to morphology. Even if it is a single biotype, and wearing strictly similar clothing, fit issues are proportional to the

subjects increase in body mass index (BMI). Thus, even if the subjects' body mass index (BMI) has not been compared statistically, it is possible to visually establish a relationship with the body to clothing interaction. In this way, it is possible, in this work, to establish a qualitative, visual and non-numerical relationship between the body mass and morphology.

## 4 Considerations

There is a crescent demand for better fitting and higher quality clothing by the plus size consumer. The expansion of the knowledge on anthropometry and morphologies of these bodies is a maximum relevance tool to reach that objective. This experiment aims to understand the effects of the interaction between clothes to body shape and measurements, also, how it affects 3 subjects with different body mass index (BMI). Likewise, observe the application of a mixed scientific method.

The results point out to gaps in the relationship between statistical tests and morphology of bodies. Even though the results of the statistical analysis and the morphological analysis show convergent and concordant findings, in this experiment, it was not possible that a dependence between both was established, mainly because the small number of participants. It is possible to emphasize that *ANOVA* and *t-test* offer binary information, of yes and no answers, and the *Tukey test* indicates the specificity of the deviant data. On the other hand, the morphological visual analysis adopted in this test, proposes qualitative results.

Qualitative analysis finds challenges and sometimes resistance in the scientific community, because of data systematization. However, considering the overweight population demand for better fit and experience with clothing, the need for the design of qualitative-qualitative experiments is evident. The results presented in this paper cannot be generalized due to reduced sampling. Next experiments should start from a significant sampling. The qualitative-quantitative approach is author's suggestion for future works.

**Acknowledgments.** Special acknowledgments to UFPR, PPGDesign and CAPES.

## References

1. World Health Organization. <https://www.who.int/nutrition/publications/obesity/>
2. WHO\_TRS\_894/en/
3. Park, W., Park, W.: Body shape analyses of large persons in South Korea. *Ergonomics* **56** (4), 692–706 (2013)
4. Organización de las Naciones Unidas para la Alimentación y la Agricultura. <http://iris.paho.org/xmlui/handle/123456789/34343?locale-attribute=es>
5. VIGITEL. <http://portal.arquivos.saude.gov.br/images/pdf/2017/abril/17/Vigitel.pdf>
6. Alexandera, M., Pisutb, G.R., Ivanescuc, A.: Investigating women's plus-size body measurements and hip shape variation based on sizeUSA data. *Int. J. Fashion Des. Technol. Educ.* **5**(1), 3–12 (2012)

7. Morlock, S., Schenk, A., Klepser, A., Schmidt, A.: XL plus men – new data on garment sizes. In: 7th International Conference on 3D Body Scanning Technologies, Lugano, pp. 255–264 (2016)
8. Medeiros, F., Cardoso, C.: Moda plus size para mulheres entre 25 a 55 Anos no Brasil. In: 6th COLÓQUIO DE MODA, Anais... São Paulo (2010)
9. Sgarbi, B.V.: Moda Plus Size Brasileira Feminina: Uma Análise do Cenário Contemporâneo. In: Congresso Internacional De Comunicação e Consumo, São Paulo (2018)
10. Romeo, L.D., Lee, Y.A.: Exploring apparel purchase issues with plus-size female teens. *J. Fashion Market. Manag.* **19**(2), 120–135 (2015)
11. Keiser, S.J., Garner, M.B.: Beyond Design the Synergy of Apparel Product Development. Fairchild Books, New York (2008)
12. Hamad, M., Thomassey, S., Bruniaux, P.: A new sizing system based on 3d shape descriptor for morphology clustering. *Comput. Ind. Eng.* **113**, 683–692 (2017)
13. Stewart, A., Ledingham, R., Williams, H.: variability in body size and shape of UK offshore workers: a cluster analysis approach. *Appl. Ergon.* **58**, 265–272 (2017)
14. Cools, J., Raevel, A., Ransbeeck, P., Vasile, S., Vandersmissen, B., Vermeulen, M.: The use of 3D anthropometric data for morphotype analysis to improve fit and grading techniques – the results. In: 5th International Conference on 3D Body Scanning Technologies, Lugano, pp. 46–54 (2014)
15. Bastos, S.F., Sabrá, F.G.: The body shape of Brazilian woman. In: 5th International Conference on 3D Body Scanning Technologies, Lugano, pp. 155–166 (2014)
16. Domingo, J., Simó, A., Ibáñez, M.V., Dura, E., Ayala, G., Alemany, S.: Towards a mean body for apparel design. *Image Vis. Comput.* **52**, 88–96 (2016)
17. Chunga, M.J., Lina, H.F., Wang, M.J.J.: The development of sizing systems for Taiwanese elementary- and high-school students. *Int. J. Ind. Ergon.* **37**(8), 707–716 (2007)
18. Duarte, S., Saggese, S.: Modelagem Industrial Brasileira. Letras e Expressões, Rio de Janeiro (1998)
19. Ramos, A.M.P.: Modelagem Industrial Feminina. SENAI, Belo Horizonte
20. Audaces. <https://www.audaces.com/padiao-de-roupas-femininas-tabela-de-medidas-abnt/>



# A New Tool for Cognitive Workload Assessment in System Design Prototypes

Pedro Mendonça<sup>(✉)</sup> and Manuel Adler Abreu

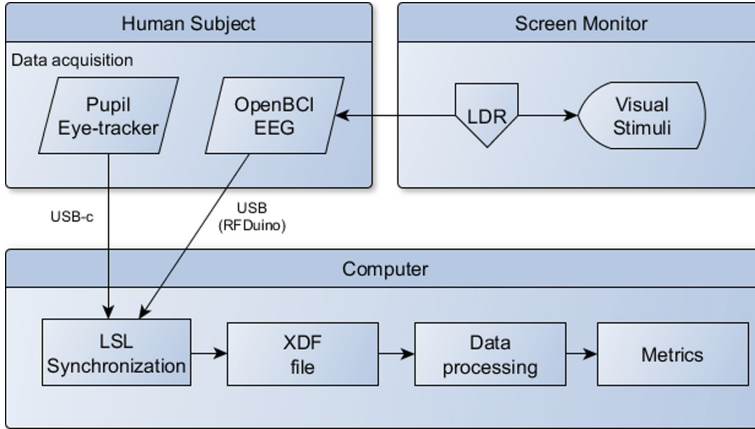
Faculdade de Ciências, Laboratório de Óptica, Lasers e Sistemas,  
Universidade de Lisboa, Campo Grande, 1749-016 Lisbon, Portugal  
pedro.mendonca@fc.ul.pt

**Abstract.** Mental workload is an important indicator of an operator's performance when executing a certain task. As a design concept, it is fundamental for monitoring and assessing his interaction with technological devices, such as imaging systems. A bad design can affect the mental workload of the operator, and therefore, becomes useful to assess it while performing the required tasks. This work presents a tool for cognitive workload assessment that is composed of two open-source and low-cost hardware parts: an electroencephalography system and an eye-tracker. Both are synchronized via an open-source software: Lab Streaming Layer. This paper describes the architecture of the sensor system, considering also specially developed hardware and software components that were included to allow the integration of the different subsystems. In order to show the performance of the system as tool to assess some psycho-physical indicators, examples of dedicated signal processing are also presented.

**Keywords:** Human factors · Human-systems integration · Systems engineering · Electroencephalography · Eye-tracker · Brain-computer interface · Signal processing · Cognitive workload

## 1 Introduction

A human operator is a critical link in the decision loop of some imaging systems, whose overall success rate is directly related to the operator's performance. One important indicator of the need for rest, or change of operator, can be a relative low performance of his mental workload and high fatigue level, when evaluated over time. To this purpose, a low cost system was developed in order to assess such indicators, using electroencephalography (EEG) to read brain waves and an eye-tracker to detect pupil size. The paper here presented shows some of the work produced towards the implementation of an integrated hybrid system tool that includes open-source hardware and software, test environment and data processing algorithms. An overview of the system can be seen in Fig. 1.



**Fig. 1.** The overview of the system, including a Light Dependent Resistor (LDR) and the Lab Streaming Layer (LSL) software, used to synchronize both the eye-tracker from Pupil-Labs and the EEG system from OpenBCI. The output is saved to an Extensible Data Format (XDF) file to be further analyzed.

## 2 Equipment/Hardware

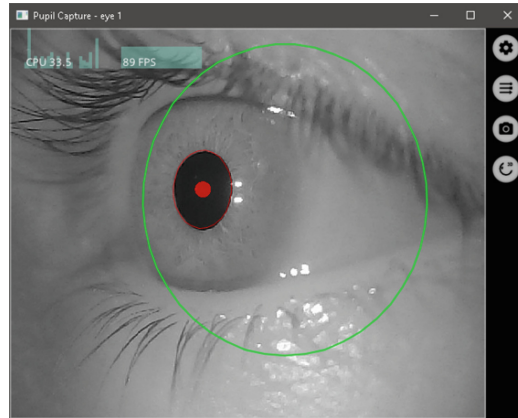
The hardware systems included in this solution are divided in two main categories: (1) the Electroencephalography (EEG) signal acquisition device and (2) the Eye-tracker device.

### 2.1 OpenBCI EEG Setup

Electroencephalography was the method used to acquire electrical activity from the brain by means of an OpenBCI [1] Cyton V3 32-bit board. This board has a Texas Instruments ADS1299 [2] analog to digital converter with 24-bit channel resolution and independent gain control that enables the use of sensors with a multitude of gains, from  $\times 1$  to  $\times 24$  gain. This is particularly relevant as sensors with different sensitivity can be used at the same time. The board was mounted on a 3D-printed OpenBCI Ultracortex “Mark IV” EEG Headset, enabling the use of up to 35 different 10–20 locations [12]. The first iteration of the system had wet gold cup shell shaped electrodes, applied with *Ten20* paste. However, those were replaced with dry electrodes, in a more stable configuration and faster experiment setup. This board can hold up to 16 electrodes (8 from Cyton + 8 with Daisy module) and communicates via wireless link to a computer through the OpenBCI USB dongle using RFDuino radio modules. The sampling frequency can vary from 250 Hz to 16 kHz, allowing the data to be transferred to the computer via Wi-Fi or saved to a micro SD-card.

## 2.2 Pupil Eye-Tracker

Apart from reading brain waves, another method to evaluate mental workload is by analyzing the operator eye movements, mainly pupil dilation [3–5]. Therefore, an eye-tracker device was added to the OpenBCI system but in order to accommodate the eye-tracker and EEG Headset, the former had to be unobtrusive and lightweight. The used eye-tracker was *Pupil* from Pupil-Labs [6] and has 3 cameras: 1 world camera with a sensor able to acquire images of  $1920 \times 1080$  pixels at 30 fps (or higher fps with lower resolution), located on the forehead of the user; and 2 other cameras, able to acquire images of  $400 \times 400$  pixels at 120 fps, one assigned for each eye. The Pupil eye-tracker makes use of the “dark pupil” detection method [7]. In this method, the subject eyes are illuminated with a surface mounted IR LED emitting at 860 nm wavelength, and IR images are acquired using an IR band-pass filter. Results of performance evaluation show, that under ideal conditions, Pupil can provide an average gaze estimation accuracy of  $0.6 \pm 0.08^\circ$  of visual angle with a processing pipeline latency of only 0.045 s [8] (Fig. 2).

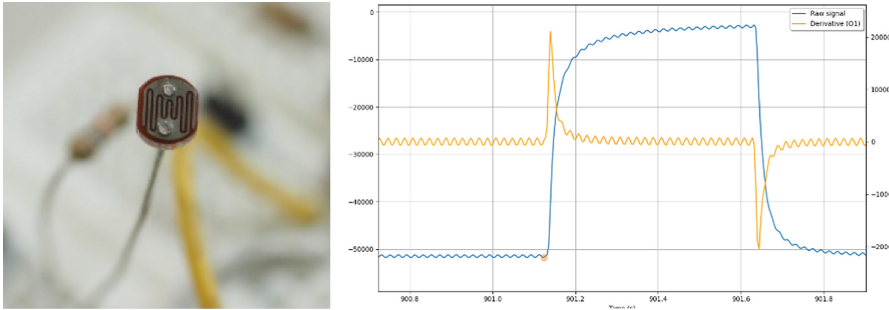


**Fig. 2.** Pupil detection performed by the eye-tracker.

## 2.3 EEG-Stimuli Sync Device

As opposed to spontaneous potentials EEG acquisition, where stimuli does not exist or is not relevant for the analysis, there are tests, such as *Visual Evoked Potentials*, in which the stimuli presentation needs to be synchronized with the bio-sensors, i.e. present stimuli to the subject and record its response in the same timeline. Since the OpenBCI board has independent gain control for each channel, the synchronization was achieved using a Light Dependent Resistor (Fig. 3, Left). A LDR is a light sensitive resistor whose resistance decreases, as the intensity of light it is exposed to, increases. If the stimuli are presented on a white background screen and, at the same time, a small black square is also presented on a corner, the LDR positioned over the square area can detect the light intensity changes. As can be seen in Fig. 3 (right), the

change from light to dark and back to light causes a distinct peak from the constant background that can easily be detected in the signal pre-processing stage, allowing the synchronization between the EEG sensors, LDR (both connected to the OpenBCI board) and the stimulus presentation.



**Fig. 3.** (Left) The LDR; (Right) Example of an output from the LDR with screen brightness changes.

### 3 Equipment/Hardware

#### 3.1 Graphical User Interfaces

Graphical User Interfaces (GUI) software are available for both OpenBCI and Pupil-Labs hardware. They can be used to acquire data and/or visualize data recorded from other sessions.

Visualization of EEG data streaming from the Cyton board is also useful to check if sensors are placed correctly and have a good signal-to-noise ratio, either prior to a data acquisition or during a session. The default output of the OpenBCI GUI is a text file with  $n + 5$  columns, with  $n$  being the number of active channels and the remainders for indexes, x, y, z coordinates of the accelerometer, and time stamps.

Data from the Eye-tracker can be recorded via Pupil Capture software and then seen, processed and analyzed through Pupil Player software. The output contains information about gaze, fixations and pupil diameter over time. One useful capability of this software is the generation of gaze heatmaps allowing a better visualization of where the operator was looking at over a defined period of time.

These GUIs can be used independently to test each part of the system, but in order to have the EEG and eye-tracker signals synchronized, the Lab Streaming Layer software was used as the software interface to combine both data and time stamps recorded simultaneously.

#### 3.2 Lab Streaming Layer

The Lab Streaming Layer (LSL) [9] was used as an interface to synchronize all the recorded data (EEG and eye-tracking data) by the included default program *LabRecorder*. This program combines data and time stamps from the available LSL plugin of

each hardware part, saving the data into the Extensible Data Format (*XDF*) which is a general-purpose container format for multi-channel time series data.

## 4 Tasks and Stimuli

The main purpose of the system presented in this paper is to be used as a tool to analyze a subject mental workload while performing certain task(s). In order to test the system some tasks were implemented, using either software environment (PsychoPy and Processing) or hardware (Arduino). A couple of these test setups are explained in the next sections.

### 4.1 Psychomotor Vigilance Task

The Psychomotor Vigilance Task (PVT [10]) is a sustained attention, reaction-timed task that measures the speed with which subjects respond to a visual stimulus. This 10-minute task [11] was implemented via Arduino with a red LED and a button, having 3 outputs: LED on, LED off and button pressed. These states were passed through a single analog channel using a scheme of voltage dividers on which the 3 different values could be distinguished (1.25 V, 1.67 V and 2.5 V) as seen in the oscilloscope screen in Fig. 4. The Arduino power was isolated from the OpenBCI board (using a couple of CNY17 Optoisolators) where the signal was being acquired, therefore, synchronized with the rest of the EEG channels.

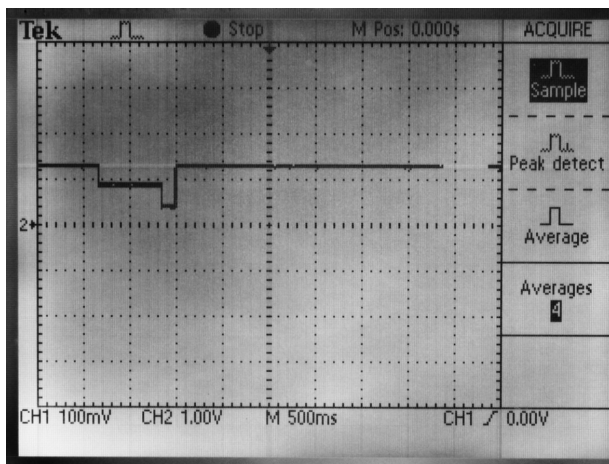


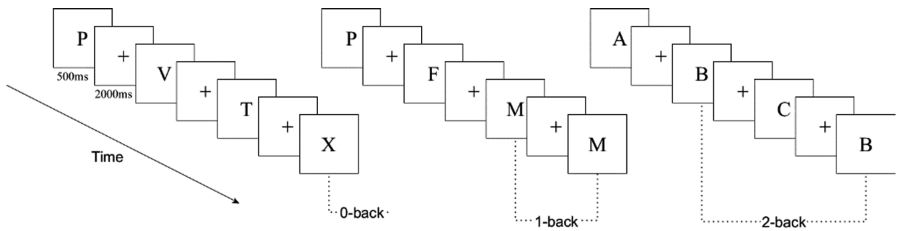
Fig. 4. A single analog channel used to transmit 3 different values.

### 4.2 N-Back

The *N-back* is a task in which the subject has to temporarily memorize information from a past event and compare it to the present one (Fig. 5). When presenting a



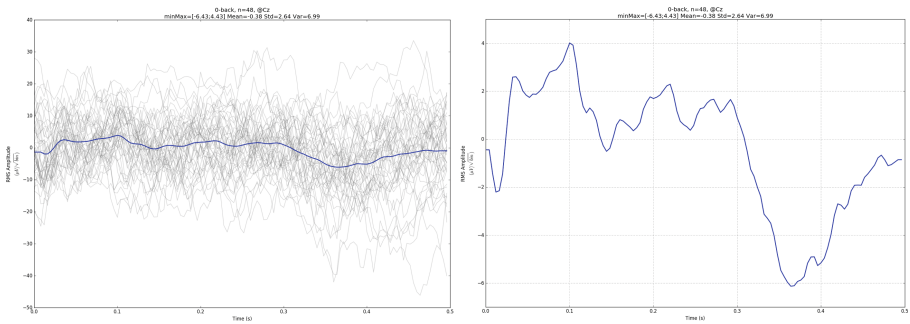
sequence of letters, if the present letter is the same as N steps before, the participant should press a button. As N increase, the amount of mental effort and concentration also increase and might be detected in a mental workload metric.



**Fig. 5.** The N-back experiment, exemplified with for N = 0, 1 and 2.

This task was implemented with Processing and synchronized via LDR, positioned on the low right corner of the stimuli presentation screen.

A result from a 0-back sequence of 48 letters can be seen in Fig. 6. On the left, EEG signals from Cz channel were plotted in thin lines and their average in a bold line. Rescaling the bold line (Fig. 6, right), it can be seen that the system is able to detect a peak 100 ms after the stimulus presentation and a valley after 300 ms, which can be matter for a Visually Evoked Potentials study.



**Fig. 6.** (Left): 48 gray curves and the average of them in bold blue; (Right): Same average curve on the left, rescaled.

## 5 Data Acquisition

By default, the OpenBCI Cyton board has eight available EEG channels. Seven of these were used to EEG acquisition and one was assigned for the output signal of the LDR, for applications that need synchronization with the stimulus presentation. The seven corresponding dry sensors were placed in a 10–20 positioning system, namely *Fp1*, *Fp2*, *F3*, *F4*, *Cz*, *Pz* and *Oz*. The sampling frequency used was 250 Hz and samples were sent via wireless to the PC.

In order to have a good confidence level for recognition and tracking of the pupil, IR eye-cameras on each user need to be adjusted and focused on the pupil before acquiring eye-tracking data as shown in Fig. 7. The world camera also needs to be tilted, or change lenses (between  $60^\circ$  and  $100^\circ$  of field of view) in such way that the field of view (FOV) includes the desired scenery. After the calibration process, one or more areas of interest (AOI) can be defined using 5-bit markers and fine tuned to match the object(s) of study.

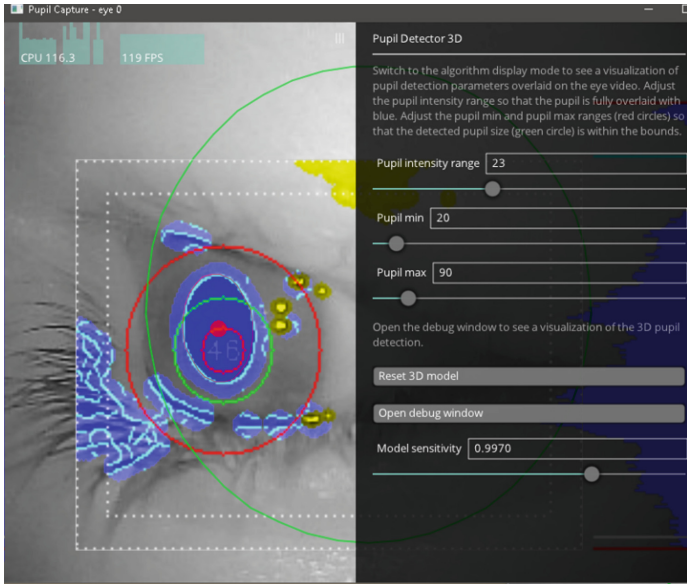


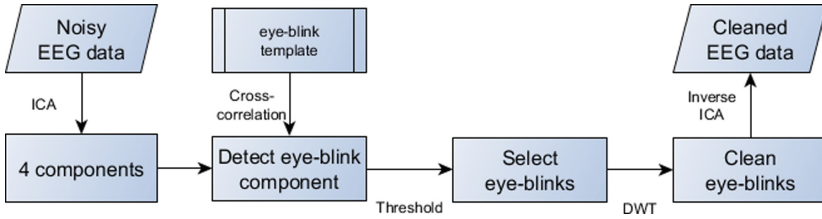
Fig. 7. Fine tuning the pupil detection on the *Pupil Capture* software

## 6 Signal Processing

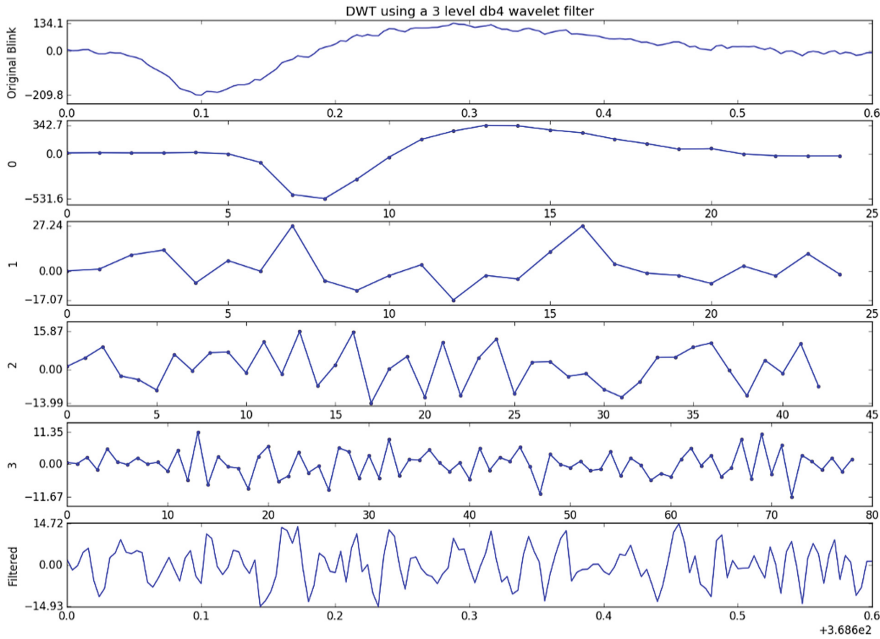
Processing and analyzing of EEG data can be performed in several implement tool-boxes such as EEGLAB (for MATLAB) and MNE (for Python). Nevertheless, we choose to implement the software in Python language, in order to minimize dependencies and facilitate expandability. The implemented software deals with signal processing and analysis using typical Python libraries.

### 6.1 Pre-processing

The first steps in pre-processing the acquired signals were focused on reducing noise as much as possible, without discarding important information. The 50 Hz peak, always present due to power supply, was suppressed using a Notch filter centered on 50 Hz and 100 Hz followed by a 2<sup>nd</sup> order high-pass Butterworth filter with cutoff frequency of 1 Hz to minimize low frequencies noise. An overview of the signal pre-processing stage can be seen in Fig. 8.



**Fig. 8.** Overview of the signal pre-processing stage



**Fig. 9.** Decomposing an eye-blink using DWT.

It is important not only to identify eye-blinks (noise) but also to remove them as their (much higher) amplitude affects further signal processing steps and analysis. One way to accomplish this would be by zeroing the time segment where the eye-blink appears. That would be straightforward to implement but relevant information (especially high frequencies) would be lost in the process. So, a separation between low and high frequencies is necessary. One method developed to minimize the loss of information when removing eye-blink artifacts was using a Discrete Wavelet Transform (DWT), that decomposes a given signal into approximation and details coefficients. A *db4-Daubechies* wavelet filter was used as an input to a 3 - level DWT. As can be seen in Fig. 8, the component zero can be interpreted as the low frequency of the eye-blink. Zeroing that component and reconstructing the signal will maintain the high frequency content (Fig. 10).

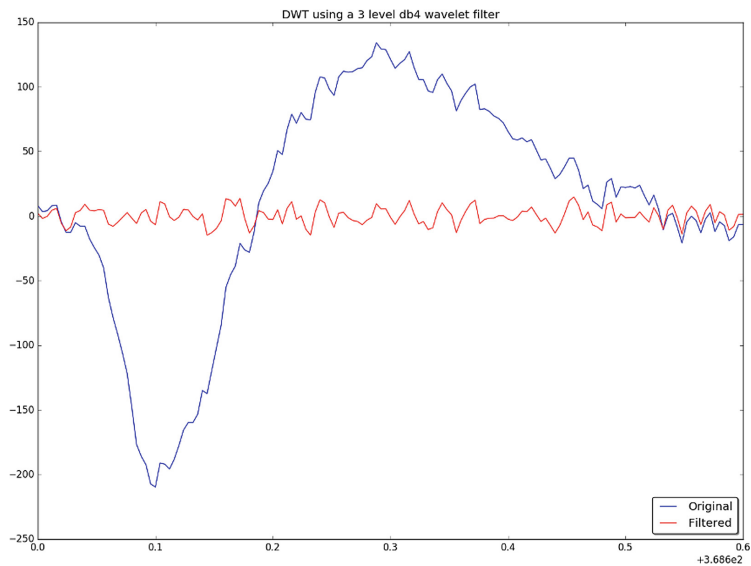


Fig. 10. Comparison between original and filtered eye-blink.

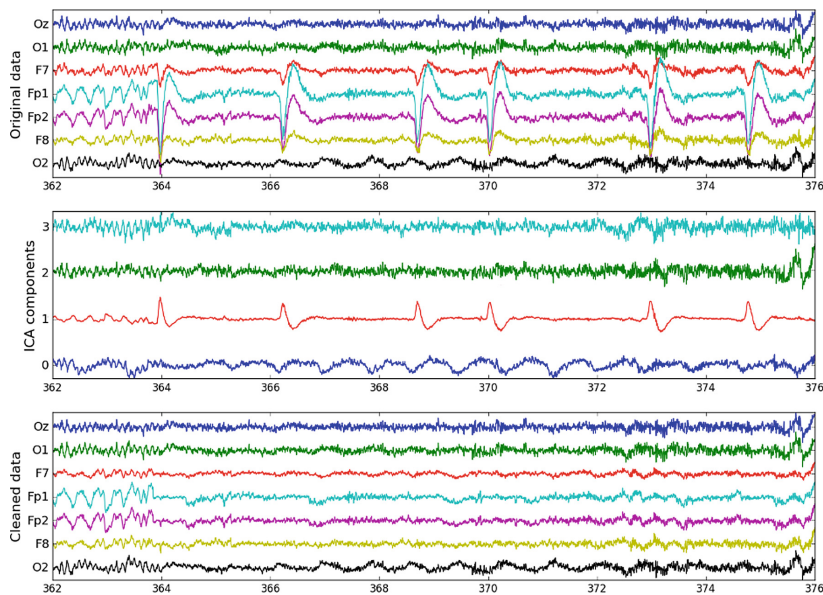
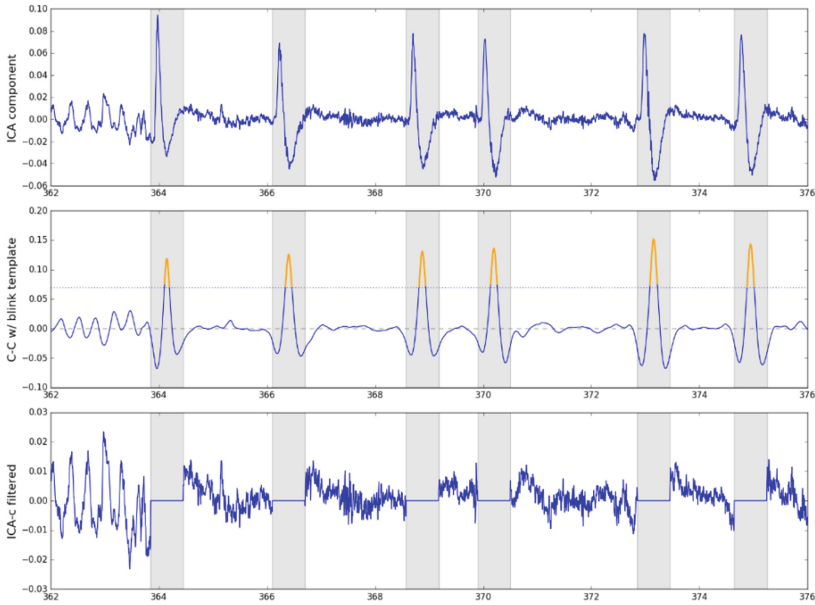


Fig. 11. Using ICA to remove eye-blinks from the seven EEG channels, on a 14 s time-series segment.



**Fig. 12.** Cross-correlation of an eye-blink template with ICA component to identify and null eye-blinks

Although the DWT is successful in removing eye-blink artifacts, mainly because of their signature on the *frontoparietal* channels, it is hard to detect the contamination of other channels like  $C_z$ ,  $P_z$  and  $O_z$ . Therefore, another method was developed to process all the 7 channels. The Independent Component Analysis (ICA) was used to analyze all the EEG channels (top graph of Fig. 11) and decompose them into four components. As can be seen in the middle graph of Fig. 11 one of the four components (in this case, component one, but it might change at every execution) has emphasized the six eye-blinks, while the other three do not exhibit such peaks. Zeroing this component would eliminate the eye-blink artifacts, but nulling also other information contained in the base waveform (Fig. 12). As referred above, DWT was applied on the eye-blink artifacts of the *ICA-eye-blink component* and, after cleaning them, the seven EEG signals were reconstructed from the four ICA components using the ICA inverse transform. The result can be seen in the bottom graph of the Fig. 11.

## 6.2 Metrics

Metrics are the last step of the signal processing stage and are an important and objective measure for determining the cognitive state of the operator. After de-noising and having as clean as possible data, for each EEG channel and each band ( $\delta$ ,  $\theta$ ,  $\alpha$ ,  $\beta$  and  $\gamma$ ) the Power Spectral Density (PSD) was computed using a Hanning window with 50% overlap as the base for calculating relative power for each band. Having the relative powers, some metrics related to EEG mental workload [13–15] and engagement [16] were implemented from literature, e.g.  $\alpha + \beta/\theta$ ,  $\beta/(\alpha + \theta)$  and  $\theta/\alpha$ . A change

in pupil size, from a calibration or baseline recording, can also be used to assess cognitive workload and furthermore compare it with the obtained metrics from EEG.

## 7 Conclusions

The work here presented proposes a new tool for cognitive workload assessment through EEG and eye-tracking metrics. It is composed of two open-source and low-cost subsystems: an electroencephalography acquisition board and an eye-tracker both synchronized with a free and open-source software interface. The subsystems can be used independently of each other, but their combination, performing simultaneous data acquisition, allows a greater confidence level in the analysis of an operator cognitive workload. Cross-validation or correlation of results can be obtained and different analysis can be performed at the same time. The fact that all hardware components are open-source allows a customization that other systems either do not allow, or require extra cost in order to give access to the raw data or connect other sensors (ECG, EKG, EMG) within the same EEG board. It can also be used with different stimuli for different type of analysis, like, for example, short time analysis with Visual Evoked Potentials and longer time analysis for spontaneous potentials. Its versatility, availability and low cost can lead to more people performing brain and eye movement analysis and the field of application, so far, are in engineering, biophysics, psychology and medicine.

**Acknowledgments.** Pedro Mendonça acknowledges the financial support from the Portuguese Foundation for Science and Technology (FCT), PD/BD/52329/2013 and “CAMELOT - C2 Advanced Multi-domain Environment and Live Observation Technologies” Project ID: 740736, funded under the European Commission grants

H2020-EU.3.7.3. - Strengthen security through border management;

H2020-EU.3.7.7. - Enhance standardization and interoperability of systems, including for emergency purposes.

## References

1. OpenBCI Biosensing for everybody. <http://www.openbci.com>. Accessed 23 Nov 2018
2. Texas Instrument ADS1299 ADC datasheet. <http://www.ti.com/lit/ds/symlink/ads1299.pdf>. Accessed 26 Nov 2018
3. Granholm, E., Steinhauer, S.R.: Pupillometric measures of cognitive and emotional processes. *Int. J. Psychophysiol.* **52**, 1–6 (2004)
4. Erol Barkana, D., Acik, A., Duru, D. G., Duru, A. D. Improvement of design of a surgical interface using an eye tracking device. *Teor. Biol. Med. Model.* **11**(Suppl 1), S4 (2014)
5. Smink, D.S., et al.: Utilization of a cognitive task analysis for laparoscopic appendectomy to identify differentiated intraoperative teaching objectives. *Am. J. Surg.* **203**, 540–545 (2012)
6. Pupil Labs Open source eye tracking. <http://pupillabs.com>. Accessed 23 Nov 2018
7. Pupil: an open source platform for pervasive eye tracking and mobile gaze-based interaction. <https://doi.org/10.1145/2638728.2641695>. Accessed 26 Nov 2018

8. Pupil Capture and Pupil Player software. <https://github.com/pupil-labs/pupil/releases/latest>. Accessed 23 Nov 2018
9. Lab Streaming Layer. <https://github.com/scen/labstreaminglayer>. Accessed 28 Nov 2018
10. Wilkinson, R.T., Houghton, D.: Field test of arousal: a portable reaction timer with data storage. *Hum. Factors* **24**, 487–493 (1982)
11. Loh, S., Lamond, N., Dorrian, J., Roach, G., Dawson, D.: The validity of psychomotor vigilance tasks of less than 10-minute duration. *Behav. Res. Methods Instrum. Comput.* **36** (2), 339–346 (2004)
12. American Electroencephalographic Society: Guideline thirteen: guidelines for standard electrode position nomenclature. *J. Clin. Neurophysiol.* **11**, 111–113 (1994)
13. Kramer, A.F.: Physiological metrics of mental workload: a review of recent progress. In: Damos, D.L. (ed.) *Multiple task performance*, pp. 279–328. Taylor & Francis, Washington, DC (1991)
14. Berka, C., Levendowski, D.J., Lumicao, M.N., Yau, A., Davis, G., Zivkovic, V.T., et al.: EEG correlates of task engagement and mental workload in vigilance, learning, and memory tasks. *Aviat. Space Environ. Med.* **78**, B231–B244 (2007)
15. Borghini, G., Vecchiato, G., Toppi, J., Astolfi, L., Maglione, A., Isabella, R., Caltagirone, C., Kong, W., Wei, D., Zhou, Z., Polidori, L., Vitiello, S., Babiloni, F.: Assessment of mental fatigue during car driving by using high resolution EEG activity and neurophysiologic indices. In: *Proceedings of Conference on IEEE Engineering in Medicine and Biology Society*, San Diego, pp. 6442–6445 (2012)
16. Pope, A.T., Bogart, E.H., Bartolome, D.S.: Biocybernetic system validates index of operator engagement in automated task. *Biol. Psychol.* **40**, 187–195 (1995)



# Research on Human-Computer Interaction Design of Bed Rehabilitation Equipment for the Elderly

Zhijuan Zhu, Wenzhen Pan<sup>(✉)</sup>, Xin Ai, and Renjun Zhen

School of Mechanical Science and Engineering, Huazhong University of Science  
and Technology, Wuhan, People's Republic of China  
pwz1053205611@foxmail.com

**Abstract.** The aging of the population is a relatively prominent social problem in China, and the proportion of elderly people living in bed in China is also increasing. This article takes the home rehabilitation equipment on the elderly bed as the research object. On the one hand, the needs of home users for home rehabilitation equipment are analyzed by using the user-tool-task model. Discussed the user psychology, the experience in the process of using rehabilitation equipment, combined with the specific scenes when using, found the “human” factor of the rehabilitation equipment for the elderly in bed. On the other hand, the hardware and software interfaces of the elderly rehabilitation equipment for the elderly are analyzed. Combined with the existing bed rehabilitation equipment in the hospital, the “machine” factor of the elderly equipment on the bed was discussed, and the software and hardware interfaces of the existing bed rehabilitation equipment were improved. On this basis, the rehabilitation combined with physical rehabilitation and psychological rehabilitation was further proposed. system design. In order to achieve the purpose of rehabilitation of the mental physiology of the elderly in bed.

**Keywords:** Rehabilitation equipment · Human-computer interaction · Product design

## 1 Introduction

At present, the aging of the population has become an extremely serious social problem in China. According to statistics of the National Bureau of Statistics and the China Aging Committee, the proportion of elderly people who lost their ability to self-activity and self-care is 25.0% due to various related diseases such as advanced dementia, post-stroke, Parkinson's disease, fracture or disability, diabetic foot, etc., and the age of long-term bedridden patients is about 64 to 89 years old, with an average of 74.6 years. In addition, prolonged bed rest can lead to accidental pneumonia, hemorrhoids, deep vein thrombosis of the lower extremities, osteoporosis, heart failure and even myocardial infarction. According to this background, this paper will analyze the physiological and psychological dimensions of the elderly, and use human-computer interaction and ergonomics methods to explore the home rehabilitation system for the elderly in bed, and further enhance the rehabilitation experience of the elderly in bed [1, 2].



## **2 Research and Development of Human-Computer Interaction**

### **2.1 Research on Human-Computer Interaction**

From relative market research, it has been found that the interaction mode of human-computer interaction has changed a lot. From the keyboard and screen very early, to the deep integration with smart devices, and with the maturity of artificial intelligence technology, it has been more and more integrated. In-depth virtual robots such as speech recognition and natural language processing begin to integrate with smart devices. In the future, they will become personalized assistants for medical treatment in many scenarios, and can provide different services for different patients according to their individual needs. Can truly communicate with people, making machine-to-human communication more natural, friendly and human-like, such as Amazon's Echo smart speaker, GoogleHome's smart home and voice assistants in various mobile phones, domestic like Lenovo Huawei Such large companies have established specialized UCD departments [3]. In addition, in terms of theoretical research, Long et al. of Tongji University has proposed the general principle of interaction design of elderly products based on human-computer interaction [4]. Nanjing University of Technology Kai, has analyzed and summarized the natural interaction, and has constructed a conceptual model for natural interaction [5]. Jiang Nan University, Shuyang et al. has demonstrated the concept of "human-machine harmony" by analyzing the human-centered design concept in the field of interaction design with actual cases [2].

From these studies, although human-computer interaction has developed rapidly, there are few practical applications and researches on the subfield of rehabilitation equipment for the elderly. There is also no in-depth exploration of the rehabilitation needs of the elderly, and the correlation between home medical care is not high. So in the next study, we will explore from the perspective of ergonomics.

### **2.2 Ergonomic Framework in Product Design**

The successful integration of ergonomics and industrial design in the user-tool-task model will result in an aesthetically pleasing and superior product [6]. Most research organizations and design philosophy followed the user-tool-task system design model proposed by Kreifeldt [6]. Various influences and interactions in the user-tool-task system was shown in Fig. 1, with particular emphasis on three aspects: people, tools (products), tasks; two interfaces: user-tool interface (operation), tools-task interface (participation), and many interactions in the system. The user-tool-task model is designed to solve the problem of using tools to complete tasks, focusing on the user interface between the user and the tool, and then focusing on the engagement interface between the tool and the task. Under normal circumstances, the user needs to manipulate the interface to control the tool, and the tool uses the joint interface to complete the task [7, 8].

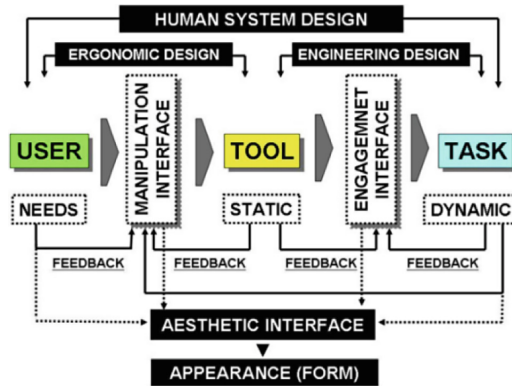


Fig. 1. User-tool-task model

The most important factor in the rehabilitation equipment for the elderly is the physiological needs and psychological needs of the elderly. According to the model in Fig. 1, the framework of this study is set. As shown in Fig. 2.

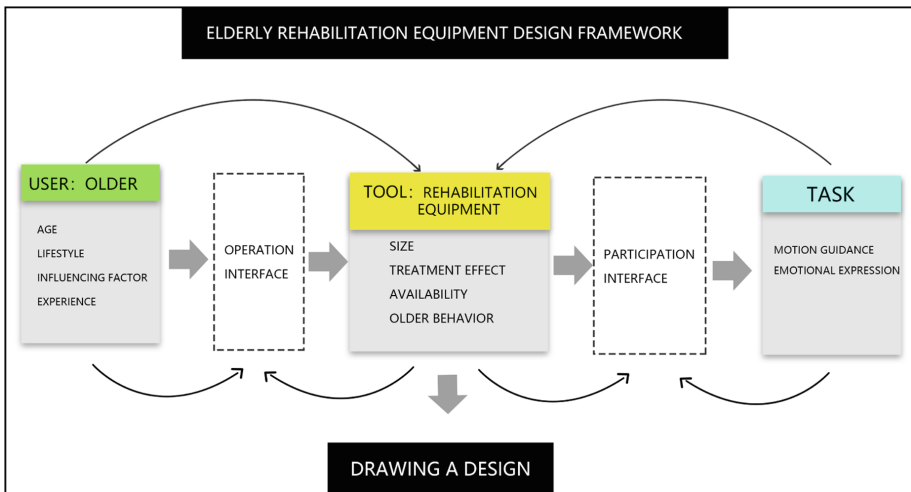


Fig. 2. Elderly rehabilitation equipment user tool task model framework

### 3 Users: The Main Factors Affecting the Use of Rehabilitation Equipment for the Elderly

#### 3.1 Psychological Factors

According to relative literatures, the elderly with poor daily activities, and will be less supported by families. Meanwhile, the disabled physical activities also affect their

social activities in daily life. Thus, the limited ability of daily living activities will also affect the social interaction of the elderly and long-term isolation is likely to cause psychological discomfort, triggering corresponding negative emotions. They will also be more resistant to contact with new rehabilitation equipment [3].

### **3.2 Physiological Factors**

The elderly are aging, their brain slows down, and the function of the sensory organs and the moving organs declines. Therefore, their ability to learn new things declines, their ability to coordinate movements decreases, and their ability of visual and hearing declines.

### **3.3 Social Factors**

In today's elderly group, the vast majority are empty-nest elderly, and most of them in China are distributed in rural areas, so they must use rehabilitation equipment independently after they purchase them [3].

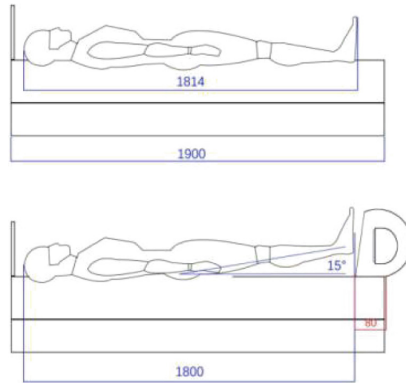
## **4 Tools: Home Rehabilitation Equipment Status and Ergonomics Related Analysis**

### **4.1 Psychological Factors**

Rehabilitation nursing for the elderly who have been in bed for a long time mainly includes life care, condition observation and nursing records. The life care mainly includes 8 training parts, bed gymnastics, chest and abdomen breathing exercises, bridge sports, shrugging fists, sitting training, acupoints. Press training, and secondly, these need to be carried out under the guidance of a doctor. The bed rehabilitation equipment used in hospitals can play a role in the physical rehabilitation of the elderly, but the disadvantages are that they are not flexible enough to be used at home and occupy a large area. In addition, it is very troublesome for the elderly to move to the rehabilitation bed and needs to be completed with the help of professional medical professionals. Therefore, bed rehabilitation equipment for hospitals is not suitable for elderly people who are staying in bed for a long time [9].

Existing home rehabilitation products in the market can only be used on the ground (such as Fig. 3), so the elderly need to get out of bed to use. However, the physical function of many elderly people who have been bedridden for a long time cannot support him to get out of bed for rehabilitation training. And also, the current rehabilitation products only pay attention to the physical rehabilitation of the elderly. It has played a certain role in the rehabilitation of the physical functions of the elderly, but in

the psychological problems of the elderly, the effectiveness of the existing rehabilitation equipment products is far from enough. The product and user interaction design are not well integrated into the rehabilitation product.



**Fig. 3.** Size of rehabilitation equipment

## 4.2 Ergonomics Related Size Analysis

Ergonomics, as an important part of human-computer interaction, is a factor that designers must consider when designing human-machine interface products. It is based on human psychological and physiological characteristics, applying systems engineering perspectives, analyzing the interaction between people and the environment, machines and machines and the environment, in order to provide convenient, labor-saving, safe, comfortable products which makes human-machine-environment to the best condition. It provides theory and method to study the size of the human body, which helps the designer to conform to the human-machine size when designing [10].

## 4.3 Length of Rehabilitation Equipment on the Bed

The length of the rehabilitation equipment is based on the length of the bed and the length of the human body. The length of the bed is generally 1900–2000 mm. In this paper, the length of the bed is set 1900 mm. considering the universal design for more elderly, the P95 body size of man 1814 mm is chosen. Moreover, since the person should properly lift the leg by  $15^\circ$  when using the rehabilitation equipment, the length of the person at this time is 1800 mm, and therefore, the length of the contact between the rehabilitation equipment and the bed is 80 mm (as shown in Fig. 3).

4.4 Rehabilitation Equipment Handle Stretch Length

The stretched length of the rehabilitation equipment is mainly determined by the length of displacement of the human hand after lying down and sitting up. The length of the hand function of the person lying down to sit up, based on the ergonomic table, can be obtained as a displacement of 310–376 mm, therefore, the distance of the pull of the pull ring should also be within the range of 310–376 mm (as shown in Fig. 4).

Sitting position forearm	416	447	478	383	413	442
Sitting position forearm hand function elongation	310	343	376	277	306	333

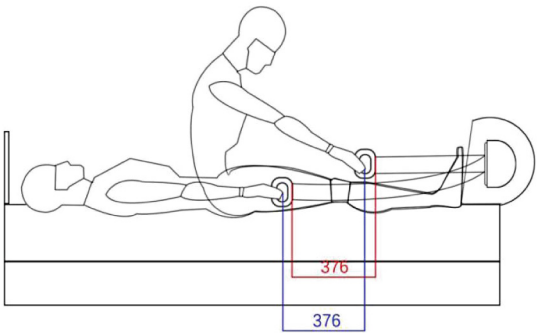


Fig. 4. Size of rehabilitation equipment

4.5 Foot and Pull Ring Size on Rehabilitation Equipment

The size of the pedal on the rehabilitation equipment is mainly determined by the length, foot width and foot distance of the human body. Since the length of the foot and the width of the foot are 95 mm, which are 265 mm and 105 mm respectively, the length and width of the design pedal are 270 mm and 110 mm respectively. The distance between the two pedals is 80. Since the human hand has a hand width of 195 mm and 90 mm, respectively, the design pull ring has a length of 130 mm and a width of 70 mm and a thickness of 20 mm (as shown in Fig. 5).

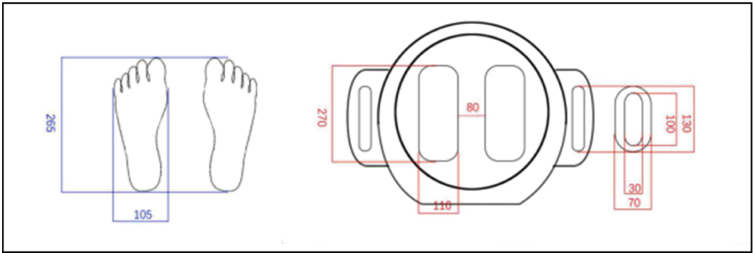
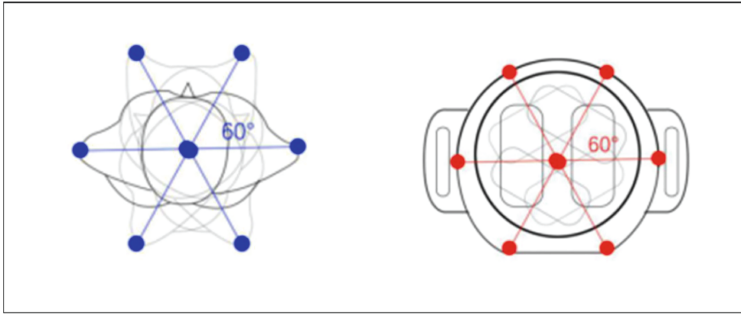


Fig. 5. Rehabilitation equipment size

#### 4.6 Foot and Pull Ring Size on Rehabilitation Equipment

The rotation angle of the rehabilitation equipment is determined by the turning angle of the human body, and the body turns over  $+60^\circ$  and  $-60^\circ$ . Therefore, the pedal rotation angle of the rehabilitation equipment is also at an angle of  $\pm 60^\circ$  (as shown in Fig. 6).



**Fig. 6.** Size of rehabilitation equipment

The design of the elderly home rehabilitation equipment must be based on human-computer interaction, and ergonomics is an important part of human-computer interaction. Therefore, the size of the rehabilitation equipment needs to meet the size requirements of the elderly in the process of research, and the rehabilitation equipment must More humane and intelligent use by the elderly.

### 5 Task: Self-recovery Feedback Design for the Elderly in Bed

The barriers to the use of electronic products by the elderly are mainly reflected in the way products interact with people. Therefore, we must start with interactive methods and use new media interactions in product design to overcome these obstacles, which will largely solve this problem. Designers must also consider the interactive design strategies of older people into the new media art.

The results of interaction design require a user experience to be demonstrated. Interaction design makes a product more practical, easier to use, and better to use to create a more comfortable user experience. This requires interactive design not only to meet the necessary needs of users, but also to meet the potential needs of users. The visualization of these needs are necessary to satisfy users' requirement unconsciously and then generate a sense of dependence by user. In this design, our necessary need is to help the elderly exercise through the app control rehabilitation equipment, the potential demand is the psychological needs of the elderly social entertainment.

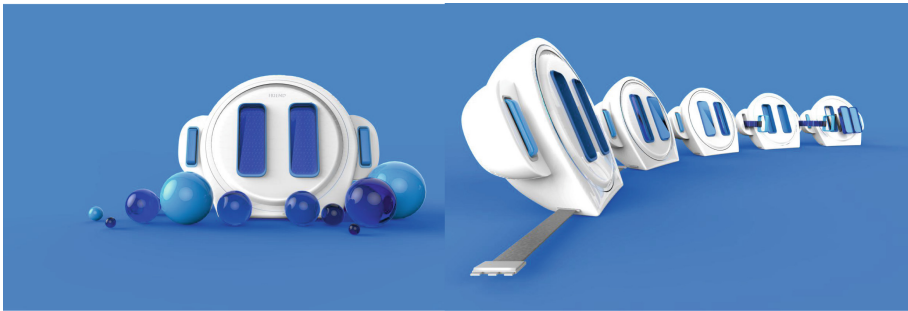
## 6 Design Practice

### 6.1 Design Positioning

During the procedure of the research objective, it was found that the elderly rehabilitation equipment of the elderly can only be experienced after getting out of bed, and for the empty nest elderly, the elderly also has certain problems in their psychology. The design is intended to solve these problems by improving the use of rehabilitation equipment and integrating product and user interaction into rehabilitation products to improve the use of rehabilitation equipment and increase the recovery rate of the elderly.

### 6.2 Design Plan

Through the research on the rehabilitation equipment of the elderly in bed, the design direction and design orientation of the rehabilitation equipment are analyzed, and the relevant theories of human-computer interaction are followed to further conceive and propose a relatively complete design scheme (as shown in Fig. 7). Functionally, the rehabilitation equipment includes three functions:



**Fig. 7.** Design scheme

- (1) Foot part - guides the activity of the foot;
- (2) The part of the bracelet - guides the body's getting up movement;
- (3) Fixed part - enables rehabilitation equipment to be fixed on the bed;

In details, these functions are shown as follows,

- (1) Back lift function: Through the pull ring adjustment, the 0–90° back angle lifting function of the back is realized, which is convenient for the patient to eat and perform the rehabilitation exercise of the upper limb exercise function.
- (2) Stretching arm flexing arm function: multi-directional traction treatment of the affected limb, assisting the upper limb to perform the upper and lower flat extension, the rehabilitation action, and promoting the recovery of muscle function such as triceps and biceps.

- (3) Lifting leg bending leg function: This exercise can be used for single-limb training, with the hip as the center, assisting the lower limbs to lift up and practice, to achieve the effect of exercising waist and abdomen muscles, gluteus medius and rectus abdominis. Focusing on the knee joint, assisting the lower extremity to perform the flexion leg exercise to achieve exercise for the knee joint and the leg muscle tissue. In terms of styling, the shape design is a lovely and anthropomorphic shape, giving a kind and lovely feeling, bringing a sense of spiritual comfort to the elderly who have been in bed for a long time.

## 6.3 APP Design

### 6.3.1 LOGO Design

Intended to accompany the elderly - accompanying the elderly in bed to move their bodies, through the accompanying app. Help the elderly social entertainment, bring physical and psychological recovery to the elderly in bed, LOGO: direct Chinese characters, “companion with” plus icon, emphasizing emphasis, visual communication directly (as shown in Fig. 8).



Fig. 8. APP LOGO design

This design uses a lot of card-type bearer information, simple and intuitive symbol button, the title font size is 60px or more, and the font size is 40px or more, which strives for simple and bright visual effects. For the platform used by the elderly, the design has no three-level interface, basically the behavior of the background operation is concentrated in the home page for direct processing. For example, we will use all the drawers of the interactive view language to display the interface. Not a pop-up window. Through such a design, the elderly can be greatly accelerated to obtain information.

### 6.3.2 Interface Design

Through analysis, the elderly need a long time to learn electronics, so designers should adopt a more intuitive, convenient and simple interactive design. Simplify the operation process in the process of using the elderly products, make the operation process more interactive, optimize the operation and reorganize, and remove redundant operation steps and procedures. Physically restrictive logic procedures are employed to minimize the operational steps and processes of logical reasoning. This method is utilized to reduce the part of the user who needs to think about using the product, taking instinctive actions or habitual behavior (as shown in Fig. 9).





Fig. 9. APP interface design

In the product design, the main information and the part that needs to be memorized are entrusted to the product, instead of relying on the user to memorize, the product only needs to provide the required information to the user at the right time. The product design of the elderly is first of all to meet the functional needs of the elderly in use, and then to design elements of safety, convenience, health care, health, culture, etc., so that the elderly can accept new things in a relaxed and happy mood. To make progress and improvement, while gaining fresh information and maintaining close contact with society. Such positive social information exchange and communication has weakened the sense of loss of the elderly in the intelligent age.

Children’s side (mobile phone): The child uses the mobile app to check the physical condition, social situation and physical status of the blood pressure, pulse, and heart. The home page is simple and functional, and the children can clearly understand the day of the elderly through it (as shown in Fig. 10).

7 Conclusions

This paper took the household rehabilitation equipment in bed for the elderly as research object. On one hand, the main users’ needs of household rehabilitation equipment were analyzed by using the user-tool-task model. The users’ psychology, the experience in the process of using rehabilitation equipment, combined with the specific scene when using, were discussed to discover the “human” factors of rehabilitation equipment for the elderly in bed. On the other hand, the hardware and software interface of the elderly rehabilitation equipment for the elderly in bed were analyzed. Combined with the existing bed rehabilitation equipment in the hospital, we



Fig. 10. APP interface design

discussed the “machine” factors of the equipment for the elderly in bed, and improves the software and hardware interface of the existing bed rehabilitation equipment.

For the elderly in bed, they are difficult to rehabilitate at home, and prone to frustration and emptiness. In the process design, the home rehabilitation system for the elderly in bed was proposed. In addition, the conceptual design of rehabilitation system combining physical rehabilitation and psychological rehabilitation is proposed in order to achieve the purpose of rehabilitation of the psychology and physiology for the elderly in bed.

**Acknowledgments.** This work is financially supported by 2017 Chinese Ministry of Education Humanities and Social Sciences Research Youth Fund Project (No. 17YJCZH231), the Teaching Research Project of Hubei Province (No. 2016075) and Huazhong University of Science and Technology (No. 2018056).

## References

1. Shangyong, Y.: The “seven sins” of the elderly who have been in bed for a long time. *J. Health Care*. **6**, 25–27 (2011)
2. Shuyang, M.: Research of interactive design strategies for the old people (2007)
3. Luyang, W.: Application of human-computer interaction design in product design. *Packag. Eng.* **14**, 85–88 (2014)
4. Long, L., Yu, L., Tao, S.: Design of products for older based on human machine interaction. *Ind. Eng. J.* **13**, 89–94 (2010)
5. Kai, F.: Design of elderly medical products for the elderly. Nanjing University of Science and Technology (2016)
6. Lin, R., Kreifeldt, J.G.: Ergonomics in wearable computer design. *Int. J. Ind. Ergon.* **27**, 259–269 (2001)
7. Lin, C.L., Chen, S.J., Hsiao, W.H., et al.: Cultural ergonomics in interactional and experiential design: conceptual framework and case study of the Taiwanese twin cup. *J. Appl. Ergon.* **52**, 242–252 (2016)

8. Demirbilek, O.: Involving the elderly in the design process: a participatory design model for usability, safety and attractiveness (1999)
9. Jinmei, Y., Huizhen, P., Guiping, L.: Effect of rehabilitation nursing on self-care ability of elderly patients with chronic illness. *Chin. J. Rehabil. Med.* **19**, 548 (2004)
10. Zhenzhen, H.: The Research by domestic limbs rehabilitation training product design of the older. DongHua University (2014)



# Visual Storytelling - Creative Strategy of Visual Clues Promoted by Archetypal Images

Jose Silva<sup>(✉)</sup>, Daniel Raposo, João Neves,  
and Fernando Moreira da Silva

CIAUD - Faculdade de Arquitetura da Universidade de Lisboa Rua Sá Nogueira,  
Pólo Universitário, Alto da Ajuda, 1349-063 Lisbon, Portugal  
Gago.silva@gmail.com, fms.fautl@gmail.com,  
{draposo, joaoneves}@ipcb.pt

**Abstract.** The following article describes a creative strategy in the learning environment regarding Digital Design, specifically the development of visual exploration on emotional archetypes to a group of students of Master of Graphic Design of the School of Applied Arts of the Polytechnic Institute of Castelo Branco, Portugal in the academic year 2018/19. The research topic was introduced in the development of a communication project for the Agro-Food product, bee pollen. The article presents the introduction to the problem, hypothesis, objectives, strategy, results, and conclusion. The development of the visual exploration strategy included the theoretical framework of Wertime [8], and Woodside, Sood and Miller [9]. Although the results point out the richness of the proposed strategy in communicating the importance of the emotional concept among students and the notion of structure in the communication, The authors assessed from the resulting experience, the complexity of communicating the possibilities of the use of archetypal images in the development of communication solutions.

**Keywords:** Archetypal images · Learning strategy · Visual maps ·  
Exploratory studies

## 1 Introduction

The intuition, defined by Paul Rand as a flash of insight conditioned by experience, culture, and imagination [11], is of great value to the Designer. In the aspect of communication oriented to a particular culture, the emotional archetypes play an essential role in the empowerment of the imagination.

According to Matthews [6], valuing the imagination and the image can lead to a methodology for understanding and participating in world-making. Carl Jung emotional archetypes suggest that the power of the image could offer a method for interpreting and responding to the complexity of a particular system, the authors refer to the economic system as an example. Although it is manifest in a specific form or image, the archetypal worlds hide the source of the “treasure” but a process of creative imagination may reveal it.

According to Jacobi [3] because the representation of the archetype goes beyond our rational understanding, an archetypal content is first expressed in metaphors. Abstract relations, situations, or ideas of the archetypal nature are visualized by the psyche as forms, figures, images, specific objects, or at least translated into events susceptible of being represented in images or pictorial sequences.

Carl Jung's emotional archetypes, through archetypal imagery, enable a vast universe of applications in the development of communication solutions. However, his understanding is enormous and may give rise to some confusion in what is understood explicitly by archetypes and what is the perspective of Carl Jung.

This proposed creative strategy follows, implicitly, the interpretation of Jacobi [3] who present that archetypes as pre-dispositions of action, or succinctly in patterns of behavior. Several disciplines work the concept related to archetypal images the area of consumer behavior highlights the applications associated with the image issue. In this perspective interpretations associated with the mapping of archetypes and their correspondence with the brands are found, [2, 3, 5, 9]. The proposed creative strategy follow the table of correspondences of archetypes of Wertime [8], according to the author, the archetypes are neither learned nor acquired, but they are with the human being from birth, maintain their basic form over time and are of universal scope, crossing racial, gender, age and language boundaries.

In this sense, a wide range of applications that allow meeting the perspectives of action of a product can integrate the concept of archetypal images. This idea is in line with what is meant by the emotional positioning of consumer products.

The visual exploration developed in the proposed strategy focused a bee pollen produced by the microenterprise "Olhar Campestre," based in the city of Castelo Branco, Portugal.

The visual exploration, aimed at the communication of products, sought to explore different perspectives of product consumption and behaviors associated with bee pollen.

The early stages of the design process included exploratory research, defined by the planning phase, definition of scope and meaning, leading later to generative concept design. The focus of activities is to gain a solid ground of knowledge of the territory of existing design and artifacts and to forge an empathic sense of the people targeted by the design work. Exploratory research should be an immersive experience for the designer, inspiring the creative momentum and empathy through intense exposure to relevant people and products, using a wide variety of diverse and complementary methods.

The proposed creative strategy explores the hypothesis of using archetypal images as a contribution to improving the visibility and appropriateness of ideas arising from the idea generation phase.

## 2 Problem

There is a wide number of literature on the applications of the principles of the emotional archetypes in the field of product communication, among them, manuals that allow subdividing the main archetypes into several representations and others that alter the denominations of these same archetypes. There are a priori and a posteriori

applications of the archetypes. A priori image applications allow the use of categorization systems to aid in the creation of a “personality” of the product. The systems that act afterward focuses on the identification of archetypes in brands and products. Such identification results of consumers’ individual and social-emotional expectations when “experiencing” products. Another problem associated with the concept of archetype and related to education in design concerns the need to overcome the theoretical complexity of the concept and develop a practical application where the concept works as a tool.

### 3 Hypothesis

The hypothesis tested integrates two “tools”, one referring to a categorization adapted from the interpretive panel of table of archetypal correspondences according to Wer-time [8] and a prism of association with the integration of elements of a narrative according to Woodside, Sood, and Miller [9]. The hypothesis aims to understand if the use of the concept of archetypes as a creative tool allows improving the visibility and adequacy of ideas arising in a work of generating ideas.

### 4 Objectives

The objectives were the following:

- The use for the development of an exploratory work of archetypal images based on the table of archetypal correspondences according to Wertime [8] from Carl Jung’s emotional archetypes interpretive table and a prism of association of archetypal elements called the “Brand enabling archetype enactment by consumer” from the authors Woodside, Sood and Miller [9].
- The use of the concept of archetypal images as a tool for generating ideas.

### 5 Strategy

The visual exploration strategy was tested in a learning module, focused on the introduction of a digital design project on the communication of an agro food product, included the following five mixed learning sessions (classroom and online) each with the duration of 3 h.

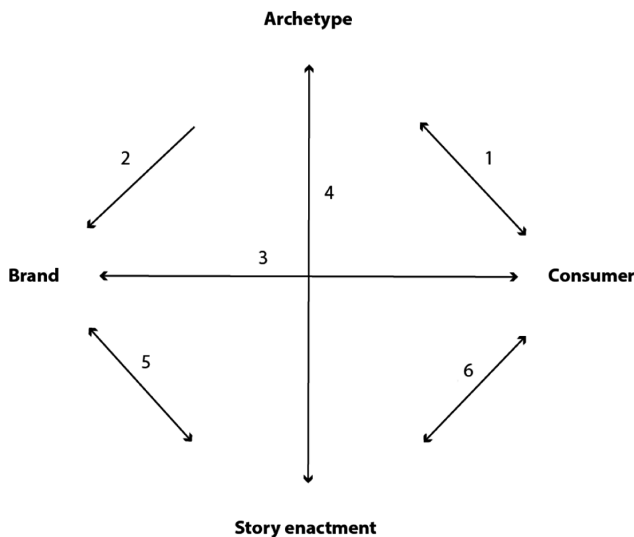
- Experimental session physical exploration
- Theoretical session
- Development
- Development, discussion and presentation (first refinement)
- Development, discussion and presentation (second refinement)

In the Experimental Session with the bee pollen product, the students were able to taste the product and mix these products with other available food products (provided by

the teacher) to test their compatibility. Then followed a Theoretical Session on Carl Jung's emotional archetypes and archetypal images forms in contemporary culture. In the visual exploratory sessions (Development Sessions), which took place during three sessions were organized so that in the first session students could collect images of the archetype that had been distributed to them and create their first associations and narratives. In the second and third sessions, students continued the visual exploration, but also discussed their findings and present them to the group of students in a two-round refinement.

In the Development Sessions an Archetypal Images Schematic Working Map containing a table of archetypal correspondences according to Wertime [8] and Archetypal Image Association Prism adapted from Woodside, Sood and Miller [9], was made available to the students. The table adapted from Wertime [8] provides gist's of stories for twelve archetypes together with examples of brands that explicitly or implicitly communicate these archetypes.

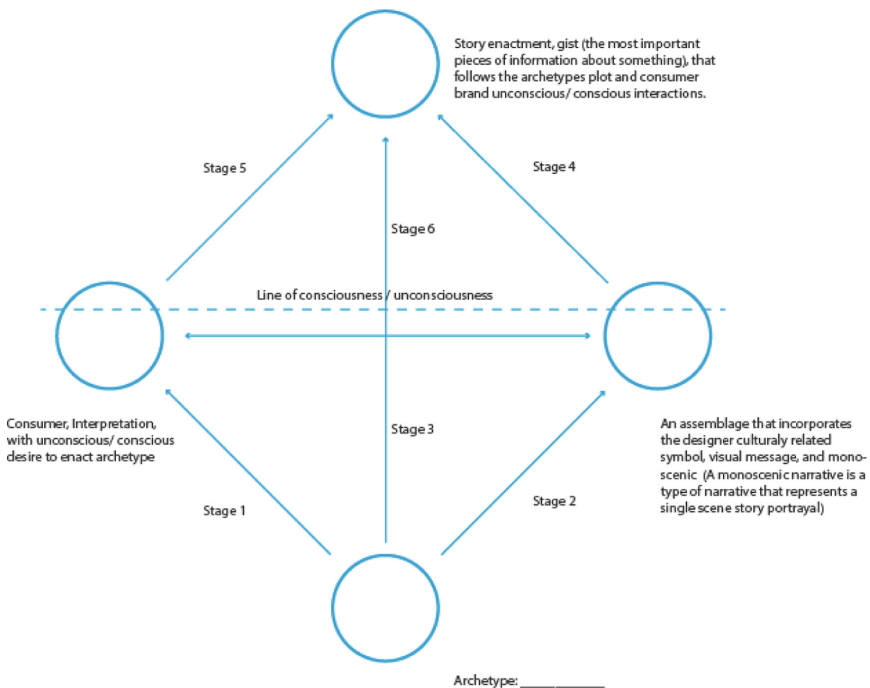
The Archetypal Image Association Prism adapted from the "Brand enabling archetype enactment by consumer" from Woodside, Sood and Miller [9], see Fig. 1, emphasizes the importance of archetypes in deepening the meaning-making of classic narratives applied to marketing and consumer psychology. Arrow 1 represents the proposition that the predominantly unconscious desire to realize archetype leads consumers to act. Arrow 2 proposes that dramaturgical representations reflect one or more archetypes. Arrow 3 reflects the proposition that the archetype produced by the communication professional in a brand dramaturgy must correspond to the archetypal urges, mainly or totally unconscious, of the intended client. Arrows 4, 5, and 6 illustrate that the staging of a story by consumers, their retrospective storytelling reflect one or more archetypes; the same proposal applies to the brand narrative developed by the author of the brand communication.



**Fig. 1.** Summarized information from the "Brand enabling archetype enactment by consumer", retrieved from the authors Woodside, Sood, Miller [9] - Fig. 3.

However, Woodside, Sood and Miller [9], citing an earlier paper [10], caution that researchers should not be arrogant and vain in believing that their interpretations of consumer story reports are necessarily accurate, complete, or the only ones applicable to the interpretation of the relevance of specific archetypes.

In the prism presented to the students an adaptation was developed to the initial diagram of Woodside, Sood, Miller [9], the arrows were dubbed phases, in order to experience a phasing of the information and to try another operability in the conceptual tool. The proposed strategy sought to understand how the representation of the archetypal image would provide clues to the logic of the product. This logic would be based on a dramaturgy representative of a real emotional experience, Fig. 2.



**Fig. 2.** The Archetypal Image Association Prism resulted from the adapted structure from the authors Woodside, Sood, Miller [9], distributed to students contained image references, which due to copyright issues cannot be reproduced in this document.

Although Woodside, Sood and Miller had already referred to the Wertime table in their 2008 paper [9], the proposed strategy in this paper tested how these two “tools” could work together in the context of a digital design.

The Archetypal Images Schematic Working Map included three steps, a framework with the categorization of archetypes followed by an archetypal association prism and a diagram of associations resulting from the archetype association prism.



In order to complete the information needed to create the Archetypal Image Association Prism students worked with images collected on the Getty Images Bank. This image bank, although commercial, has a rich indexation attributed to the images, allows correlating concepts and, thus, to evaluate the cultural and commercial classifications of images.

The third phase presented in the schematic represents the extrapolation of information to a sketch, an approximate idea of the actual product using the elements resulting from the archetype association prism, Fig. 3.

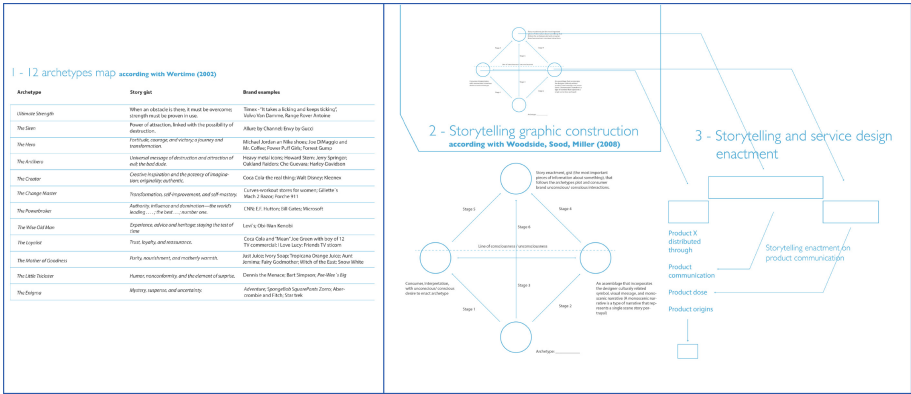


Fig. 3. Archetypal Images Schematic Working Map distributed to the students.

The group of twenty students was divided into 10 groups and each group developed an archetype from the table of archetypal correspondences according to Wertheim [8]. Each group had the challenge of working the original bee pollen product, developing a consumer and communication solution. In this way, the use of archetypal images would produce an emotional differentiation of perspectives of consumption and communication.

The strategy worked a sequence of divergent thinking followed by convergent thinking. According to Bowers [1], the problem-solving process diverges and converges, expands and contracts. Divergence is the process of identifying, creating, and developing various ways to solve a problem. Convergence is the process of selecting and developing concepts of the multiple objectives developed at the beginning of the project.

In the learning phase, the process diverges and expands as the information is gathered, then contracts as the information is analyzed at an identification phase. The process then expands again into the generation of ideas as multiple concepts are developed and contracted in the evaluation phase, where a single concept is refined and implemented. In the proposed strategy, in the phases of divergent thinking regarding the learning and generation of ideas, occurs an expansion shaped by the cultural context characteristics represented by the archetypal images.

## 6 Results

The application of the proposed creative strategy resulted in an understanding of archetypal images as a constructive element in exploratory diagnostic studies that support the development of a design project.

By dividing the work process into several phases the students detailed each step and reflected on the action value of the archetypes. The development of an exploratory reflection phase allowed students to develop a phased argumentation of the proposed solutions. When the solution does not work, the problem may be associated within the developed narrative, with a poorly constructed sequence, constituted of moments of anti-climax, followed by climax moment where the product should appear as a credible solution. Students worked narrative logics based on patterns of action, represented by archetypal images.



**Fig. 4.** Nigma Panel - Polen in tea, exploratory work on the Archetypal Images Schematic Working Map. Panel of students Marco Martins and Marco Moreira.

A simple trend research does not offer a complete sampling, if anything, it can offer clues, ‘arborescent’ structures, but stripped of a narrative. Beyond the narrative that results from the Archetypal Image Association Prism, the intensity of the narratives is also “worked” through exposure to other colleagues and thus there is a co-production of value in the project.

According to Mootee [7], growth-oriented narratives help extract emotional inputs and responses from stakeholders and can be used to instill optimism in the organization or reveal anxieties about the future. A limit-seeking strategy is used, according to Jones [4] to find limits within which acceptable solutions, the tested creative strategy follows the principles of incremental search, simulation and limit search rather than acceptable or unique acceptable values. The students had the opportunity to reorganize the support tool of the Schematic Work Map of Archetypal Images in their proposals, as can be seen in the example portrayed in Fig. 4.

## 7 Conclusion

According to the objectives defined in the present paper, the use of an table of archetypal correspondences according to Wertheim [8] of Carl Jung’s emotional archetypes and a Archetypal Image Association Prism, adapted from Woodside, Sood and Miller [10] for the development of an exploratory work on the concept of archetypes was successful, although there have been some difficulties in constructing a narrative using only a sequence of images, it is worth noting the difficulty felt by the students in the construction of moments of anti-climax and climax.

When students used with the Schematic Work Map of Archetypal Images a bank of commercial images, as a support tool, they understood the importance of cultural indexing of images and how that indexation relates with the emotional archetypes.

The Archetypal Images Schematic Working Map was effective as support tool. It allowed students to test different associations, the coherence of the elements, and the reverberation of the archetype in the narrative and the proposed product experience.

By using the concept of archetypal images as a tool for generating ideas, students were able to understand the possibilities of using the concept as a tool, but it was necessary to include a small clarification session to reinforce the perspective of the emotional archetypes as patterns of action, in Institutions. The term “Institutions” applied refers to the sociological meaning commonly applied to customs, or behavior patterns.

With regard to the hypothesis presented concerning the concept of archetypal images as a creative tool and related to their ability to improve the visibility and adequacy of ideas arising from a work of generating ideas, the concept of archetypal images has great possibilities in terms of application in exploratory studies. It becomes clearer for students the possibilities of these “Institutions” in structuring narratives and contextualizing the visual exploration.

The use of the proposed creative strategy is validated as a support tool in reinforcing the diagnostic practice of visual exploratory studies as support for design projects.

The development of this exploratory study allowed the students to develop a phased argumentation supported by the narrative logic, from the exploratory work. The

intensity and coherence of these narratives were “worked” through the presentation and dialog to other colleagues thus creating a co-production of value in the project.

**Acknowledgments.** The authors of this article acknowledge the collaboration of the Master of Graphic Design, student class of 2018/19 of the course New Media Production and Consumption, of the Escola de Artes Aplicadas of the Polytechnic Institute of Castelo Branco in Portugal.

## References

1. Bowers, J.: Introduction to Graphic Design Methodologies and Processes: Understanding Theory and Application. Wiley, London (2011)
2. Hartwell, M., Chen, J.: Archetypes in Branding: A Toolkit for Creatives and Strategists. HOW Books; Spi edn. Cincinnati (2012)
3. Jacobi, J.: Complex, Archetype, Symbol. Princeton University Press, New York (1974)
4. Jones, J.: Design Methods. Van Nostrand Reinhold, New York (1992)
5. Martins, J.: A Natureza Emocional da Marca Construção de Empresas Ricas. Editora Campus, Rio de Janeiro (2006)
6. Matthews, R.: Competition archetypes and creative imagination. *J. Organ. Change Manag.* **15**(5), 461–476 (2002)
7. Mootee, I.: Design Thinking for Strategic Innovation. Wiley, Hoboken (2013)
8. Wertime, K.: Building Brands & Believers. Wiley, Singapore (2002)
9. Woodside, A., Sood, S., Miller, K.: When consumers and brands talk: storytelling theory and research in psychology and marketing. *Psychol. Mark.* **25**, 97–145 (2008)
10. Woodside, A.: Overcoming the illusion of will and self-fabrication: going beyond naïve subjective personal introspection to an unconscious/conscious theory of behavior explanation. *Psychol. Mark.* **23**, 257–272 (2006)
11. Rand, P.: Design, Form, and Chaos. Yale University Press, Yale (2017)



# Review of the Research on Car Seating Comfort

Xiaoli Fan<sup>1</sup>(✉), Chaoyi Zhao<sup>1</sup>, Xuemei Chen<sup>2</sup>, Yuwei Jiang<sup>3</sup>,  
Yongjia Shen<sup>1</sup>, and Tong Shen<sup>1</sup>

<sup>1</sup> SAMR Key Laboratory of Human Factors and Ergonomics, China National  
Institute of Standardization, Beijing 100191, China

{fanxl, zhaochy, shenyj, shent}@cnis.gov.cn

<sup>2</sup> Beihang University, Beijing 100191, China

cxml205@buaa.edu.cn

<sup>3</sup> China Mobile Communications Corporation Government and Enterprise  
Service Company, Beijing, China

jiangyuwei@chinamobile.com

**Abstract.** Improving car seating comfort is very important in the process of car development and design. This paper reviewed the research progress of car seating comfort at home and abroad. Firstly, the related concepts related to the comfort of car seats were introduced, and then the factors affecting the comfort were analyzed in depth. Finally, the subjective evaluation, objective behavior evaluation and physiological parameter evaluation methods for seating comfort were introduced with their advantages and possible problems being analyzed respectively. This paper will provide a large number of theoretical basis and important reference significance for the subsequent development of car seating comfort.

**Keywords:** Seating comfort · Subjective evaluation ·  
Objective behavior evaluation · Physiological parameter evaluation

## 1 Introduction

Sitting posture is one of the most commonly used postures in people's work and life. However, being in a static sitting position for a long time can cause low back pain, cervical pain, sciatica, etc., and people with these painful conditions also feel uncomfortable [1, 2], which will affect people's work and living efficiency seriously. In addition, the comfort of people in a dynamic sitting position also requires special attention, especially the impact of collision and other special circumstances on the human body from car driving and airplane driving. People's daily lives are inseparable from cars, that is, cars have established connections with everyone as a means of off-road vehicles or transportation in today's society. China is in a rapid development, and more people will buy cars with the improvement of living standards. People's requirement for car is higher and higher, from the prevention of collision damage in the past to the comfort requirements at present. Car seat is closely related with the driver. The number of vehicles in China has exceeded 100 million according to relevant

literature, meanwhile the number of drivers suffering from back pain is more than 100 million [3]. Therefore, improving car comfort, especially seating comfort, has become particularly important in the development and design of cars. In recent years, car seating comfort has been studied as a unique subject.

At present, there have been many studies on the comfort of factory and office seats, but relatively few studies on the comfort of car seats. The research methods of car seating comfort mainly include experiment, computer simulation and prediction. The experiment mainly includes subjective investigation and analysis of vehicle comfort, sitting posture analysis, measurement of body pressure distribution, performance observation and electromyography based on physiology, etc. In addition, considering the convenience and low-cost of simulation calculation more and more researchers began to evaluate car driving comfort by simulation, such as the maximization analysis of driver's visual field, analysis of control distance of steering wheel and rudder and so on. Liqun et al. [4] established a multi-body dynamic model of the seat by using MATLAB to analyze the factors that had the greatest impact on the vibration transmission characteristics of the car seat, and made corresponding improvements. Kolich [5] in University of Windsor in Canada predicted the comfort of the car seating by using the neural network method, while Grujicic [6] in University of Clemson in the United States used finite element method to study the pressure of the driver and the car seat, and used it to evaluate the comfort of the car seat. The following is a detailed introduction of the research methods and theories of car seating comfort.

## 2 Theories

The comfort of car seating mainly includes static comfort, dynamic comfort (also known as vibration comfort) and operation comfort. Static comfort refers to the comfort characteristics provide by the seating to the human body in the static state, which is mainly related to the seating size parameters, surface, quality, adjusting characteristics etc. Dynamic comfort refers to the comfort characteristics of the vehicle which transmits vibration to the human body through the seating skeleton and cushion in the moving state, it mainly related to the vibration characteristics; Operational comfort refers to the comfort of the seating in the driver, the comfort characteristics for completing the driving action in the driving process [7]. In order to systematically understand the comfort of car seating, the following concepts are explained here.

### (a) Static characteristics

The static characteristics of the seating mainly include the form and size of the seating, the material used in the seating and the coordination between the seating position and the working space.

### (b) Dynamic characteristics

The dynamic characteristics of seating [8] refer to the relative subjective comfort that human body feels in the vibration environment. The dynamic characteristics of driving seating are mainly related to the vibration characteristics [9]. Vibration mainly comes from random vibration and mechanical vibration of the vehicle itself. It mainly brings

vertical, longitudinal and transverse linear and angular vibration to the driver. Vertical vibration and angular vibration around longitudinal and transverse direction have the greatest influence.

(c) Transfer rate

Seating vibration transmission rate [10], also known as acceleration transmission rate, is the ratio of acceleration on the contact surface between seating and human body to the input acceleration of vehicle chassis excitation. The transmission rate of seating vibration is determined by the dynamic behavior of human body and seating systems.

(d) Apparent mass

Apparent mass [11] is the ratio between the excitation applied to a system and the response of the system to it. For example, the apparent mass of the human body in the vertical direction is the ratio between the force  $F$  exerted on the human body in the vertical direction and the acceleration  $a$  produced by the human body. That is  $M = F/a$ .

(e) Human body vibration sensitive frequency

The experimental results showed that the sensitive frequencies of human upper and lower vibration are within 4–8 Hz, and within 1–2 Hz, resonance occurs in some parts of the body.

(f) WILL Concept Seating

The design principle of WILL concept seating [13] is to provide safety support for the whole spine and head synchronously when collision occurs. When rear-end collision occurs, the back of the WILL Concept Seating will improve the fitness between the body and the seat.

(g) Parallel Vibration Reduction Principle of Positive and Negative Stiffness

Stiffness is defined as the ratio of load to deformation of spring. When the load increases with the increase of deformation, it is positive stiffness, and vice versa, it is negative stiffness. When the positive stiffness spring and the negative stiffness spring are connected in parallel, the total stiffness of the system in the negative stiffness region of the negative spring is smaller than that of the positive spring. The reduction is caused by the negative spring, which is the principle of the parallel elimination of the positive and negative stiffness [14].

(h) Five-degree-of-freedom model of human body-seating

In this model, the human-seating system is divided into five parts: head, upper trunk, lower trunk, buttocks, legs and seats in the vertical direction. The corresponding stiffness and damping coefficients are added to the model.

### 3 Influencing Factors of Car Seating Comfort

Among many factors, the car seating is an important part which links the occupant and driver with the body of the car, and the impact on comfort is the most direct. Vehicle seat comfort is a system engineering, which involves almost all the components of the car, including power, transmission, chassis, suspension, car shape, glass, seat, tire, sound, air conditioning, electronic configuration, noise and so on. These factors will produce different sensory stimuli to the driver and other passengers in the car, thus deciding the driving and riding comfort of the whole car from different aspects to different degrees. The factors affecting the comfort of car seats can be roughly divided into vehicle factors, social factors, individual factors and seating factors. Vehicle factors mainly include seating height, pedal and steering wheel orientation, body expansion space and shape setting of variable speed rocker. Social factors mainly include car brand and price, and the comfort level of car seats with different brand and price is different.

Individual factors mainly include demographic factors, anthropometric parameters, culture and sitting posture. Seating factors mainly include seat stiffness, geometric parameters, fabric permeability and seat style.

In addition, the noise environment inside and outside the car, air conditioning performance, operation panel, and luggage compartment also affect the rider's evaluation of seating comfort to varying degrees.

### 4 Evaluation Methods

At present, the evaluation methods of car seating comfort are mainly divided into three kinds: subjective evaluation, behavior detection evaluation and physiological parameter evaluation. Each comfort evaluation has several corresponding evaluation methods.

#### 4.1 Subjective Evaluation

Subjective evaluation is an old and practical evaluation method, which can directly and clearly reflect the driving comfort performance of automobiles. Therefore, subjective evaluation method has been widely used and studied. In China, the study of automobile comfort is mostly based on subjective evaluation method. There are many methods of subjective evaluation. This paper briefly introduces several typical evaluation methods:

##### (a) Multi-level Fuzzy Comprehensive Evaluation

The multi-level fuzzy comprehensive evaluation is to quantify the fuzzy indicators reflecting the evaluated things by constructing a hierarchical fuzzy subset (determine the membership degree), and then use the principle of fuzzy transformation to evaluate the indicators comprehensively. The advantages are: the mathematical model is simple, the context is clear, and the multi-factor and multi-level complex problem evaluation effect is incomparable to other mathematical branches and models. The factors to be evaluated of the seat selected by the method include seat height, seating width and depth, seating angle, waist height, lumbar inclination and lumbar shape curvature [15].



#### (b) Body part discomfort size

This method divides the body into several parts, the subjects point out which they feel discomfort, and choose the degree of discomfort on the scale. Then the discomfort is sorted and processed. Finally, the BPD index of discomfort is obtained [16].

#### (c) Psychological measurement

Some researchers had cooperated in making use of SD method in psychological measurement to make a subjective evaluation of car ride comfort based on body vibration, indoor environment, occupant's psychological and physiological conditions. The hierarchical model of subjective evaluation of car ride comfort was constructed by introducing fuzzy measure and fuzzy integral in Fuzzy theory. The results showed that the hierarchical fuzzy integral model was suitable for subjective evaluation of vehicle ride comfort and had better calculation accuracy [17].

### 4.2 Objective Behavior Evaluation

The evaluation of objective behavior is mainly to provide quantitative testing results. Many evaluation methods have been developed. At the same time, with the development of testing technology, the testing of objective behavior has become more and more scientific. However, human comfort is a very vague concept, it is difficult to locate accurately, so there are still many areas to be improved in the existing testing methods.

#### (a) Measurement method of body pressure distribution

When a person sits on a chair, the gravity of the human body acts on the cushion and the backrest. The pressure distribution is called the body pressure distribution or the body stress distribution [18]. When a person sits down, most of the body weight (about 80%) is pressed on the seat surface through buttocks, back bulges and attached muscles. The reasonable distribution of body pressure is an important factor affecting ride comfort. At present, GM, Ford, Toyota, Honda, BMW, Volvo, Delphi and other companies are widely using Tekscan's pressure distribution measurement system to solve the seating comfort problem. In this system, more than 4000 sensors are arranged on the seating cushion and backrest to measure the effect of the support of the cover and the hardness of the sponge on the pressure distribution and comfort of the seating. At present, the body pressure distribution testing method has become a relatively simple and easy to operate seating comfort testing method.

#### (b) Apparent Mass Method

The driver is in a state of full body vibration during driving. The influence of vibration on driver's operation is mainly manifested in the decrease of visual operation efficiency and the deterioration of operation accuracy. In the vibration environment, human body will accelerate the fatigue process. If resonance occurs in a certain area or organ of human body, it will cause corresponding physiological changes, which involve muscular system, respiratory system, blood circulation system, vegetative nervous system and sensory system. When a certain limit is reached, the working intensity of cortical

cells will be weakened, people will feel tired and work efficiency will be significantly reduced. Apparent mass method is to exert force on the human-seat system at different vibration frequencies, measure the acceleration of each part of the model, calculate the apparent mass of the corresponding part by using formula  $M = F/a$ , and get the relationship curve between the apparent mass and the vibration frequency. The dynamic performance of the seating is analyzed and vibration frequency has a great influence on the human body is determined, so as to improve and optimize the natural frequency of the seating and other parameters [11].

#### (c) Comparative method

The testing results showed that the factors affecting the dynamic characteristics of the seating were the stiffness and damping coefficient of the seating cushion, the mass, stiffness and damping coefficient of the suspension system and the dynamic performance of the seating frame structure, among which the stiffness and damping coefficient play a decisive role. The stiffness parameters determine the resonance frequency of the seating, while the damping coefficient determines the vibration attenuation characteristics of the seating. The comparison method is to measure the transmission rate of rigid seating and elastic seating under different vibration frequencies, and to compare the transmission rate of the two seats.

#### (d) Material performance testing of car seating cushion

When people are exposed to high humidity and high temperature, they often feel uncomfortable, limbs are weak and their work can not last long. Turkey's Tulin and Japan's Kazuaki's research on the influence of thermal environment on driver's driving comfort showed that the air permeability of backrest and cushion materials seriously affected sweat emission [18, 19]. In addition, the study also showed that drivers who prefer cushions and soft backs were susceptible to impact, but hard cushions were not susceptible to fatigue. Therefore, the air permeability and softness and hardness of cushion and backrest materials can be used as evaluation indexes of comfort.

#### e) Work Performance Testing

According to the statistics of relevant departments, there are as many as 1 billion road traffic accidents in the world every year. Recent studies showed that 25–30% of the causes of car crashes were caused by driving fatigue. Driving fatigue affects drivers' alertness and driving safety. Work performance testing is to evaluate the comfort of the seating by observing whether the performance of the driver after driving a car declines after a certain period of time.

#### (f) Modeling and simulation method

Due to the advantages of good repeatability, time-saving and labor-saving, more and more researchers had been beginning to use simulation methods to study the driving comfort of automobiles [20, 21]. Among them, more studies had been done on the vibration transmission characteristics of automobile seats and driver's posture prediction. A. Siefert et al. of Germany calculated the car seating and driver model by ABAQUS finite element method, and evaluated the comfort of the model according to the simulation results. This method can optimize the structure and comfort performance

of the seat in the early stage of seat development and production, and could greatly reduce the production cost of the manufacturer [20]. Some used neural network, the method predicted the subjective evaluation of car seating and achieves good results, which could greatly reduce the number of evaluators and saved time and manpower when evaluating the seats comforting subjectively. Others used the optimized non-linear active suspension seating to conduct safety and comfort analysis, evaluated the comfort performance of different suspension seating, and concluded that they have. The seating comfort performance of semi-active or active suspension was improved by 20%–30% [22]. In addition, some people in China used MATLAB simulation to calculate the vibration transmission rate of the seat, which also had a good effect.

### 4.3 Physiological Parameter Evaluation

#### (a) EMG

The EMG mainly evaluates the driver's fatigue degree by testing the driver's EMG signal. The main muscles tested were left and right trapezius, erector spine and internal trapezius. The median frequencies of left and right trapezius, erector spine and internal oblique muscles are obtained by EMG signal analysis. The median frequencies can be used to determine whether the shoulder and waist muscles are fatigued due to the type and duration of the cushion (or both). The EMG signal of signal data acquisition system is usually collected by six electrodes.

Research showed that it could reflect the changes of muscle function. When muscle fatigue occurs, the power spectral density of EMG signals was gradually compressed in the direction of low frequency. This was due to the decrease of nerve conduction velocity directly related to membrane excitation, which led to the increase of low-frequency components of the signal, and the enhancement of this effect by the low-pass filter between the surface electrodes and the active muscle fibers. Calculated from the power spectrum was a very reliable index to measure this spectrum compression. The change of nerve conduction velocity of muscle fibers caused by lactic acid accumulation was related to the increase of frequency spectrum compression and fatigue degree, and then decreased with the increase of fatigue degree.

#### (b) Temperature and Humidity

Driver's comfort temperature is 18–23 °C, comfort humidity is 40%–60%, metabolic capacity is 1.0–2.0 met, higher or lower than this range will increase driver's fatigue degree. The main influence factors of driving seating on driver's thermal environment are temperature and humidity on the seating surface. The temperature and humidity characteristics of the seating surface will affect the heat dissipation performance of the back, buttock, lower body and the respiratory function of the skin. When the temperature and humidity characteristics of the seat surface do not adapt to the physiological function of the human body, it will cause the local discomfort of the human body, thus accelerating the formation of human fatigue. In the temperature and humidity testing method, the main test sensor is placed in the test site for testing. The data of skin surface humidity such as inner thigh, abdomen, chest, waist, buttock and back need to be tested.

## (c) EEG

When the driver is tired, the brain responds slowly to traffic lights, speed restrictions, pedestrians and other traffic signals, and the corresponding electrical signals of brain tissue become weaker. EEG is to test the driver's EEG signal by EEG tester, analyze the EEG signal, judge whether the driving-related EEG is weakened, and then draw the conclusion of driver fatigue.

## (d) Eye movement

Influenced by seating discomfort, drivers are prone to fatigue, eye observation ability is weakened, eye movement speed is reduced after long driving. Eye movement measurement is to use eye movement meter to test visual information, such as eye scanning trajectory, number of eyes, time of eyes, scanning range, interest area and so on. Through these basic features of the eye, we can judge whether the driver is tired when driving a car. At present, as a research means, this method has been widely used in the evaluation of driver fatigue, but it is different from seating comfort evaluation.

## (e) Blood oxygen saturation

Measuring oxygen saturation of hip tissue is an important index for objective evaluation of comfort and endurance of subjects. The method of oxygen saturation testing is to use oxygen meter to collect oxygen saturation of lower limbs when subjects sit to reflect driver's comfort in the car seating. The measurement method is non-invasive and low-load. The main part of the medial gastrocnemius muscle is measured by near infrared light sensor.

## 5 Conclusions

Seating comfort is gradually attracting the attention of ordinary consumers and special workers, Diseases such as lower back pain, spine injury and pressure sore caused by seating discomfort will seriously affect the health and work efficiency of workers, and will increase the social medical burden. The research on sitting comfort is helpful to understand the indexes related to sitting comfort, and is of great value to the evaluation and improvement of seats and the improvement of driving comfort. From different angles, the advantages of experiment and simulation can be brought into play, which can help to accelerate the design of seating cushions with both comfort and safety.

**Acknowledgments.** This research was supported by 2017NQT project (2017YFF0206603), General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ) science and technology planning project (2016QK177) and Project of the President's Fund for China National Institute of Standardization (522018Y-5984; 522016Y-4488).

## References

1. Harrison, D.D.: Sitting biomechanics, part II: optimal car driver's seat and optimal driver's spinal model. *J. Manipulative Physiol. Ther.* **23**(1), 37–47 (2000)
2. Harrison, D.D.: Sitting biomechanics part I: review of the literature. *J. Manipulative Physiol. Ther.* **22**(9), 594–609 (1999). Special subject of optimal seating in a car seat will be the subject of part II of this review
3. Concern about occupational diseases of driver's low back pain: "Car seat" affects health, in *China Consumer Daily* (2000)
4. Liqun, G.: Research on vibration transmission characteristics of commercial vehicle seats. *Noised Vibr. Control* **23**, 45–48 (2009)
5. Kolich, M.: Predicting automobile seat comfort using a neural network. *Int. J. Ind. Ergon.* **33**(4), 285–293 (2004)
6. Grujicic, M.: Seat-cushion and soft-tissue material modeling and a finite element investigation of the seating comfort for passenger-vehicle occupants. *Mater. Des.* **30**(10), 4273–4285 (2009)
7. Xinglei, Z., Jianguo, G.: Research on automotive seat comfort technology. *Traffic Stand.* **7**, 200–203 (2009)
8. Tianbao, T.: Research on automotive seat comfort. *Enterprise technology development. Technol. Dev. Enterp.* **29**(1), 34–37 (2009)
9. Zilong, L.: Research on man-machine engineering design of automotive driving seat. *Equip. Manuf. Technol.* **7**, 21–23 (2009)
10. Demin, Z., Qichang, Z.: Research on vibration reduction of vehicle seats. *J. Tianjin Univ. Technol.* **22**(5), 34–38 (2006)
11. Stein, G.J.: Measurement and modelling of x-direction apparent mass of the seated human body-cushioned seat system. *J. Biomech.* **40**(7), 1493–1503 (2007)
12. Zuhua, J., Bin, H., Yuqing, Z.: Applied research on the comfort of bus driver seat system. *Ind. Eng. Manag.* **4**, 20–24 (2003)
13. Youzhi, X.: Improving design of automotive safety seat. *J. Hubei Auto Ind. Inst.* **23**(2), 78–80 (2009)
14. Qiang, Z., Lijie, G.: Design and simulation of positive and negative stiffness parallel spring vehicle seat suspension. *Forest Eng.* **25**(1), 33–36 (2009)
15. Jia, M.: Comfortable driving posture test and fuzzy evaluation. *Ind. Eng. Manag.* **4**, 121–125 (2008)
16. Zhenghua, W.: Subjective and objective evaluation models of car seat comfort. *Autom. Eng.* **28**, 817–819 (2006)
17. Jianzhong, L.: Construction of subjective assessment model for car ride comfort. *Automob. Technol.* **11**(9), 11–20 (1994)
18. Cengiz, G., Babalik, C.: An on-the-road experiment into the thermal comfort of car seats. *Appl. Ergon.* **38**(3), 337–347 (2007)
19. Yamashita, K.: Evaluation of summertime thermal comfort in automobiles. In: Yutaka, T., Tadakatsu, O. (eds.) *Elsevier Ergonomics Book Series*, pp. 299–303. Elsevier, Amsterdam (2005)
20. Siefert, A., Pankoke, S., Wölfel, H.P.: Virtual optimisation of car passenger seats: Simulation of static and dynamic effects on drivers' seating comfort. *Int. J. Ind. Ergon.* **38**(5), 410–424 (2008)
21. Kolich, M., Seal, N., Taboun, S.: Automobile seat comfort prediction: statistical model vs. artificial neural network. *Appl. Ergon.* **35**(3), 275–284 (2004)
22. Bouazara, M., Richard, J., Rakheja, S.: Safety and comfort analysis of a 3-D vehicle model with optimal non-linear active seat suspension. *J. Terra Mech.* **43**(2), 97–118 (2006)



# Ergonomics Assessment Criteria as a Way to Improve the Quality and Safety of People's Transport in Underground Coal Mines

Jarosław Tokarczyk<sup>1</sup>(✉), Dariusz Michalak<sup>1</sup>, Magdalena Rozmus<sup>1</sup>,  
Kamil Szewerda<sup>1</sup>, Leszek Żyrek<sup>2</sup>, and Gregor Železnik<sup>3</sup>

<sup>1</sup> KOMAG Institute of Mining Technology, Gliwice, Poland  
{jtokarczyk, dmichalak, mrozmus, kszewerda}@komag.eu

<sup>2</sup> Becker-Warkop Sp. z o.o., Świerklany, Poland  
l.zyrek@becker-mining.com.pl

<sup>3</sup> Premogovnik Velenje, d.d., Velenje, Slovenia  
Gregor.Zeleznik@rlv.si

**Abstract.** The article presents a comprehensive research aimed at identification of features to be embodied in new design ergonomic and safe suspended monorails. Survey regarding comfort of use of suspended monorails is presented – the results and conclusions drawn. The main criteria and factors to be taken into account during ergonomic assessment of suspended monorails – both the existing ones and new designed ones – were indicated. Operator's cabin and people transportation units were covered by the survey. Two computer aided analyses were presented as well. In the first one, specialistic software was introduced to create anthropotechnical system and calculate static discomfort coefficient of different segments of a passenger represented by biomechanical model. In the second one, MBS numerical method was used to find solutions which enable to reduce vibrations of the operator's cabin.

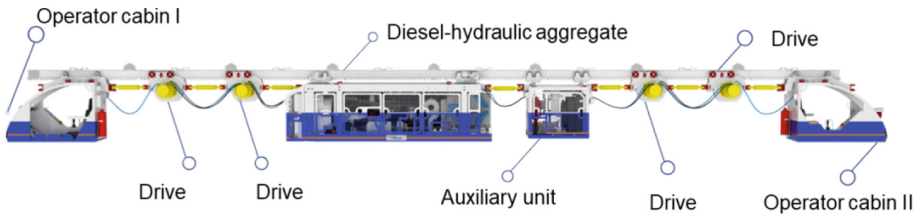
**Keywords:** Mining · Ergonomics · Mechanical engineering ·  
Suspended monorail · Underground transport MBS FEM

## 1 Introduction

The auxiliary mine transportation in underground mine workings is realized by mine underground railways (on the main transportation routes) as well as by suspended monorails or floor-mounted railway (in a department transportation). Transportation is realized on tracks placed on the floor of working (floor-mounted rail transportation) or on rails suspended to roadway support (suspended rail transportation).

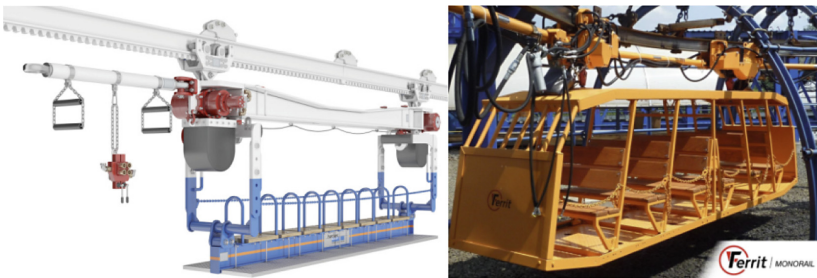
There has been a rapid development of auxiliary transportation systems in the European mines during the last two decades. For instance, a technical restructuring of Polish mines started in 1990s led to intensive development of auxiliary transportation systems. That mainly concerns the solutions of transportation by suspended monorails with own driving and control systems [6]. In the case of using internal combustion engine, they are covered by monitoring system [8]. The analyzed trends indicate that systematic elongation of people and materials transportation routes of suspended

monorails takes place, which requires supporting the control of technical conditions of their components. The suspended drivetrains are self-propelled diesel machines used for the transportation of materials and people. They have a modular design which makes it possible to adapt their configuration to transportation systems. The calculations verifying the possibility to transport people in cabins, indicated that it was technically possible to reach the travelling speed of 3.9 m/s for self-powered drivetrains. The overall view of locomotive that is used in suspended monorails is presented in Fig. 1.



**Fig. 1.** Locomotive of underground mining suspended monorail.

Locomotive is coupled with other main components by means of pull rods. For heavy load a modular lifting beams are used. In the case of people transport, special benches or passenger cabins are used, Fig. 2.



**Fig. 2.** Examples of means for transporting people in underground coal mines: bench (left) and cabin (right) [3, 4].

In the recent years, ergonomic criteria within auxiliary underground transportation means were considered as “secondary problem”. That was one of reasons that these criteria have become the subject of the tasks carried out within the INESI project [5].

## 2 Evaluation of Suspended Monorails Currently Used and Proposed Solutions in Terms of Compliance with Ergonomics Requirements

Two types of research were carried out to establish what features should characterize suspended monorails to consider them as ergonomic: (i) survey and (ii) computer aided analyses. The survey was carried out with representatives of both groups of suspended monorails' users: operators and passengers. The computer aided analysis was focused on passengers' cabin.

The survey was carried out in the JSW S.A. (the largest producer of high quality coking coal in European Union) mines in Poland and in the Premogovnik Velenje mine in Slovenia. A hundred and sixty seven respondents participated giving answers for questions regarding the comfort during riding by means of underground mining suspended monorails.

There were two sections in each survey questionnaire: (i) related with respondent's experiences with use of suspended monorails, (ii) related with respondent's expectations regarding suspended monorails to be designed. In the first section the respondents were asked to assess how particular factors contribute to comfort in the suspended monorails they have used. 5-grade scale (-2 till 2) was used. '-2' indicated that a given factor has a very negative impact on comfort and '2' indicated that a given factor significantly improves it. In the second section, respondents were asked about solutions they wish to be included in suspended monorails designed in the future. 5-grade scale was also used. -2 mean: not expected at all, 2 - highly expected.

Based on the data obtained it was established what percentage of respondents assigned a given grade to a particular factor or solution.

Detailed analysis of results is not a subject of this paper, therefore main conclusions will be given.

To calculate the static discomfort coefficient of different segments of the passengers represented by biomechanical models, specialistic software Anthropos – ErgoMax was introduced to create anthropotechnical system [1].

### 2.1 Survey with the Operators of Suspended Monorails – Results

For suspended monorails known to respondents it was established how control elements affect comfort. Factors considered were: controls location and accessibility, readability of displayed information, simplicity of use – see the Table 1.

**Table 1.** Impact of control elements on comfort - answers.

Factor	-2	-1	0	1	2
Placement of the controls	0	12	30	41	17
Access and reaching to the controls	10	10	36	29	15
Readability of displayed information	5	4	29	42	20
Simplicity of use	0	9	30	24	27



For all factors more than a half of respondents think that existing solutions are well designed in terms of operator's comfort (grades 1 or 2) and approximately 1/3 find them average (grade 0). It should be noted that opinions of 20% of respondents indicate that access and reaching to the controls should be improved because they negatively affect comfort. Taking into account respondents' differentiated anthropometrical features, it should be concluded that design changes of control elements are not an urgent task.

Operator's workplace was another aspect which was assessed in terms of impact on comfort. It concerned cabins already used by the respondents. The seat, available place as well as vibrations were taken into account – see the Table 2.

**Table 2.** Comfort in the operator's workplace - answers.

Factor	-2	-1	0	1	2
The seat can be adjusted to your own needs	22	22	38	15	3
Comfort of the seat	10	19	36	27	8
Visibility from the operator's seat while driving	2	13	42	29	14
Visibility from the operator's seat during maneuvering	9	27	25	27	12
Free space for your legs	7	19	34	23	17
The width of the cabin	2	15	39	29	15
Vibrations of the cabin while driving	44	15	20	14	5
Overall comfort	9	29	46	8	8

Answers obtained reveal that vibrations of the cabin are the most important problem to solve or at least significantly reduce in future designs of operator's cabins. Another problem which decreases the comfort are limited possibilities of the seat adjustment. The answers obtained indicate that visibility from the operator's seat during maneuvering is also an important problem (36% of respondents assigned grade -2 or -1). More thorough analysis showed that the answers are related with work seniority as the operator – the less experience, the bigger problem the visibility is considered. For 40% of experienced operators (more than 5 years), the visibility is not a problem but still for 1/3 of them it is, which indicates that in the future designs this factor should be taken into account and improved. Answers provided by most of respondents indicate that in operator's cabins currently used the following factors are at least on average level in terms of impact on work comfort: comfort of seat, free space for legs, cabin width, visibility operator has while driving. This means that these factors should be kept at the same level or improved in the future designs.

Next, the respondents were presented a list of design solutions proposed for operator's cabins to be designed in the future and asked to express their opinion about them (-2 - least expected, 2 - most expected) – see the Table 3.

The solutions were related among others with: observation during driving and maneuvering, the seat adjustment, vibrations, safety, available space, ease of getting on/off, driving support. The least expected are inertial seat belts and the highest interest was expressed for solutions aimed at reduction of vibrations. More convenient and safe

**Table 3.** Expectations regarding implementation of proposed design solutions - answers.

Factor	-2	-1	0	1	2
Improving the visibility during driving and maneuvering by means of using the vision system of the surroundings of the suspended monorail	7	8	19	32	24
Vibration dampers located in the operator's seat	1	7	12	34	46
Comfortable seat with adjustable armrests	0	1	29	27	43
Suspension of the entire operator's cabin	2	2	25	22	49
Seat height adjustment	5	8	37	19	31
Increasing the space for legs	2	12	29	30	27
Application of additional passive safety systems: inertial seat belts	29	17	32	14	8
The use of additional passive safety systems: an adjustable headrest	12	8	37	24	19
Additional storage compartments for transporting small items located in the operator's cabin	12	9	44	10	25
Widening of the operator's cabin	10	9	42	17	22
Additional handles to improve the comfort of getting on/off	2	10	20	26	42
IT systems forcing periodic inspections and machine inspections by the operator	7	5	31	37	20
Active cruise control	7	10	35	17	31
Air-conditioned interior	3	9	29	17	42
A more powerful reflector at the front of the cabin	5	5	34	17	39

getting on or off the cabin is also very important. Regarding the inertial seat belts, safety shouldn't be compromised for comfort. So the approach to follow should be: when designing, introduce safety solutions which are as comfortable as possible.

## 2.2 Survey with the Passengers of Suspended Monorails - Results

Three types of people transportation units were covered by the questionnaire: cabin with wooden seats, cabin with material hammock type seats, bench for people (with 1 or 2 rows).

For solutions known to respondents it was established how well they have been designed in terms of comfort related with traveling, getting on/off and psychical comfort which results from considered passengers' safety – see the Table 4.

Comfort while travelling is relatively highest in cabins with material hammock type seats and comparable low in the remaining solutions. Getting on and getting off is most convenient in cabins with wooden seats and relatively worst when a bench is used. Considered safety is relatively highest for cabins with wooden seats and it is significantly low when a bench is used. Summing up, the respondents' opinion indicate that a bench for transporting people is the worst solution in terms of comfort.

**Table 4.** Expectations regarding implementation of design solutions - answers.

People transportation units	Cabin – seats										Bench (1 or 2 rows)				
	Wooden					Material hammock type									
Factor	–2	–1	0	1	2	–2	–1	0	1	2	–2	–1	0	1	2
Comfort while traveling	20	23	34	16	7	4	30	28	21	17	25	16	43	11	5
Convenience getting on	9	22	27	24	18	6	32	40	15	7	20	18	41	14	7
Convenience getting off	11	18	31	22	18	6	34	38	15	7	20	16	43	16	5
Level of safety while travelling	7	12	34	24	23	4	21	34	32	9	32	16	41	4	7

Next, the respondents were asked how well units for people transportation used by them as passengers have been designed taking into account the seats, space, noise and vibrations – see Table 5.

**Table 5.** Comfort of people transportation units in terms of selected factors - answers.

Factor	-2	-1	0	1	2
The seat can be adjusted to your own needs	33	7	26	10	6
Comfort of the seat	9	16	39	17	5
Free space for legs	18	18	30	16	5
The width of the cabin	8	22	27	18	8
Influence of the other passengers' presence on the comfort of traveling	11	24	35	13	6
Noise while traveling	20	20	33	8	8
Vibrations of the cabin while traveling	12	27	30	15	5
Overall comfort	10	16	42	17	4

General conclusion is that each factor listed should be taken into account and improved in people transportation units designed in the future – designs of units used currently are not good enough to be directly implemented. Particular focus should be given to better possibilities of seat adjustment, but free space for legs as well as reducing of noise and vibrations are also very important.

In the second part of the questionnaire, the respondents were asked which solutions in their opinion should be taken into account in people transportation units designed in the future – see the Table 6.

For almost all solutions the expressed interest is high enough to consider them as important to be included in future designs of people transportation units for suspended monorails. Noticeable exception is use of inertial seat belts which was negatively

**Table 6.** Design solutions expected for people transportation units - answers.

Solution	-2	-1	0	1	2
Vibration dampers located in the seat	2	7	33	24	24
The seat is trimmed with a soft material	4	5	31	24	27
Suspension of the entire cabin	3	5	30	25	25
Increasing the space for legs	1	4	20	22	42
The use of armrest	10	6	38	16	17
Application of additional passive safety systems: inertial seat belts	25	9	36	11	7
The use of additional passive safety systems: an adjustable headrest	14	7	45	12	10
Additional storage compartments for transporting small items located in the cabin	5	5	32	14	31
Widening of the cabin	4	4	28	24	27
Additional handles to improve the comfort of getting on/off	5	5	30	17	30

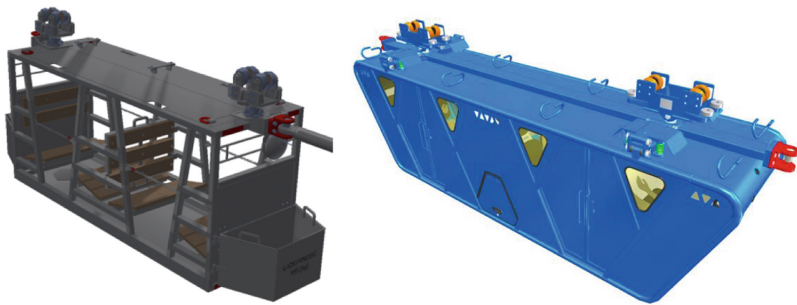
assessed by approximately 1/3 of respondents. Also adjustable headrest obtained relatively low interest. But in both cases the rule is: safety first. So both seat belts and headrest should be designed with great focus on use comfort.

### 2.3 Computer Aided Ergonomic Evaluation of the Passengers Transport Cab Used in Mining Suspended Monorails

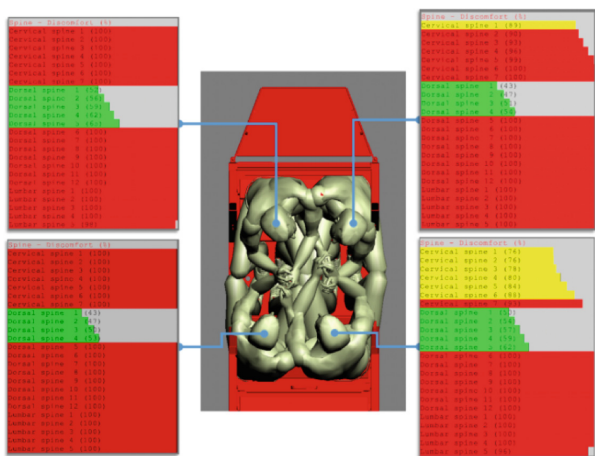
As part of research carried out within the INESI project, ergonomic analyses of typical and innovative type of passenger cabins were carried out. Commonly used cabins are equipped with wooden seats and almost vertical seat back. In the new type cabins, which were developed in the INESI project, the following solutions were included: suspension between the cab and drive system; seats filled with foam; inclined seat back; headrest and seat belt. Each cabin is designed for transporting eight people – four of them seat according to the direction of travel and the next four passengers seat in the opposite direction. 3D geometrical models of a typical and the modern cabin are presented in the Fig. 3.

Ergonomic analysis was performed for a 50-percentile model of passenger, with corresponding dimensions for 50% of the male population [7].

The results regard to four passengers occupying one compartment. Situation when the passengers have the opportunity to take upright position do not actually occur when the cabin is fully occupied. So it was necessary to place the anthropometric models of passengers in a realistic way, in accordance with the existing cab limitations. The results of the static discomfort analysis are presented in Fig. 4. The situation shows significant, unfavorable values of the static discomfort coefficient for backbone of passengers.



**Fig. 3.** 3D geometrical models of cabin for transporting people using underground mining suspended monorail: typical version (*left*), a new modern version (*right*).

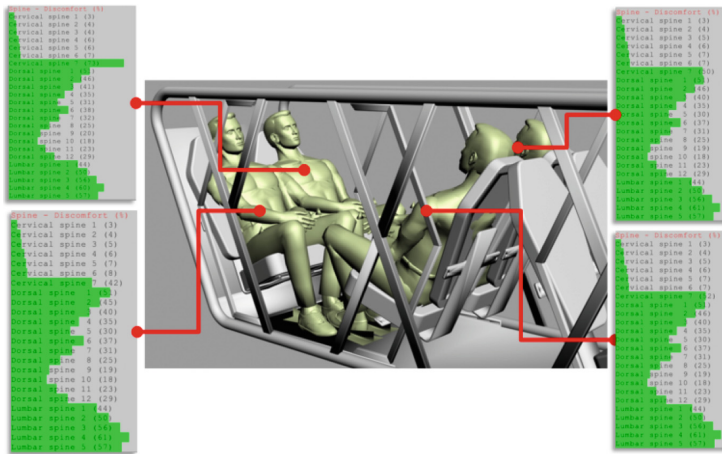


**Fig. 4.** Previous version of the cabin. The results of ergonomic numerical analysis: values of static discomfort coefficient for various sections of the spine.

Based on the results obtained, it can be stated that the initial version of passenger transport cabin was not adapted to the typical passenger's dimensions and could cause discomfort on a longer route and negatively affect their musculoskeletal system.

In the next step, the new version of the passengers' cabin was assessed. The results are presented in Fig. 5.

The comfort during travelling has been significantly improved. It is important, especially due to the extending the length of the underground transportation roads (and travel time) in coal mines [9].



**Fig. 5.** The new version of the cabin. The results of ergonomic numerical analysis: values of static discomfort coefficient for various sections of the spine.

### 3 Virtual Prototyping of the Operator's Cabin as an Anthropotechnical System

One of the important aspects to reach the required level of comfort during transportation in underground workings is vibration of the operator's cabin. Numerical analyses using multi-body system (MBS) method of operator's cabin suspension were carried out. Different values of stiffness coefficient of the cabin's suspension were used to reduce its vibration. In this case a validation process of computational model of operator's cabin was necessary to identify the stiffness coefficient of polyurethane insert (part of the cabin's suspension). Results from stand tests were the basis for the validation. Then it was possible to assess the influence of the stiffness coefficient of the suspension of operator's cabin on its vertical displacement during riding.

#### 3.1 Development of MBS Computational Model

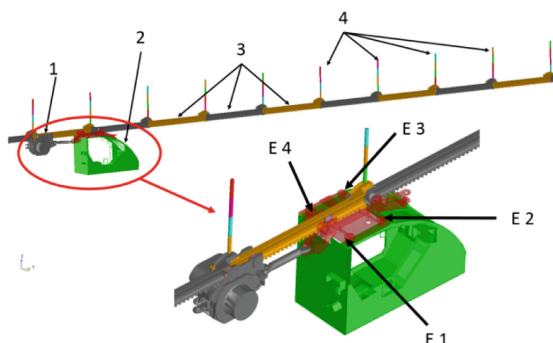
Simplified MBS computational model of suspended monorail consists of (Fig. 6): a model of gear drive (1), a model of operator's cabin (2) and a model of route which contains two meters long single rails (3) suspended on slings (4).

The following values of masses were adopted in the computational model:

- Operator's cab – 450 kg.
- The platform on which the cabin was suspended – 208 kg.
- The drive – 620 kg.

The velocity of moving through the test route section equals 2 m/s.

The operator's cab was connected to the platform via four elastic – damping elements (see E1-E4 in Fig. 6). Their stiffness coefficient was identified during



**Fig. 6.** Computational MBS model of suspended monorail.

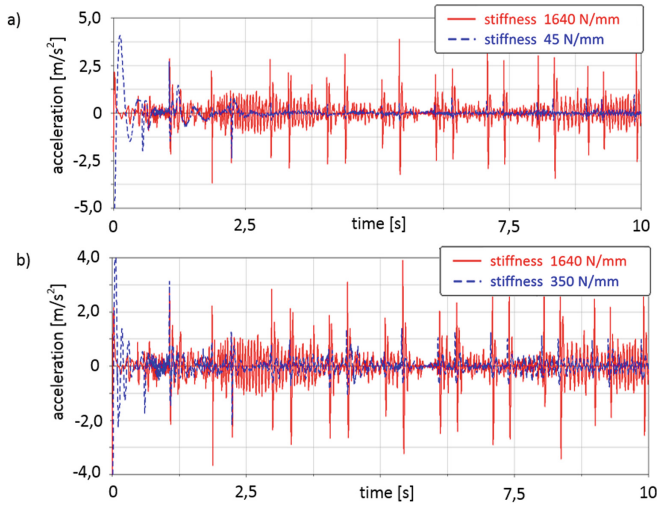
compression test carried out in the laboratory. The value of this coefficient equals 1640 N/mm.

### 3.2 Assessment of the Suspension System of the Operator's Cabin Using MBS and FEM Calculations

In order to determine the influence of the stiffness of the elastic – damping el-elements used in suspension of the cab on the operator, it was necessary to carry out many numerical simulations of riding on the test route section. Initially numerical simulation was conducted for the stiffness coefficient equals 1640 N/mm, because it was currently used in operator's cab. Next the value of stiffness coefficient was changed. During numerical calculation the value of the accelerations of the center of operator's cabin, the forces and the deflection of elastic – damping elements were recorded. Recorded accelerations are perceived by the operator as shocks or vibrations affecting their body during work, so the values had to be reduced. The comparison of acceleration in vertical axis of the center of operator's cab for different values of the stiffness coefficient of elastic – damping elements is presented in Fig. 7.

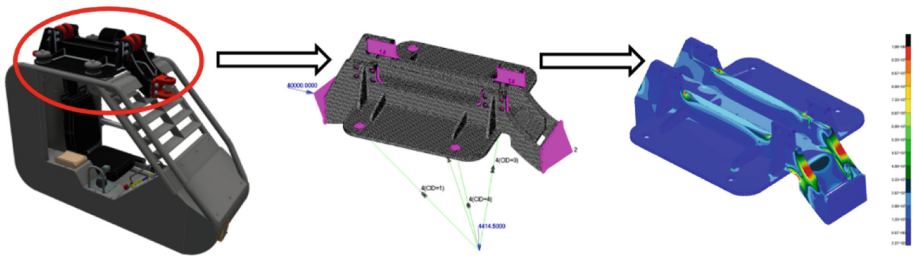
In order how the elastic suspension of the cab is important, the simulation in which the operator's cabin was fixed with the platform was also conducted. The analysis of simulation results shows that application of elastic – damping elements in suspension of the operator's cab has significant influence on safety and the comfort of work of operators of suspended monorail. The change of stiffness of elastic – damping elements in suspension allows controlling the value of vibration amplitude affecting on operator's body during the work. Reduction of the value of acceleration causes the increase value of vertical displacement of operator's cab during driving, which also affects the operator's comfort of work. Special damping elements are used for this purpose.

One of the advantages of MBS type calculations, especially where the variability of parameters in time-domain (boundary conditions and results) occur, is possibility to indicate the state of the machine, which is the most unfavorable in a given assessment criterion. These results in the form of boundary conditions are transferred to the FEM calculation model, e.g. it could the maximum value of longitudinal force acting on the operator's cab. The first step is selection and simplification a part of 3D geometrical



**Fig. 7.** Influence of the change of initial stiffness of elastic – damping elements used in operator’s cab on the vertical acceleration of the cab (a) 45 N/mm, (b) 350 N/mm.

model, which will be evaluated. Next, the part is discretized and the boundary conditions are included. Depending on the needs, individual calculation results are analyzed in order to optimize the geometric features of the verified object, Fig. 8.

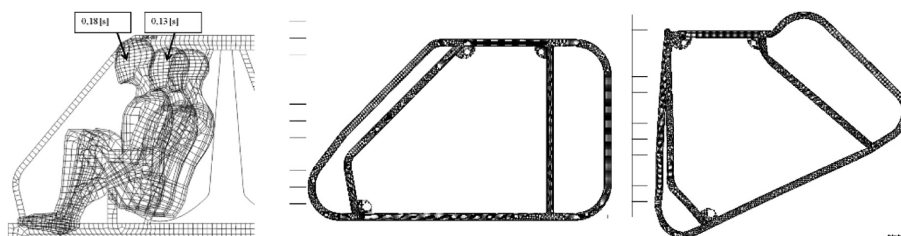


**Fig. 8.** The main steps to obtain the results of strength calculations: identification of a part of the geometrical of operator’s cab for the strength calculation (left), computational model (middle), exemplary results of numerical calculation (right).

The above example regards the FEM static analysis. To assess not only the comfort of transport mean’s user, but the safety of the passenger or the operator during driving the suspended monorail, a dynamic crash simulations are carried out. In this case the boundary conditions like initial velocity or so called *crash pulse* [2] are transferred to the explicit FEM simulation. *Crash pulse* characteristics are used when ATB (*Articulated Total Body*) crash test dummy is included to the computational model. Test dummies are used to assess the effects of frontal, side and rear collisions. On the basis of crash tests, the probability of hitting the head or chest with internal parts of the cab



or its equipment is determined. The Fig. 9 shows examples of results from dynamic simulation of cab for crew transportation and operator's cab.



**Fig. 9.** Exemplary results of dynamic explicit crash FEM simulations: ATB test dummy movement during a frontal collision the cab (*left*) [10]; high speed crash test of the cab's frame – initial position (*middle*), after frontal collision (*right*).

## 4 Conclusions

Designing phase of an innovative underground mining transport means should be more focused on the ergonomics and safety aspects, especially when these means are used for transporting people. Survey analysis and computer simulations indicated that the most important problems are vibrations of the cab and lack of adjustment of seat to the user's needs. The respondents (operators) expressed positive opinion about the majority of proposed solutions for the next generation of the transport means. For the passengers inconveniences are related with: noise, vibrations, and lack of the space in the cab. Among the proposed solutions with which the cab could be equipped, the seat belts received many negative opinions. When considering their implementation, it should be taken into account that the comfort not always is a priority, as numerical simulations' results proved.

**Acknowledgments.** The paper was written as part of the work carried out under the European project INESI, "Increase efficiency and safety improvement in underground mining transportation routes". This project has received funding from Research Fund for Coal and Steel under grant agreement No 754169. Calculations were carried out at the Academic Computer Centre in Gdańsk.

## References

1. ANTHROPOS – ErgoMax: User Guide, Version 3.0. IST GmbH, Keiserslautern (1999)
2. Christensen, J.: Development of front end crash structure for lightweight hybrid electric vehicle. *Glob. J. Res. Eng. Automat. Eng.* **12**(issue 3-B), 9–16 (2012)
3. Becker – Warkop company. <http://www.becker-mining.com.pl/indexen.html>
4. Ferrit company. <http://ferrit.cz/pl/produkty/transport-podwieszony/kabiny/kabiny>
5. INESI European Project: Increase Efficiency and Safety Improvement in Underground Mining Transportation Routes. RFCS, Contract No. 754169 (2017–2020)

6. Jura, J., Bartoszek, S., Jagoda, J., Jasiulek, D., Stankiewicz, K., Krzak, Ł.: Innowacyjny system sterowania KOGASTER. Napędy i Sterowanie **16**(7/8), 118–123 (2014)
7. Michalak, D.: Evaluation of solutions of mining machines and devices in the light of the ergonomic criterion (in Polish). *Mechanik* **86**(7CD), 393–401 (2013)
8. Trenczek S., Wojtas P.: Possibilities of monitoring the hazards resulted from use of transport means in the underground mining. In: Tytko, A., Wójcik, M. (eds.) *Work Safety of Transport Devices in Mining: Monograph – Editorial Office*, pp. 33–41. Publishing House: CBiDGP, Łędziny (2013). ISBN 978-83-929335-9-5
9. Tokarczyk, J., Kania, J.: Systems and tracks of self-powered suspended monorails for transportation of people in horizontal workings and workings with inclination up to 45°. *Min. - Inf. Autom. Electr. Eng.* **3**, 83–91 (2016)
10. Tokarczyk, J.: Methodology for identifying the selected mechanical hazards in auxiliary transport of underground mines. In: *Monograph*, vol. 52. Institute of Mining Technology KOMAG, Gliwice (2017)



# Development of an Ergonomically Designed Backpacks for Junior High School Students

Emmanuel Oliver D. C. Porciuncula<sup>(✉)</sup>, Leonard T. Aquino,  
Daniel G. Araneta, Jeremiah V. Austria, Briant Angelo M. Censon,  
John Michael A. Cruz, Patrick Henry S. Fernandez,  
Kent Xaivery L. Moreno, Joshua M. Ng, Genhino Glenn D. C. Reyes,  
Aroma M. Santillan, and Wendel Jimver De Guia

La Consolacion University Philippines, Bulihan, Malolos City,  
Bulacan, Philippines

emmanueloliverporciuncula@gmail.com,  
Aquinoleonardl8@gmail.com, aranetadaniel0@gmail.com,  
miahaustria24@gmail.com, censonbriant@gmail.com,  
John.cruz1122@gmail.com, patfernandez922@gmail.com,  
moreno.kentxaiveryl@gmail.com, Josh\_ng@gmail.com,  
ghin0127@gmail.com, santillanaroma@gmail.com,  
deguiawendel@gmail.com

**Abstract.** Backpacks are ever used to transport everyday essentials from one place to another which also come in a variety of design and specification that personify the person; yet most manufactures often overlook the importance of comfortability and posture support instead of aesthetics. Segment of the population suffer from excessively heavy loads of backpacks which lead to plenty of health problems. Contradictory to public beliefs, wearing heavy backpacks will not stunt growth [1], but will breed health problems nonetheless; bad posture, shoulders bending inwards and improper spine alignment. Furthermore, prolong carriage of heavy loaded backpacks brings great stress to a single muscle group resulting to muscle fatigue and causes the user's body to compensate to the weight misaligning the axis of the body [2, 4]. As backpacks have a high demand of use for students the researchers envision of creating a backpack that diminish the payload by properly distributing the weight. This method utilizes the muscle's carrying capacity and improves of the user's posture [3, 7]. In order to develop this design, anthropometry and statistics are used to determine the appropriate dimensions for each part of the product: Shoulder breadth (Bideltoïd), Shoulder breadth - (Biacromial), Lumbar height and average bag weight. Choosing junior high school students as participants, ranging from 13–17 years old, who are typically carrying a heavy loaded bag. Gathering the participant's body segments and integrating it for the dimensions of the design with respect to the 5th and 95th percentile of the stated body measurements. The design serves the purpose of bringing materials with the minimal possibility of having discomfort due to overstrengthening of muscles [7]. Applying stress absorbers in the straps of the bag which will be designed to minimize the strain received by the user's shoulders. The ergonomic design should bring the user comfortability as well as functionality.

**Keywords:** Backpack · Junior high school · Posture · Anthropometry

## 1 Introduction

Backpacks are often used in transporting the user's belongings from one place to another. Backpacks in the modern times comes in various of ways and designs personifying the bag, while serving its primary purpose of carrying things, most manufacturers often overlook the importance of safety. Over the years, people suffered from excessively heavy loads of back packs, which in long term, leads to health problems and possible injury [7, 9]. Contrary to public beliefs, "wearing heavy backpacks will not stunt growth" [1], but will breed health problems nonetheless, bad posture, shoulders bending inwards, improper back bone alignment to name a few [2, 3]. Without proper equipment these pre-existing problems that result from regular use of conventional back packs will worsen let alone multiply. Junior high students are the most viable subjects for the test given their demographic nature. Junior high-school students are observed to carry backpacks way more than their suggested capacity. With these age group 13–17, where human bones are in its developmental stage are viable for series of tests. Most of the students used traditional backpacks as their school bags which greatly affects their health, productivity and safety [9]. At times, students tend to disrupt the natural posture of their musculoskeletal system causing the body to go off-Axis of its natural position which lead the body to compensate with postural distortion [7, 8]; is one of the reasons for causing musculoskeletal pain. To counteract this regrettable reality, the researchers partake into a research devising a bag that alleviates and/or prevents the aforementioned health problems brought about by using a poorly designed back pack. Chronic musculoskeletal pain may arise from frequent incorrect use of heavy backpacks.

## 2 Conceptual Model

In order to develop an ergonomically designed back-pack for junior high-school students, the researchers identified the functions of the existing bags with regards to their study and recommend an abstract design improving the usage of back-packs. The approach requires survey questionnaire for gathering the necessary data and measurements; integrate the initial concept design with the gathered data. Finally, the projected output of the study comprises ergonomically intervened back-pack prototype preventing posture misalignment while serving the purpose of carrying the user's belongings (Fig. 1).



Fig. 1. Conceptual model

### 3 Methodology

**Sampling Procedure:** The study followed a procedure using a close ended proportion questionnaire. The research instrument contains a questionnaire wherein respondents are to state their perception of their bags in a physical comfort/discomfort sense. The research instrument is then given to the eligible test participants within ages 13–17 on the selected population, which has a total of Six Thousand and Forty-Two (6042); and composing of Three hundred Eighty Seven (387) respondents. The researcher presumed that this group of students are the ones who often carry a heavy bag. The queries are constructed based on factors affecting the user and backpack, one of which quantifies the factors in concern with the comfort ability of the user's backpack while wearing it, regardless of the payload carried. Another concern is the load they set in the backpack, considering if they place all of their things within the backpack. Moreover, we need to look over is how they wear their backpack, despite the different built or design of the backpack have. Additionally, we also considered the discomfort to the body while wearing he bag especially on shoulders and the stress on the back or the pain that users feel while wearing it for long periods of time. After filling out the information necessary, the researchers proceed to get the lengths of the student's following body parts: Shoulder Breadth (Bideltoid), Shoulder Breadth (Biacromial), and their Lumbar height, as well as their bag weight; which are essential data in the process of incorporating the concept.

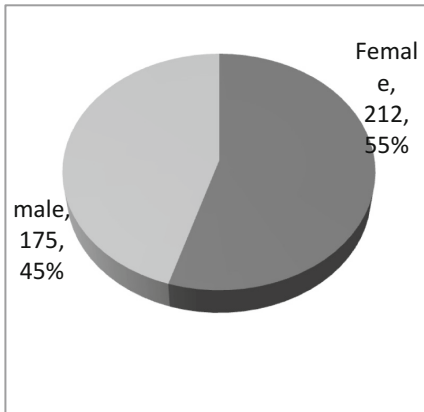
**Sampling:** There was Six Thousand and forty-two (6042) number of population during the time of the study. Using the Slovin's formula to calculate the sample size, it was approximated that Three Hundred and Seventy-Six (376) respondents were required to obtain  $\pm 0.05$  margin of error. However, the proponents gathered data from Three hundred eighty Seven (387) respondents thus giving a margin of error of  $\pm 0.0492$ .

**Data Analysis:** The current study used descriptive statistics, anthropometric statistics and inferential statistics for the demographic profile of the respondents. The fundamental means were analysed to identify which fragment greatly affects the general accomplishment of the goal. Finally, a test of hypothesis one-sample p-test and z-test validated the qualitative evaluation of the respondents [5].

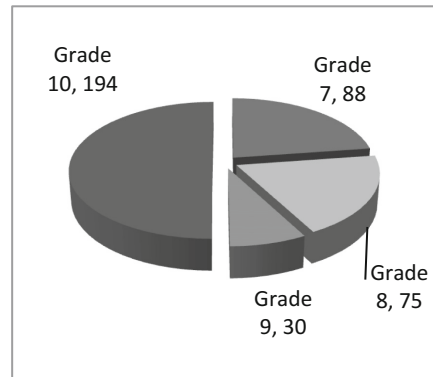
### 4 Results and Discussion

**Demographic Factors:** Surveys had been done to determine the factors that cause shoulder and back pains among junior high schools student in publics school in Bulacan. Age, Gender and Bag weights were assumed to be occurrences to be related to the problem. Since the target population of Three Hundred and Seventy-Six (376) was exceeded and Three hundred eighty Seven (387) respondents were gathered giving the study, Four point Ninety Two percent (4.92%) error.

The total sample gathered from the three (3) Institutes is comprised of One Hundred and Seventy-Five male respondents (45.22%) and Two Hundred and Twelve female respondents (54.78%). See Figs. 2 and 3.



**Fig. 2.** (Gender)



**Fig. 3.** (Year Level)

**Diagnostics:** The proportion who answered that they feel comfortable wearing their backpacks exceeds by 72 respondents, and 258 reported that they place most of their belongings within the backpack, the majority answered that they wear their backpacks loose, exceeded by 95 respondent replies, and 200 respondents reported they feel shoulder pain, while 275 stated that they suffer from back pain after prolonged use of heavy loaded backpack. The relationship observed that wearing backpacks loose result in higher probability of having shoulder pain as well as back pain after using heavy loaded backpack (Table 1).

**Table 1.** Questionnaire diagnostic

Questionnaire diagnostics										
Grade	Comfortability Q1		Placement Q2		Loose Q3		Pain while wearing Q4		Pain after wearing Q5	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
7	50	50	98.86	1.14	52.27	47.73	63.64	36.36	77.27	22.73
8	45.33	54.67	72	28	58.67	41.33	58.67	41.33	76	24
9	30	70	76.67	23.33	73.33	26.67	60	40	66.67	33.33
10	42.27	57.73	58.25	41.75	70.1	29.9	43.81	56.19	70.62	29.38

**Anthropometric Measurement:** Harvested data are segmented into two (1) anthropometric measurement for male, and (2) anthropometric measurement for female in consideration to the variation of anthropometric measurement of genders.

Measurements for male are as follow: Bag Weight 4.807, Shoulder Breadth (bideltoid) 16.823 inches, Shoulder Breadth (Biacromial) 19.537 inches, Lumbar Height 18.903 inches (Table 2).

**Table 2.** Anthropometric measurement for male users

Male				
	Bag weight	Shoulder breadth (bideltoid)	Shoulder breadth (biacromial)	Lumbar height
Max	10.3	21	26	25
Min	1.1	12	13	13
Mean	4.807	16.823	19.537	18.903
Std dev	2.045	1.504	2.358	2.465

Measurements for female are as follow: Bag Weight 4.807, Shoulder Breadth (bideltoid) 16.823 inches, Shoulder Breadth (Biacromial) 19.537 inches, Lumbar Height 18.903 inches. (Table 3)

**Table 3.** Anthropometric measurement for female users

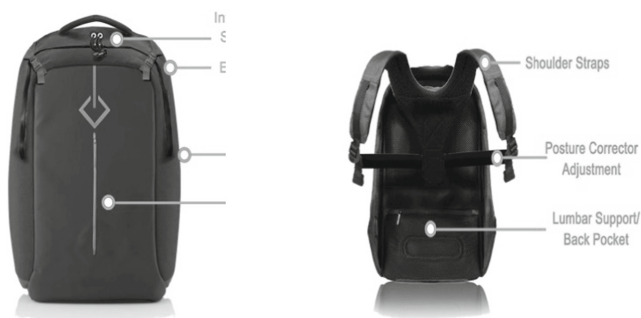
Female				
	Bag weight	Shoulder breadth (bideltoid)	Shoulder breadth (biacromial)	Lumbar height
Max	8.5	20	29	21
Min	1.2	13	12	12
Mean	3.697	8.359	18.359	17.160
Std dev	1.617	2.590	2.59	1.633

## 5 Recommendation

The current attributes of the mainstream bag line-up has significantly improved through generations. The room of improvement was filled by researchers. But as good as these improvements may come, much work is still needed. The tolerability level of having the strap on for extended periods of time varies from user to user and the level of comfort, occurrence of health problems over time from misuse, and all other relative factors that is in need of addressing.

With further research and development, optimum comfort and safety can be achieved by making the strap adapt into the user's body and make them part of the body, thus further reducing body sway and therefore reducing the overall multiplying factor of weight when moving. By successfully decreasing body sway, the bag will further reduce the likelihood of developing an ailment related to misuse of a backpack.

Skin torsion is another observable immediate negative effect of a heavy bag. The researchers took this factor into account. By using dampening systems on the straps of the back pack combined with materials less abrasive to human skin, the researchers lessened skin torsion, abrasion and shoulder bruising therefore effectively relieving pain from the user (Fig. 4).



Bag Height	420 mm
Bag Width	265 mm
Bag Breadth	160 mm
Bag Strap Adjustment	510 mm

**Fig. 4.** Propose designed with ergonomic intervention

The proposed design was then constructed to aid the user in developing good body posture, while serving the principal purpose of carrying materials from one point to another. The designed back-pack has one primary opening as its main storage and a front pocket providing easy access. Furthermore, the bag provides a compression system by pulling the string placed at the upper section of the bag; the system will reduce the movement of things within the bag which causes the movement of the load away from the core [7, 10] of the user and direct the pull of the load downhill. External adjustable snap locks were also placed to help the compression of the upper section of load and provide added security to the primary opening. The backpack straps were designed to pull the user’s shoulders backwards serving as a posture correction system to the user, allowing the shoulders muscles to adapt in the position, eventually developing good posture habits and the backpack’s dimensions are projected to fit user’s body measurement; with respect to the 5th and 95th percentile quantities gathered. Because the back-pack is design in a way to help the user’s posture, the initial phase of using the bag will cause discomfortability to the user due to it adjustments of the muscles to its proper alignment. The lower section of the bag then provides lumbar support with thick paddings as most of the weight



rests there, and an additional secret back pocket for small important things. Developing good posture habits prevents slouching and hunching of the back which then leads to rounded shoulders and spine which are causes to many disorders. Likewise, mounting good posture habits prevents the compensation of the body to the weight thus avoiding the posture misalignment; moreover the designed system also contributes to the muscle exercise of the user strengthening the core muscles.

## 6 Conclusion

After verifying the factors that gives pain in the lower back of the body, the application of ergonomics specifically human factors and ergonomics the following are suggested to the natural structures of backpacks; the placement of the bag should be at thoracic region correlated to the body structure- according to Kroemer, in her study the “Muscle functions and disorders” stated that, there are three types of muscle that the human body, Cardiac, the smooth muscles and the skeletal muscles which the maintains the body’s postural balance, and with the backpacks unbalanced weight the body’s balance is broken thus gives the body pain in the lower back which is the core. The researchers redesigned the backpack for ergonomics function providing the user minimal risk of having injuries and strain on the muscles. Adjustments and features with regards to the back-pack considering the response of the user’s body—with accordance to Forester’s study, posture distortion, pain and injury are factors to consider. Moreover, with respect to the Fifth and Ninety-Fifth percentile of both male and female, the adjustment range used are the fifth percentile from the female which has smaller body structure and the Ninety-fifth percentile from the male with broader body structure.

## References

1. Rosenbrock, K.: The Negative Health Effects of Heavy Backpacks, And How Your Kids Can Avoid Them. *The Active Times*, 3 September 2015
2. Foerster, M.M.: Marilyn Miller Von Foerster. Retrieved from marilyn von foerster (2018)
3. Kroemer, K.H.: *Fitting the Task to the Human*. Taylor & Francis, London (1997)
4. Garcia, M., Laubli, T., Martin, B.: Long term muscle fatigue after work. *Hum. Factors Ergonomic Soc.* **57**, 1162–1173 (2015)
5. Isip, J., Caparas, H.: *Advance in Usability and User Expirience*. Springer, Orlanfo (2019)
6. Rawlks, A., Fisher, R.: *Development and Functional Anatomy*. Springer, Heidelberg (2010)
7. Athanassiou, G., Spyropoulos, E., Chroni, E.: Muscle fatigue estimation in repetitive lifting task using electromyography-based analysis. *J. Ergonomics* (2015)
8. Holeyun, M., Lotens, W.: The influence of backpack design on physical performance. *J. Ergonmics* **35**, 149–157 (1992)
9. Milanese, S., Grimmer-Somer, K.: Backpack weight and postural angles in preadolescent children. *Indian Pediatr.* **47**, 571 (2018)
10. Ramadan, M., Al-Shayea, A.M.: A Modified backpack design for male children. *Int. J. Ind. Ergonomics* **45**, 462–471 (2013)
11. Perron, M., Hing, W., Orr, R., Milne, N., Pope, R.: The impact of backpack loads on school children: a critical narrative review. *Int. J. Environ. Res. Public Health*, 23–25 (2018)



# A Study on the Correlation of Head and Face Data of Chinese Adults

Linghua Ran<sup>(✉)</sup>, Chaoyi Zhao, Hong Luo, Xin Zhang, Taijie Liu, Huimin Hu, Zhongting Wang, Nicole Sator, Erika Siebert-Cole, and Peter Straßer

China National Institute of Standardization, Beijing, China  
{ranlh, zhaochy, luohong, zhangx, liutj, huhm, wangzht}  
@cnis.gov.cn

**Abstract.** Based on the data of the second national anthropometric survey conducted from 2014 to 2018, this study analyzed the correlations among 11 head and face measurement items, and the correlations between head and face measurement items and influencing factors. And the effective linear regression equations are established, which provided a technical reference for the optimization of human head and face measurement items. Head and face data were acquired according to the method defined in the Basic Project of Anthropometry for Technical Design (GB/T5703-1999). The research results can be directly applied to human head and face measurement, to update human head and face size data and reduce the difficulty of human body measurement field work.

**Keywords:** Correlation · Head and face · Chinese adults

## 1 Introduction

The anthropometry data has broad application prospects in the field of labor protective field. The analysis and application of head shape data are not only related to the design and evaluation of gas masks and work caps, but also closely related to other head and face protective products (such as safety helmet, protective glasses, protective masks, earmuffs, etc.). The measurement items of human head and face reflect some aspect of the morphological characteristics of head and face. The human body is a unified whole, and the growth and development of each part are in harmony. There is also a regular relationship between the data of head and face and some measurement items of human body, and the correlation is one of them.

It is impossible for any anthropometric work to measure and count all the indexes of human body. Generally, the main parameters of human body (such as weight, height, chest circumference, etc.) are selected to carry out the investigation. This paper carries out the correlation research between the main items of human head and face and key influence factors for head and face size based on the latest Chinese adult human head and face data. The purpose is to optimize human head facial size measuring projects, to reduce the human body data acquisition work difficulty, to meet the industrial design of the practical need of head face to the human body size data.

## 2 Research Background

Head and face characteristics are an important part of anthropologic research. Scholars from various countries have carried out a large number of head and face measurements and studies and applied them to various related fields. Head and face databases for different countries, different nationalities, different regions, different genders and different age groups have been established, which provides valuable information for the development of Ethnology and anthropology.

China has the largest working population in the world. It requires the head and face data for designing protective equipments. In 1958, China conducted its first large scale head data collection which involved 43,173 soldiers. In 1980, the Beijing Institute of Labor Protection and the National Academy of Sciences conducted a survey of 9392 people's head size. According to these data, The GB 2428-81“China Adult Head Series” [1] was established, in which 29 measurements were used to describe and classify the head shape characteristics. In 1988, China Institute of Standardization launched the first nationwide measurement of human body size, surveyed 22,300 Chinese adults, and established a database of human body size of Chinese adults. Subsequently, the standard of Adult Head and Face Size (GB/T 2428-1998) [2] for 41 head and face items was established by analyzing and statistical techniques of small sample (393 persons).

In 2013, the Chinese National Institute of Standardization launched the second nationwide measurement of human body size. The measurement includes head and face data, foot data, hand data and trunk data. The purpose of this survey is to understand the latest physiological parameters of Chinese adults, and to provide basic basis for industrial design and industrial production. Based on the data of adult head and face size obtained in this survey, the correlation between the data is analyzed in this paper.

## 3 Sampling Methods

### 3.1 Age Distribution

A total of 26,000 people aged from 18 to 75 years old were collected in this national anthropometric work. During the sampling, the subjects were divided into six age groups. The distribution of people in six age groups is shown in the Table 1 below.

**Table 1.** Number of samples in all age groups.

Age groups	18–24	25–34	35–44	45–54	55–64	65–75
Male	1,613	1,982	1,679	1,726	1,368	432
Female	1,389	1,647	1,845	2,290	1,781	511

3.2 Geographical Distribution

China has a vast territory, and there are great differences in the body shape of adults in different regions. According to anthropologists’ suggestions, the whole country is divided into six natural areas, each of which contains a number of measuring places to ensure the representativeness of the samples. The six natural areas is shown in the Table 2 below.

Table 2. Six natural areas.

Number	Areas
1	Northeast & North China
2	Midwest
3	The lower reaches of the Yangtze River
4	The middle reaches of the Yangtze River
5	Guangdong & Guangxi & Fujian
6	Yunnan, Guizhou and Sichuan

3.3 Occupational Distribution

Because of different occupations, there are also differences in body size and proportion. Therefore, this survey also classifies the population according to different occupations, which are divided into five occupational categories. The five occupational categories is shown in the Table 3 below.

Table 3. Occupational categories.

Number	Categories
1	Students
2	Government-affiliated institutionst
3	The secondary industry
4	The Third industry
5	Countryside

4 Measurement Methods

4.1 Definitions of Measurement Items

The head and face size data collected in this study are all defined by national standards GB/T 5703-1999 basic human body measurements for technological design [3].

The measurement items included 10 items: Head breadth, head length, head circumference, bitracion arc, head sagittal arc, face length, pupil spacing, head height, ear length, nose length and nose width.

## 4.2 Measurement Equipments

This data acquisition adopted two methods, that is, manual measurement and three-dimensional scanning. Martin rulers were used for manual measurement and three-dimensional head and face scanner was used for three-dimensional scanning. Surveyors were trained and assessed in the early stage, and can operate the measuring equipment skillfully.

## 5 Data Analysis

### 5.1 Inter-project Correlation Analysis

According to the physiological characteristics of human body, the indices of various parts of the human body are not completely independent, and there is a strong correlation among the characteristic parameters [4, 5]. The statistical analysis software SPSS was used to analyze the correlation of 10 datas of human head and face size, and the correlation coefficients of 11 datas were obtained, as shown in Table 4.

- (1) The correlations among the three main parameters. For the three main parameters of head length, Head breadth and head circumference, the table above shows that there is a certain correlation among them. The correlation between head length and head circumference is high to 0.726 ( $P < 0.01$ ). Although there was some correlation between head length and Head breadth, only 0.314 ( $P < 0.01$ ).
- (2) The correlation between the three main parameters and other data. Head length, Head breadth and head circumference are also correlated with other head and face items. There is a significant linear correlation between head length and head sagittal arc and shape surface length and the correlation coefficients were 0.448 and 0.411 ( $P < 0.01$ ). It indicates that the arc length from the eyebrow point to the back of occipital point was larger in the people with large head length. Head breadth has a high correlation with the bitragion arc, and has a certain correlation with the morphological surface length and pupil spacing.
- (3) The correlation between height terms. The height related items are head height, shape and face length, appearance and ear length and nose length. Among them, the morphological surface length and nose length have significant linearity. The correlation coefficient is 0.422, which indicates that the people with long distance from the bridge of nose to the submental point also have a long nose. The correlation coefficient between the other projects is not high.
- (4) The correlation between width terms. Head breadth, pupil spacing and nose width were used in this study. The correlation coefficient between Head breadth and pupil distance is 0.351, while the correlation coefficient between other data is smaller.
- (5) The correlation of items in the same head position. There was no significant correlation between head length and Head breadth, nose length and nose width. That is to say, statistically speaking, a person with a large head length does not mean a large Head breadth, and as person with a large nose length may not necessarily have a large nose width.

Table 4. Correlation coefficients of head and face items

	Head breadth	Head length	Head circumference	Bitragon arc	Sagittal arc	Face length	Pupil spacing	Head height	Ear length	Nose length	Nose width
Head breadth	1										
Head length	.314**	1									
Head circumference	.590**	.726**	1								
Bitragon arc	.603**	.280**	.565**	1							
Sagittal arc	.260**	.448**	.463**	.408**	1						
Face length	.371**	.411**	.422**	.314**	.217**	1					
Head height	.351**	.304**	.401**	.251**	.067**	.302**	1				
Pupil spacing	.228**	.227**	.318**	.359**	.264**	.311**	.131**	1			
Ear length	.137**	.227**	.237**	.100**	.079**	.262**	.154**	.131**	1		
Nose length	.249**	.219**	.240**	.188**	.105**	.422**	.166**	.142**	.240**	1	
Nose width	.192**	.343**	.312**	.194**	.160**	.207**	.191**	.127**	.270**	.188**	1

## 5.2 Analysis of Influencing Factors on Head and Face

Head size is influenced by many factors, including age, race, sex, birthplace, and many other factors [38]. These factors are not isolated from each other, but are interrelated and restrictive. This paper analyzed the influence of stature, weight, age, gender, region, occupation on the head and face data (Table 5).

**Table 5.** Analysis of influencing factors on head and face

Items	Age	Gender	Stature	Weight	Occupational	Region
Head breadth	-.250**	-.462**	.476**	.376**	-.165**	-.114**
Head length	.017**	-.554**	.428**	.395**	.051**	.108**
Head circumference	-.152**	-.510**	.528**	.508**	-.078**	-.031**
Bitracion arc	-.330**	-.331**	.466**	.320**	-.178**	-.077**
Sagittal arc	-.138**	-.345**	.313**	.208**	-.014*	.074**
Face length	.075**	-.510**	.461**	.373**	.012	-.104**
Pupil spacing	-.097**	-.289**	.308**	.250**	-.076**	-.139**
Head height	-.102**	-.191**	.326**	.228**	-.046**	-.088**
Ear length	.204**	-.250**	.214**	.267**	.050**	-.051**
Nose length	.050**	-.368**	.326**	.188**	-.015*	-.051**
Nose width	-.011	-.388**	.263**	.215**	.011	.094**

From the table above, it can be seen that the influence of different factors on head size is also different. Overall, gender, age, height and weight are the major factors affecting head size, while occupational categories and measurement locations have relatively small impact on head and face data.

Age plays a negative role in most of the head and face data, such as Head breadth, head circumference, intertrabecular arc, head sagittal arc, head full-height head and face large-scale data, with the increase of age, the data gradually decreases. For head length, shape and face length, appearance and ear length, nose length and other length data, the data increase with the increase of age. It shows that with the increase of age, the size of the head gradually shrinks due to the decrease of body metabolism level. However, facial features do show a slight increase in size with age.increase.

The influence of gender, height and weight are obvious. All the head data size for male is significantly larger than that of the female. This has a certain relationship with the characteristics of the body shape between males and females. Males are tall and large, and their sizes are generally larger than that of females. Height and weight are also highly correlated with head and face data, especially head circumference, Head breadth, head length, tragus arc and shape surface length. It shows that people with large stature and body weight generally have larger head and face contours, and the size of their five senses is also relatively large.

Compared with other factors, occupational factors and geographical factors have little effect on human head and face data.

Table 6. Linear relationship of head and face measurement items

Items	Gender	Regression Equation	R2
Bitrignon arc	Male	$70.073 - 0.260X1 + 0.768X2 + 0.303X3 - 0.229X4 + 0.032X5$	0.449
	Female	$48.207 - 0.316X1 + 0.678X2 + 0.406X3 - 0.113X4 + 0.021X5 + - .049X6$	0.382
Sagittal arc	Male	$97.797 + 0.504X1 + 0.307X3 - 0.186X4 + 0.012X5 - 0.106X6$	0.194
	Female	$95.817 + 0.515X1 + 0.278X3 - 0.086X4 - 0.048X6$	0.119
Face length	Male	$11.7 + 0.129X1 + 0.144X2 + 0.158X4 + 0.032X5 + 0.024X6$	0.146
	Female	$22.879 + 0.051X1 + 0.164X2 + 0.036X3 + 0.110X4 + 0.017X5 + 0.048X6$	0.123
Pupil spacing	Male	$3.819 + 0.048X1 + 0.095X2 + 0.044X3 + 0.010X4 + 0.005X5$	0.152
	Female	$14.349 + 0.084X2 + 0.049X3 + 0.002X5 + 0.014X6$	0.085
Head height	Male	$80.479 + 0.125X3 - 0.041X4 + 0.049X5$	0.128
	Female	$93.538 + 0.075X1 + 0.038X2 + 0.127X3 - 0.031X4 + 0.026X5 + 0.105X6$	0.111
Ear length	Male	$11.041 - 0.032X2 + 0.047X3 + 0.142X4 + 0.014X5 + 0.048X6$	0.116
	Female	$28.914 + 0.026X3 + 0.087X4 + 0.008X5 + 0.046X6$	0.049
Nose length	Male	$13.143 + 0.055X2 - 0.009X3 - 0.079X4 + 0.015X5 - 0.016X6$	0.048
	Female	$6.678 - 0.037X1 + 0.081X2 + 0.022X3 + 0.040X4 + 0.010X5 - 0.014X6$	0.043
Nose width	Male	$11.253 + 0.066X1 - 0.019X2 + 0.026X3 + 0.011X4 + 0.012X6$	0.042
	Female	$16.192 + 0.070X1 - 0.031X2 + 0.018X3 - 0.016X4$	0.022

Note: Head length: X1; Head breadth: X2; Head circumference: X3; Age: X4; Stature: X5; Weight: X6



There is interaction between these factors and head size, and the same factor has different effects on different indicators. For example, the correlation between age-to-Head breadth and intertrabecular arc is  $-0.250$  and  $-0.330$ , the two data are mainly Head breadth data; the correlation between gender and most of the head and face data is higher, especially head length, head circumference, and shape surface length data, the correlation is more than  $-0.5$ . The influence of height and weight on head and face data is consistent, and the correlation between height and weight and head circumference, head length and width is greater. Overall, these factors have greater correlations with the size of the head and face, but have a smaller impact on the local data such as pupil distance, ear, nose and so on. It shows that the local data of human head and face have certain diversity.

### 5.3 Linear Regression Equation

**Establishment of Regression Equation.** From the previous correlation analysis results, we can see that there is a statistical linear relationship between human head and face measurement items and head length, Head breadth and head circumference. Age, sex, height and weight have great influence on the data of human head and face, and these factors are also taken into account. Multivariate stepwise regression analysis for head and face data was carried out well as age, sex, height and weight factors. The regression equation are shown in Table 6.

**Test of Regression Equation.** The significance test was used to analyze the regression equation and the results show that the regression coefficients of each variable are significant and the regression equation can reflect the corresponding relationship among the measurement items. Therefore, in the future actual human head and face measurement work, we can use the linear relationship between the measurement items to optimize the basic items of anthropometry. By collecting only part of the main human head and face measurement items, the regression equation can be used to predict the human head and face data, which has strong correlation with the main measurement items but is difficult to implement.

## 6 Conclusions

This paper analyzed the correlation among 10 head and face measurement items and the correlation between head and face measurement items and influencing factors based on the latest human body size data of Chinese adults, and established an effective linear regression equation, which provided technical reference for the optimization of human head and face measurement items. The research results can be directly applied to human head and face measurement and updating of human head and face size data to reduce the difficulty of human body measurement. In order to improve the practical application ability of Chinese anthropometric data in industrial design, we will continue the research on the correlation between basic anthropometric items, various parts of the human body measurement items and anthropometric items for industrial design.

**Acknowledgments.** This research is supported by “Special funds for the basic R&D undertakings by welfare research institutions” (522016Y-4680), National Key R&D Program of China (2017YFF0206602), National Science and Technology Basic Research (2013FY110200).

## References

1. GB 2428-81 Head Configurations: Chinese Adults. National standard (1981)
2. GB/T 2428-1998 Standard Head-face Dimensions of Adults. National standard (1988)
3. GB/T 5703-1999 Basic human body measurements for technological design. National standard (1999)
4. Liu, B., Guo, X., Ma, X.: Character of anthropometry usefulness for Chinese male pilot. *J. Ergon.* **8**, 1–3 (2002)
5. Li, S.: CATIA body dimension correlation analysis. *Sci. Technol. Guide* **34**, 448–449 (2013)



# Directions Towards Sustainability Through Higher Education

Theresa Lobo<sup>(✉)</sup>

Unidcom/IADE-Universidade Europeia, Av. D. Carlos I, 4,  
1200-649 Lisbon, Portugal  
theresa.lobo@universidadeeuropeia.pt

**Abstract.** The aim of this paper is to contribute to associating higher education in design towards meeting the challenge of global sustainability [1]. Ideas from several models and from within several disciplines as design are integrated to construct a framework through the challenges can be examined and then transacted into learning outcomes, expressed as graduate attributes. The focus of design education for global sustainability has been on encouraging consumers to modify patterns of resource consumption and waste management. To actualize this potential requires that higher education curricula in design offer experiences, which develop graduate attributes of self-efficacy, capacity for effective advocacy and interdisciplinary collaboration, as well as raise awareness of social and moral responsibilities associated with professional design practice. It is important to consider the practicality of developing programs of study, which can prepare graduates with the necessary knowledge and values. Higher education in design must develop the capacity in graduates to prioritize actions after balancing all the social, environmental and economic costs and benefits [2]. So, the curriculum in design should include experiences, which lead to a greater awareness of social and moral responsibilities. Especially, in a larger self-awareness of personal value systems and a willingness to revise them is required to prepare design graduates for work towards sustainability.

**Keywords:** Curriculum development · Higher education · Consumers · Design graduates

## 1 Introduction

We are living in a rapidly changing and less predictable global system. Consumption patterns, once a consequence of local factors, are now influenced by less visible and more remote economic, technological, social, political and environmental drivers. In many ways, the far-reaching effects of local actions can be attributed to technology that has enabled the fast transformation of resources, transfer of energy and information.

The increasing affluence and growing expectations for personal comfort and convenience in the developed world have led to consumption patterns that are unsustainable, degrading the global resource base and the quality of the physical and social environments. Citizens in less developed countries are often the victims of this exploitation. These trends have generated much discussion and debate about social

justice, and have provided a strong incentive for scientific innovation to deal with emerging problems. Simplistically, it can be argued that sustainability will be achieved when all consumers can make choices to conserve, to minimise damage and to maximise benefit. Based on this approach, government policies in many countries have placed only limited emphasis on challenging producers to review the ways they manufacture, package and distribute products.

Rather, emphasis has been placed on changing consumer behaviour, specifically consumption patterns and waste management. The solution seems simple, yet there is no evidence of substantial progress towards achieving sustainable states on a global scale. The explanation for lack of success is complex and the solution may lie elsewhere. After examining the barriers to acting to promote sustainability from a consumer perspective, this paper outlines some key elements of a framework for a potentially effective and long-term approach through the higher education sector.

## **2 Impediments to Achieving Sustainability**

### **2.1 A Challenging Concept**

The problem of developing a more sustainable society is complex. At the heart of this complexity is the lack of understanding of the concept of sustainability as a basis for goal-setting. In 1987, the World Commission on Environment and Development defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [3]. This statement represented a landmark, alluding to factors beyond those related to the condition of the physical environment, traditionally the focus of discussion around sustainability.

Emerging from the Earth Summit in Rio de Janeiro in 1992 was a formal recognition of the significant relationship between ecology and economy, articulated in 27 principles [4]. By 1997, sustainable development was dependent on “economic development, social development and environmental protection” [1], later interpreted as the triple bottom line for assessing the impact of consumption [5].

### **2.2 Restrictions of Technological Solutions**

Over the past few decades, research has maintained a strong focus on measuring change in the physical environment. Efforts have been directed at quantifying climate change, with emphasis on measuring global warming and greenhouse gas emissions. It has led to the Kyoto Treaty, to which many nations are signatories.

Another important area for research has been the development and application of technologies to significantly reduce energy consumption [6]. Such technologies are designed to reduce resource consumption and pollution, while they maintain living standards. Use of these new technologies may be encouraged by economic incentives, such as cost savings due to greater fuel efficiency, or by government regulation with penalties for non-compliance with standards, such as in building design.

### 2.3 Restrictions of a Consumer Based Approach

Environmental degradation has been attributed to “careless individual and household behaviour,” [7] suggesting an alternative focus for strategies to promote sustainability. The multi-function role of the household means that changing behaviour could potentially lead to effective management of resources. Noorman has introduced the concept of “household metabolism” as a practical way of understanding the global impact of local, daily consumer activity [8]. Drawing from the ecological sciences, this concept can be applied to households to describe the flow of materials and energy. According to this model, the failure to recognise the importance of the household as a “social decision-making unit” represents a loss of countless opportunities to change behaviour and achieve sustainability.

Contemporary consumers would be regularly required to choose a product, for instance, according to the biodegradability of packaging, or whether its regular consumption might protect health. This assumes a certain standard of competence on the part of consumers as well as motivation to make sustainable choices. Consumers may be reluctant to make changes towards more sustainable consumption, for instance, because they feel that their individual decisions will not have a significant impact, particularly in the long-term. Assigning responsibility for important decisions to disaffected individuals is unlikely to bring about the major changes required to achieve sustainability.

More importantly, moves towards sustainability through a household based approach assumes that consumers have access to the relevant and reliable scientific information, interpreted in ways that they can apply to everyday situations. It also assumes that more sustainable options are available to consumers. The following discussion explains why these assumptions may not be valid.

### 2.4 Restrictions to Reliability of Information for Decision-Making

Scientific facts may appear as reliable for use in decision-making by consumers. However, the derivation of these facts is subject to the processes of collecting and interpreting evidence, and influenced by established conventions and expectations of researchers. Careers are made and kudos derived through discovering new scientific knowledge. As such, empirical science is not value free, with “vested interests... driving the research agenda” [9]. Such interests may compromise the reliability of the information needed by consumers to make decisions in the interests of themselves, their communities or the broader environment.

The processes through which science is filtered for the public influences its reliability. Generally, information about products and services delivered through the media are prepared by public relations or marketing teams. By no means does this filtering lead to a systematic and balanced presentation of all the facts needed to make informed decisions. Even claims such as “biodegradable”, which potentially could be scientifically verified, can be variously applied and then widely interpreted by consumers and even, be misleading [10]. In many instances, consumers receive information which has been selected by stakeholders for its potential to encourage purchase, to improve the

public image of a company, or perhaps for political reasons, rather than for its contribution towards providing a balanced perspective.

There are many examples where scientific facts have been debunked or substantially revised after adventitious events, further research and even through uncovering fraud. The complexities of scientific phenomena inevitably mean that there is always some level of uncertainty about the facts which describe them. Lowe explains that it is this uncertainty which makes science vulnerable to the values and assumptions of those involved in its interpretation. [9] Essentially, there are always likely to be limits to the reliability of information for decision-making by consumers.

## 2.5 Cognitive Processes

It is necessary to consider the cognitive processes involved to fully understand the notion of informed decision-making. Along with many other theories, various information processing models have been used to explain how new information is acquired and organised by individuals. Essentially, information received through the senses enters the sensory memory. The processing system involves many steps in which the information is manipulated in the short-term memory, and encoded in preparation for long-term storage. The encoding is dependent on perceptions of the quality or value or reliability of the information, and even the sensory pathways through which it has been perceived. An individual's sensory acuity, as well as education, experience, values, attitudes and beliefs, may influence perception. This means that consumers will selectively respond to segments of information, depending on personal capabilities and circumstance and interests, or even the medium through which the information is channelled.

For some input, cognitive processing is limited and decisions are apparently intuitive. Other information received may be stored in the long-term memory to become part of the file through which an individual sort when weighing the options in the process of decision making. An individual's stage of cognitive development is an important variable which will determine the speed of processing, the number of information bits processed in each time, whether the information is stored, and the storage capacity. This model indicates the complexity, and explains the unpredictability and individual nature of the decision-making process.

Considering the cognitive effort required to search through an extensive data base of relevant stored information and evaluate the relative importance of each bit of information, it is understandable that individuals will often simplify the process by choosing decision-making strategies [11]. Frequently selecting household food supplies at the point of sale in the supermarket would be a daunting task if consumers were to weigh up all the options when deciding on each product. Choosing products according to brand names is an example of a strategy which may simplify the process. The choice is a balance between the cognitive effort they are prepared to make, and their perceptions of the implications of making the wrong decision. This type of decision-making may not necessarily lead to choices which contribute to global sustainability.

Research has highlighted the influence of situational factors on the decision-making process [12], with the information environment a dominant factor. In a consumption-based culture, its impact is all-pervasive so that information segments compete for

consumer attention. Consumers may receive a vast number of messages via a variety of communication pathways at any one time, potentially overwhelming the human processing system. Rather than due to lack of motivation, failure to store information in the long-term memory may also be due to its inconsistencies with the established knowledge base. So even if information is reliable and accessible, the human information processing system may limit the capacity of individual consumers to make the complex decisions required for sustainability.

### **3 Higher Education: A Resource for Sustainability**

An approach based on consumer action relies on individuals with motivations, competencies and access to information which enables them to make choices which do not degrade or deplete resources in the physical, cultural and social domains. It also relies on sustainable choices being available. Recognising the barriers facing consumers to making sustainable choices shifts the focus to the training of professionals who manage the resources, educate the public or design the options from which choices are made. The institution of higher education is where these professionals are trained. In fact, many argue that the higher education sector bears a significant responsibility for sustainability by its influence on society and academic freedom to explore ideas [2, 13]. This provides a strong justification for investing in this social institution as an agent to bring about change.

The Consultation on Sustainable Development in Prague in 2003 acknowledged the failure of higher education sector to produce graduates with the skills, motivation and knowledge to address the problems emerging in the work towards sustainability. Unusually, the recognition that most world leaders had completed tertiary studies is strong evidence that the education which empowered did not encourage the aspirations or develop the capabilities required for sustainability.

The higher education sector is a complex realm, involving students, academics and administrators, and their diverse attitudes, skills, experiences and knowledge, and programs of study which traditionally transform students into graduates who assume responsibilities in society. So, curricula delivered within this sector should derive directly from the needs of the society that it serves. As such, there are many challenges facing higher education if it is to actualise its potential for contributing to sustainability.

The higher education in design is a complex realm, involving students, academics and administrators, and their diverse attitudes, skills, experiences and knowledge, and programs of study which traditionally transform students into graduates who assume responsibilities in society. So, curricula delivered within this sector should derive directly from the needs of the society that it serves. As such, there are many challenges facing higher education in design if it is to actualize its potential for contributing to sustainability.

## **4 The Tasks for Higher Education**

### **4.1 Promoting Diversity**

Generally, tertiary students represent a population with the intellectual capability to assimilate the many dimensions of the concept of sustainability. They are at a formative stage when they can be encouraged to experiment with ideas to find creative solutions to problems in their chosen field of work. However, opportunities to develop this capability are likely to vary for different degree programs due to the type of students they attract.

For instance, applicants for a Consumer Science program in the UK come with a wide-range of academic backgrounds [14] so, as a group, already have opportunities to practice meeting the challenges of working from a multi-disciplinary perspective. This diversity is not usually evident in disciplines, such as medicine, engineering and law, where students are trained for practice based on traditional concepts and long-established conventions. The importance attached to meeting targets for recruiting students from diverse ethnic or economic backgrounds and other indicators of alternative social experience by some universities may be a positive first step towards producing graduates capable of contributing to sustainability.

### **4.2 Understanding the Concept of Sustainability**

The public misunderstanding and ambivalence about the term “sustainability” extends to the higher education sector [15, 16], with few opportunities to challenge the assumption by academics and the university community that environmental science is the only place for studies about sustainable development [17]. According to Sherren [13], this amounts to an academic focus on understanding the environment, rather than the way humans interact with it.

So, even programs in design with an environmental focus are typically multi- or inter-disciplinary [16]. This may not be obvious because the “flexibility (of sustainability and related terms) allows for comfortable use in meaningless rhetoric” [13], potentially masking an inability or reluctance to really teach principles of sustainability in design.

### **4.3 Redesigning Courses**

It is important to consider the practicality of developing programs of study which can prepare graduates with the necessary knowledge and values, a capacity for critical thinking and the motivation to deal with the multitude of diverse problems associated with non-sustainable states.

Teaching in the higher education sector involves the transfer of knowledge organised in units called subjects or courses. Although a subject can be considered as “a resource... to educate for sustainability” [17] traditionally it derives from a single discipline. Because sustainability depends on ways natural and social systems interact, studies in a single discipline cannot provide the opportunities to learn how to devise practical and effective ways of overcoming the barriers to achieving sustainability.



Even if the program of study includes subjects from different disciplines, the challenge for undergraduate students to integrate the acquired knowledge is considerable. For higher education to “play a crucial role in building the knowledge, skills and attitudes for a sustainable future” [18], recommends developing curricula based on concepts related to sustainability, rather than the traditional set of concepts associated with each discipline. This would require a complete revision of policy and practice in the higher education sector.

At present, there are a few university programs designed to educate students to adopt an interdisciplinary approach to understanding and solving problems. There are even a few programs which directly relate to the notion of interdisciplinary cooperation and social justice, training graduates for practice focused on promoting design products for healthy individuals, societies and environments. Some programs involve the study of household and broader scale resource consumption. However, with the obvious exceptions in some environmental design and engineering programs [19], there are many science based programs which do not include even a token reference to sustainability. Applying the traditional scientific method promoted in these disciplines is unlikely to produce solutions to the poorly defined, dynamic and “messy” problems to be overcome [20].

In a review of initiatives in the tertiary sector [20], Thomas reports on the lack of information, incentives, experience, interest or financial resources for sustainability education within the university community [16]. Lacked shared vision across the university, and conflicting values of various sectors within the tertiary infrastructure, can also counter initiatives [2]. Effectively, these factors leave a void rather than an opportunity for constructive collaboration, recognised as essential for integrating concepts of sustainability across the curriculum. Given the daunting task of changing the higher education institutions [16], developing new curriculum models as design may be a more effective approach. Potentially, there are many sources of ideas which could contribute to the new curricula. Drawing ideas from several models and paradigms, guidelines which form a framework for the design of curricula to meet the challenges of sustainability, are outlined in the following section.

## 5 Concepts for Curriculum Design

### 5.1 Social Cognitive Theory

Social Cognitive Theory [21], a synthesis of ideas from associations and cognitive theories, contributes to understanding the relationships between individual behaviour and environments. Given the importance of understanding interactions at the human-environment interface, this knowledge seems particularly relevant to sustainability education.

According to Bandura, “outcome expectations”, a person’s belief that a given behaviour will lead to an outcome, and “personal efficacy”, a person’s belief that they can undertake that behavior, combine in the concept of self-efficacy [22]. Individuals’ perceptions of their own capability to carry out an action are learnt from various sources and relate to their personal experiences of success on prior occasions, their

observations of others, their psychological and physiological states. A high level of self-efficacy means a degree of autonomy and self-determinism attributes recognised as important outcomes of higher education for sustainability [23].

Bandura has long advocated the importance of self-efficacy as a powerful predictor of behaviour and performance because it determines an individual's initial decision to execute the behaviour, the effort expended and persistence in the face of adversity when pursuing the outcome. Motivation, persistence and confidence of success are important attributes in individuals, given the challenges they face in working towards sustainability.

To develop self-efficacy in students, curricula should include hypothetical or real problem solving exercises, structured with appropriate levels of professional and peer support to assure positive outcomes [24]. This support might be provided through a mentoring relationship with teachers in a 'project-learning' approach which encourages greater risk taking and independence [14].

## 5.2 Boyer Model of Scholarship

The Boyer model of scholarship [25] provides another theoretical basis to guide the design of curricula to educate individuals for sustainability. Scholarship is a key concept of this model, and requires an inclusive view of the human condition, which emerges when knowledge is acquired through the processes of discovery and integration. There are strong parallels with sustainability education.

According to Boyer, scholarly research focuses on pressing human problems. Certainly, this describes the urgent and intractable problems associated with non-sustainable states. The scholarship of discovery refers to disciplined inquiry, and requires openness to ideas from less familiar fields on the part of students and academics, corresponding directly with the demands facing those working towards sustainability. To demonstrate the scholarship of integration requires a capacity to recognise the potential for linkages and synergies between disciplines and fields of research, and to be able to form new insights, as a consequence. Being able to integrate ideas to establish new insights is a process which is widely recognised as essential for responding to the challenge of achieving sustainability.

Applying the ideas of Boyer directly to tertiary education, Smith [24] claims that education should allow students to develop their capacity "to go beyond their own interests... to build bridges between areas of specialisation... and to apply their knowledge to life." Setting these goals as learning outcomes provides a focus for the education of graduates for practice within multidisciplinary frameworks, a requirement for working towards sustainability.

## 5.3 Global Perspective

Adopting a global perspective is essential if higher education is to decide effective ways to respond to unsustainable patterns of consumption. From a global perspective, important objectives of education include the development of an appreciation of the concept of conservation, a respect for indigenous peoples and their culture, knowledge of the state of the natural environment, an understanding of global dynamics, and the

protection of routes of transmission of culture, knowledge and skills to future generations [26]. The question is how these objectives can be translated into graduate attributes.

As part of a proposal for citizenship education, McGregor describes three components which together could orient individuals to global realities. The civil component embraces community involvement, including contributions toward community development and learning through community participation. The political component involves skills such as conflict resolution and decision-making, as well as opportunities to acquire the breadth of knowledge to enable an effective role in public life. Teaching to promote acceptance of social and moral responsibilities is another important component of citizenship education. By integrating these components, individuals can “see that their consuming role is linked to their role as a socially responsible citizen” [26]. There are many parallels here with the ideas proposed by Sherren, as a basis for the design of higher education for sustainability.

The complexity of the information required and the barriers to accessing it disempowers consumers motivated to choose sustainable options. To achieve an equitable balance in negotiations with stakeholders in a global environment may require professionals who can adopt an advocacy role on behalf of their clients. Adopting a global perspective means that higher education must offer students the opportunities to learn the effective communication and negotiation skills required for this role.

Professionals need to reflect on their own knowledge and awareness of global issues. This is important if they are to recognise how their contributions in public forums affect consumers’ decisions, such as in comments they make to the media, in textbooks and the commercial, community or government policies they write. This means that it is important to educate students to recognise their personal values, recognise conflicting values, and then revise them so that sustainability becomes a priority when formulating solutions to human problems. Values education is probably more effective in higher education because it involves individuals at a stage when they have accumulated some life experience and gained some maturity. In one study, role play was used effectively to raise university students’ awareness of their own values and how these values influence the decisions they make [27]. However, even with a well-planned approach and mission, there are many challenges for higher education in implementing effective values education [28]. This may be one of the more significant barriers to reorienting higher education as a resource for sustainability.

## 5.4 Sustainability Science

Developing a new discipline is one way to overcome the constraints of working within traditional disciplinary domains [29]. Researchers at Harvard University proposed the development of the field of sustainability science, which is characterised by an integration of ecological and social processes at the local and global levels, with an overall aim of achieving sustainability [30]. Consistent with the Boyer Principles, it is based on the idea that scientific research is undertaken as real problems are being addressed, allowing for emergence of innovative solutions. Decisions are based on knowledge constructed through a conventional scientific approach which provides the facts, as well as “more informal, cultural knowing” [31], so involve value judgements [32].

In interpreting the principles and objectives of sustainability science for higher education curricula, students would be trained to seek validated and balanced scientific information about the effects of interaction of society and the environment, have opportunities to formulate responses to unsustainable patterns of consumption, to test and revise them. Graduates trained in this way would recognise the needs and interests of all stakeholders and seek to empower them with reliable, understandable and objective information required for effective participation in the processes of decision-making. Through their studies, they need to develop awareness that any action involves uncertainties and risks with moral and ethical implications which must be acknowledged in the decision-making process.

The value of integrating the principles of sustainability science into the framework for higher education curricula is that it brings together “scholarship and practice, global and local perspectives, and disciplines ...” [33].

Although it remains far from being recognised widely as an integral or legitimate discipline, it provides a focal point to which the efforts in many fields can converge to address the complex issues arising when working towards sustainability. In the conclusion following, these diverse ideas are integrated to form guidelines for curriculum design.

## 6 Conclusion

Approaches to design sustainability, which have relied solely on changing consumer behavior, have not been successful because individuals do not have access to reliable and understandable scientific information, nor the skills or resources to apply the information in everyday decision-making. Information is often unreliable due to different interests driving its construction and interpretation, and due to the influence of the wide variety of sources through which it is disseminated. The limitations of the human.

Traditional education has not provided the training for graduates to work towards developing solutions to the new and complex world problems emerging. These problems are multi-dimensional and cannot be addressed by a specific application of conventional scientific, economic or social theory. So, while sustainability is dependent on proactive responses from consumers, they need to be guided by professionals with an understanding of emerging problems, and a commitment to reversing unsustainable trends. Through their work in government, design industry and communities, these new graduates will enable consumers, individually and collectively, to deal with the threats to the environment, and to social and economic stability in the twenty-first century.

Higher education in design, as the training ground for professionals, plays a central role in this process. To meet this challenge requires that learning experiences in higher education be restructured. It requires teaching by academics from many disciplines that collaborate to share ideas and make new connections within a flexible and dynamic theoretical base. It also requires them to work beyond their own areas of specialization to supervise students' work across disciplines.

Design students need opportunities to explore the relevance of concepts such as sustainability to their proposed field of professional practice. They need to recognize

the importance of their role as graduates in empowering their clients with knowledge in design and skills to address local problems, which threaten future wellbeing. They need opportunities to make contributions to resolving real world dilemmas, with appropriate adaptations for the learners and the learning setting, in place of standard assessment tasks. To meet the challenges such tasks present, strategies to develop self-efficacy and advocacy skills in students need to develop and tested [34].

Higher education must develop the capacity in graduates to prioritize actions after balancing all the social, environmental and economic costs and benefits. So, the design curriculum should include experiences, which lead to a greater awareness of social and moral responsibilities. In particular, greater self-awareness of personal value systems and a willingness to revise them is required to prepare design graduates for work towards sustainability [35].

Finally, there is an imperative for every academic to consider how their area of expertise as design relates to other disciplines and how their teaching could contribute to developing graduate attributes necessary for work towards sustainability. This requires support of the whole institution, and possibly considerable professional development of staff to help them appreciate how they can actualize the potential of higher education to lead the next generation to global sustainability in design [36].

## References

1. Von Schomberg, R.: The objective of sustainable development: are we any closer? In: Foresight, Working Papers Series No. 1 (2002)
2. Davies, S., Edmister, J., Sullivan, K., West, C.: Educating sustainable societies for the twenty-first century. *Int. J. Sustain. High. Educ.* **4**(2), 169–179 (2003)
3. World Commission on Environment and Development (1991)
4. United Nations: Report of the United Nations conference on the human environment stockholm, 5–16 June 1972 (1995)
5. Elkington, J.: *Cannibals with Forks: The Triple Bottom Line of the 21st Century*. New Society Publishers, Gabriola Island/Stony Creek (1997)
6. Van Der Wal, J., Noorman, K.: Analysis of household metabolic flows. In: Noorman, K.J., Uiterkamp, T.S. (eds.) *Green Households? Domestic Consumers, Environment and Sustainability*. Earthscan Publications Ltd., London (1998)
7. Marcoux, A.: Population and environmental change: from linkages to policy issues sustainable development department. Food and Agriculture Organisation of the United Nations (1999)
8. Noorman, K.J., Biesiot, W., Uiterkamp, A.J.M.: Household metabolism in the context of sustainability and environmental quality. In: Noorman, K.J., Uiterkamp, T.S. (eds.) *Green Households? Domestic Consumers, Environment and Sustainability*. Earthscan Publications Ltd., London (1998)
9. Lowe, I.: Social behaviour: incentives for sustainability. In: *Plenary Proceedings of CRC Coast to Coast Conference Proceedings* (2002)
10. Cude, B.: Consumer perceptions of environmental marketing claims: an exploratory study. *J. Consum. Stud. Home Econ.* **17**, 207–225 (1993)
11. Niva, M., Timonen, P.: The role of consumers in product-oriented environment policy: Can the consumer be the driving force for environmental improvements? *Int. J. Consum. Stud.* **25** (4), 331–338 (2001)

12. Payne, J.W., Bettman, J.R., Johnson, E.J.: *The Adaptive Decision Maker*. Cambridge University Press, New York (1993)
13. Sherren, K.: Core issues: reflections on sustainability in Australian University coursework programs. *Int. J. Sustain. High. Educ.* **7**(4), 400–413 (2006)
14. Byrne, M.: Factors involved in the learning of consumer studies. *Int. J. Consum. Stud.* **25**(4), 322–330 (2001)
15. Schriberg, M.: Institutional assessment tools for sustainability in higher education: strengths, weaknesses and implications for practice and theory. *High. Educ. Pol.* **15**, 153–167 (2002)
16. Thomas, I.: Sustainability in tertiary curricula: what is stopping it happening? *Int. J. Sustain. High. Educ.* **5**(1), 33–47 (2004)
17. Institute of Environmental Studies: *Education for Sustainability*, UNSW Publishing and Printing Services, Sydney. International Association of Universities (2006), IAU Conference: *Education for a Sustainable Future*. Conference General Report (1999)
18. Reid, A., Petocz, P.: The UN decade for sustainable development: what does it mean for higher education?. In: *HERDSA 2005 Conference Proceedings* (2005)
19. Clugston, R.: Introduction. In: Filho, W. (ed.) *Peter Lang, Frankfurt* (2002)
20. Potschin, M., Haines-Young, R.: *Rio + 10, sustainability science and landscape ecology* (2006)
21. Bandura, A.: Social cognitive theory. In: Vasta, R. (ed.) *Six Theories of Child Development*, pp. 1–60. JAI, Greenwich (1992)
22. Mumaw, C.R., Sugawara, A.I., Pestle, R.: Teacher efficacy and past experiences as contributors to the global attitudes and practices among vocational home economics teachers. *Family Consum. Sci. Res. J.* **24**(1), 92–109 (1995)
23. Wals, A., Jickling, B.: Sustainability in higher education: from doublethink and newspeak to critical thinking and meaningful learning. *Int. J. Sustain. High. Educ.* **3**(3), 221–232 (2002)
24. Smith, F.M.: Assessment of student outcomes in home economics higher education. *Family Consum. Sci. Res. J.* **23**(4), 347–367 (1995)
25. Boyer, E.: *Scholarship Reconsidered: Priorities of the Professoriate* (1990)
26. McGregor, S.L.T.: Towards developing a global perspective in the field of consumer studies. *J. Consum. Stud. Home Econ.* **23**(4), 207–211 (1998)
27. Crompton, S., Roy, R., Caird, S.: Household ecological footprinting for active distance learning and challenge of personal lifestyles. *Int. J. Sustain. High. Educ.* **3**(4), 313–324 (2002)
28. Muijen, H.: Integrating value education and sustainable development into a Dutch university curriculum. *Int. J. Sustain. High. Educ.* **5**(1), 21–32 (2004)
29. McMichael, A., Butler, C., Folks, C.: New visions for addressing sustainability. *Science* **302**, 1919–1920 (2003)
30. Kates, R., Clark, W., Corell, R., Hall, M., Jaeger, C., Lowe, I., McCarthy, J., Schnellhuber, H., Bolin, B., Cdicson, N., Faucheux, S., Gallopin, G., Gruebler, A., Huntley, B., Jäger, J., Joha, N., Kaspersen, R., Mabogunje, A., Matson, P., Mooney, H., Moore, B., O’Riordan, T., Svedin, U.: *Sustainability Science. Research Centre and Assessment Systems for Sustainability*. Environment and Natural Resources Program, John F. Kennedy School of Government. Harvard University, MA (2000)
31. O’Riordan, T.: Vignette 2.1 education for sustainability. In: Scott, W., Gough, S. (eds.) *Key Issues in Sustainable Development and Learning*. RoutledgeFalmer, New York (2004)
32. Dobson, A.: Economic behaviour: value and values. In: Scott, W., Gough, S. (eds.) *Key Issues in Sustainable Development and Learning*. RoutledgeFalmer, New York (2004)
33. Clark, W., Dixon, N.: Sustainability science: the emerging research program. *Proc. National Acad. Sci. U.S.A. Sci. Technol. Sustain. Dev. Spec. Feature* **100**, 8059–8061 (2003)

34. Wright, J.: The introduction of sustainable design into the curriculum of the architectural studies program, SIUC. In: Human, Earth, Culture: Summary of World Congress on Environmental Design for the New Millenium, World Congress on Environmental Design, Seoul, Korea (2000)
35. Yang, Y., Giard, J.: Industrial design education for sustainability: structural elements and pedagogical solutions. Paper presented at the IDSA National Design Education Conference, Boston, MA (2001)
36. Fleming, R.: Design Education for a Sustainable Future, 1 s edn. Routledge, Abingdon (2013)

# **Information, Design and Visualization**





# Water Museums and Digital Media: Two Case Studies on Digital Media in Water Museums

Joana Lessa<sup>(✉)</sup>

CIAUD – Research Centre for Architecture, Urbanism and Design,  
Lisbon School of Architecture, University of Lisbon, Rua Sá Nogueira,  
Pólo Universitário, Alto da Ajuda, 1349-063 Lisbon, Portugal  
jlessa@ualg.pt

**Abstract.** The paradigm of museum as “a place without borders” meets new possibilities in the age of globalization and digital media. The highly technological driven audiences present a continuous challenge for most Museums to attract and engaged. The focus is now mainly on the experience – the Museum experience, that can also be modeled and enhanced by the use of digital media. This article presents a preliminary view on the presence of digital media in two identified Water Museums: two case studies from the Global Network of Water Museums (WAMUT-NET, an initiative of UNESCO). We’ve identified the presence of similar digital technologies and tools, but different forms of integrating them in each Museum’s scale, context and mission. Further research should follow, to identify in situ, and in articulation with curators and visitors, new findings.

**Keywords:** Digital media · Water museums · WAMU-NET · Experience Design · Emotional design

## 1 Introduction

This paper presents a first step of a preliminary on-going study on the existence of digital media in water museums. It identifies, through the available resources, digital media in two water museums, which we believe represent interesting realities to study: The Changjiang Civilization Museum, Wuhan, China; and the Waterline Museum (*Waterliniemuseum Fort bij Vechten*), Bunnik, The Netherlands. Both of them integrate an international non-governmental initiative – the Global Network of Water Museums (WAMUT-NET) by UNESCO, which is a platform for promoting and disseminating sustainable water management values. Information was gathered online, and after the museums were contacted, more information was made available.

Today, water is a global issue: water crises are being debated transversely and at a global scale in international agendas for ecology, health, politics, economics, education, culture, ethics, among other. Governmental and non-governmental institutions are increasingly taken the responsibility to raise awareness for water related issues: “water scarcity, exhaustion of resources, water pollution, desertification, melting glaciers and recurrent floods due to climate change, with the consequent dramatic reduction of biological and cultural diversity and the exodus of entire populations” [1]. Among

these institutions, museums are a strong and effective place (place in the broad sense of the word) to disseminate water culture and educate for sustainability.

A great diversity of water museums started to appear all over the world. Each one presents a specific form of water civilization: cultural, natural, material and immaterial, presented through artifacts, techniques, narratives, etc. The mission of water museums, facing the global water crises, is to focus on the emergency to communicate to a large audience and educate for its importance, cherishing water heritage, promoting good practices and positive action [1].

## 2 Museum's Today

The notion that a Museum is a physical place that collects objects and presents them to visitors for an expected passive attitude has change [2] along the XX century: from the concept of the “museum without walls” in the vision of André Malraux, where the works of art would be easily accessible without physical constraints [3]; to the vision of George Henri-Rivière who pointed the importance of visitors participation and a strong connection to the community where the museum is established – in his perception of the concept of *Ecomusée*, he expressed the value of interpreting territory in connection to time and place displaying the relationship between man and nature [4]; and later in the century, the critical museology which emphasizes the function of the museum as a place of cultural democratization, reflection, debate, negotiation, controversy [5], that also assumes cultural and social responsibilities in the respect for the individual and in a vision of inclusion [6].

Today, in many museums, the impact of those visions reveal a major shift from object-centered to visitor-centered museology, accompanied by a participatory and interactive presence of the visitors in the museum experience, designed for the visitors [7, 8]. The experience is the focus, and museums look to attract more diverse audiences [9] and to engage their participation, developing strategies to explore the connection to tangible and intangible contents in a more accessible manner [9].

More recently, and in tune with today's global issues, emerged another aspect we believe relevant – the notion of a “*Mindful Museum*”: a Museum that, aware of contemporary issues and conscious of the museum privilege position in society, addresses those issues with a set of values that “might include idealism, humility, interdisciplinarity, intimacy, interconnectedness, resourcefulness, transparency, durability, resilience, knowing your community and knowing your environment.” [10].

Individuals of today are technological driven – from “digital natives” to “digital emigrants” [11, 12]: they are accustomed to access and share contents; are active in social media; and always surrounded by digital tools that empower them. Their lives are immersed in digital media, which influences the way they process information, with impact in their learning styles, preferences and habits [12].

Understanding their audience allows museums to meet the visitor in his/her own terms, by creating strategies and designing the foundations for a museum experience that, not just fulfills the visitors' expectations, but also goes beyond what they can foreseen [13], vital to captivate and sustain audiences [13]. In this context, the museums understand the importance of participatory platforms [6, 9]. To be able to

adjust to the modifications of social needs [14] and to look for new possibilities of conveying culture and knowledge, they should adapt continuously. Which motivates reflecting and exploring relevant issues of our time.

More and more, audiences perceive learning, culture, and self-fulfillment as possibilities for leisure [7], and consequently museums are increasingly a place for leisure and cultural tourism, where visitors aim to broaden their culture and knowledge by learning about heritage (tangible or intangible) in a pleasurable and informal way [13]. According to Black, museum audiences primary visit motives are social and leisure and “their museum experience is voluntary, exploratory, spontaneous” [13].

### 3 Experience, Emotion and Digital Media

Today, museums share the need to captivate and engage visitors. From this premise museums understand or should understand the value of experience. The museum experience is now part of the identified aspects that contribute to a museum’s success [13], because visitors also look for an experience: an enjoyable, cultural, educational, self-improvement experience while flowing in the museum at their own pace and choice, self-exploring space and exhibitions – tailoring the experience to their own interests [13]. Learning is both cognitive and emotional [7], and exploring positive emotional states while conveying cultural, pedagogic, informative contents promotes a positive emotional experience, which is engaging and simultaneously stimulates long time memory and learning [15, 16]. A rich and memorable experience is an emotional one [16], and the use of multi-sensorial information concurrently directed at different senses, like vision and hearing, induces emotional richness [17, 18], promoting a more engaging experience [17, 18]. For designing meaningful experiences, Nathan Shedroff, a designer, writer, pedagogue in the area of Experience Design points the importance of addressing five forms of value in a product or service, which is applicable in every user experience [19]: price; function; emotion; identity; and meaning. He distinguishes two groups: the quantitative values (price and function); and the qualitative values (emotion, identity, meaning), being the latter intangible and more important when valuing an experience. Focusing on the qualitative values: the emotion relates to “how” the user feels about the it (usually subconscious); the identity, refers to the affinity of the user with it; and the meaning, relates to the principles that define the user existence at the most deeper level [19].

Digital media offers powerful possibilities to attract, engage and allow participation in museums [9]. It opens new forms to connect with the museum without physical presence, namely through websites, APPs, virtual online tours (many museums have part of their collections digitize [20, 21]; some museums exist mainly on the digital arena [21]), and presence in social media. It makes museums more accessible to larger, distant, diverse audiences and promotes a more active citizen participation fostering a space of convergence [6]. It supports customized experiences, online [20] and inside museum walls. Inside, more flexible user-personalized visits can be enabled with assistance devices and digital applications that meet visitors’ needs: information, orientation, interpretation and interaction [8].

The design of interactive interfaces can explore multimedia contents in connection to artefacts and exhibitions, using techniques like Virtual Reality (VR) [21] Mixed Reality (MR) [22] or Augmented Reality (AR) to give access to otherwise inaccessible information, or additional interpretative materials, and/or enhance the museum experience, which might even explore multi-sensorial content [23]. In VR, the visitor is immersed “into a completely artificial world” [21], while in AR, virtual information is seen as an “over layer” on real-world environments, “augmenting” it, and MR it’s a “combination of VR, AR and the real environment” in a more complex reality with space continuity [21]. These technologies are being use along with techniques like storytelling games strategies [24] to explore multi-sensory experiences promoting rich, emotional and engaging museum visits [21–24]. The social aspect can also be enhanced, e.g. by creating spaces to share opinions, like digital Kiosks [9, 21] or contexts for shared experiences, like multi-users or collaborative interactive installations, e.g. using interactive surfaces (touch screens or projection on surfaces, like wall or floors or tables).

#### 4 Water Museums

Water is a precious resource in the planet, essential to life, and at the core of universal human identity: the connection to the ancestral origin and also the presence in the human body representing 50–65% of its composition [25].

The growth in awareness for the uniqueness and importance of water, as part of human heritage led to the foundation of water museums all over the world. They are fundamental for they present “distinctive repositories of different water civilizations and of humanity’s multifaceted water heritage” [1]. Some examples are presented next.

The Living Waters Museum: Visualizing Narratives, Cultures and Ecologies of Water Center for Heritage Management, Ahmedabad University in India is an example of a water museum that is mainly a digital platform and a set of pop-up exhibitions. The museum uses the digital platform as a means to approach its audience and to create a flexible and easy connection for distant visitors. The museum project is focused on education and raising awareness in young generations, and presents a strong sense of community integration. And conveys an holistic approach, integrating several areas: from science to art, environmental, social, spiritual, history [1].

The Water Museum of Venice, Civiltà dell’Acqua International Centre, in Italy, is a multi-site museum, constituted by a set of buildings and natural landscapes. In this museum the use of digital media is principally focused to orientate visitors between the different museum sites, namely using APP’s with virtual tours, videos or sound descriptions to complement the perception *in situ* (adding extra information) [1].

The Museum of Water, in London, UK (but also travelling collection) is an art project with a vital presence online to fuel the project and to engage the audience to actively participate in it. This museum is structured as a growing shared memory repository on water – it comprises a continuously construction of the collection: the audience contributes to the development of the museum, providing worldwide water specimens and giving meaning to them [1].

Although water museums are very different in size, nature, location, type of audiences and how they relate to them, purposes and specific set of values, they all have one thing in common: aiming to contribute to the preservation of water heritage (natural, cultural, tangible or intangible) and engaging individuals and communities to actively participate in that effort.

#### 4.1 WAMU-NET: The Global Water Museum Network

The Global Water Museum Network (WAMU-NET) is an initiative endorsed by UNESCO with the mission of: “calling on authorities and citizens who believe wholeheartedly in preserving all waters” to reconnect humanity with Water in all its dimensions including social, cultural, artistic and spiritual, to create “a new sense of civilization” [1].

Now, more than sixty water museums are part the WAMU-NET. As a recent structure, they are starting to invest in visibility, namely through their digital online presence (a website) where they present their mission, the members of the network, a digital archive of tangible and intangible water related heritage and all the initiatives they develop and/or endorse. WAMU-NET considers that today water museums urge to disseminate their message to bigger audiences in a more coordinated mode [1] (each one is a unique reality and some are very isolated). The Network allows it, promoting good practices and creating a platform to extend each museums voice.

#### 4.2 Two Case Studies

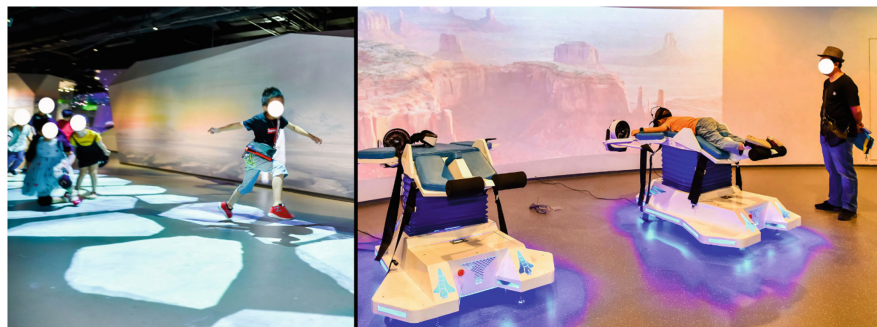
There was made a selection of two water museums as case studies. Criteria of selection included the use of digital media, distinct location (country and continent), distinct dimension (number of collection pieces and staff), and different type of heritage. Information was gathered online, and after, the museums were contacted and more information was made available. The first case study is The Changjiang Civilization Museum, Wuhan, China, and the second, the Waterline Museum (*Waterliniemuseum Fort bij Vechten*), Bunnik, The Netherlands.

The Changjiang Civilization Museum, Wuhan, China opened in 2015 and is focused on the ecology and civilization of the Yangtze River and other major rivers in the world. It can be considered a big museum, with more than 8000 pieces collection of the Tibetan-Qiang, Ba-Shu, Jing-Chu, and Wu-Yue cultures, organized in three permanent exhibitions: “Into the Yangtze River”, “Perception of Civilization,” as well as the experience hall of “The Magical Yangtze” with 9,141 exhibits in total, and one hundred people staff.

The message the museum intends to convey is one of hope for a peacefully coexistence between man and nature: “water nourishes mankind, giving mankind the ability to create civilizations”.

It is a highly digital media equipped museum with state of the art technology. Inside, the museum integrates a dark ride called “The Magical Yangtze” (4D ride), a four dimensions sensorial experience tunnel ride in a ten minutes tour based on the natural landscapes of the river Yangtze. But also other digital media technology and tools: a dome theater fully VR immersive multi-sensorial experiences and VR

experiences with head-mounted device (see Fig. 1 – *right*); multi-sensorial installations; AR (Augmented Reality) experiences; digital displays/totems and interactive kiosks; interactive guide; 360° digital screen and 360° interactive digital projections; interactive floor/wall/table projections; interactive touch screen tables and walls; interactive wall with gesture-control movement of 2D or 3D characters; hologram technology; access to digital information with the use of QR codes and other codes/visual cues. Online, the museum presents itself through a website which includes a virtual tour and maintains its presence in social media.



**Fig. 1.** Children experiencing floor interactive projection (*left*) and full immersive VR (*right*), at The Changjiang Civilization Museum, Wuhan, China. Courtesy of The Changjiang C. Museum.

The digital tools in this museum support or present: storytelling/narrative techniques, evocative content and abstract imagery; literal descriptions and captions; doing and experiencing; games; fictional and real-world environments; immersive and interactive experiences and multi-sensorial experiences.

In this museum digital media is mainly designed to: better captivating the audience during the visit and engage them in the museum experience; better explain/inform about specific data or contents but also allow access to otherwise inaccessible contents; provide access to additional interpretative material, additional information to enhance the museum experience; and provide possibility of shared experiences between visitors.

The Waterline Museum (*Waterliniemuseum Fort bij Vechten*) in Bunnik, The Netherlands is composed by two distinctive elements integrated in a one musicological project which opened in 2015: the contemporary building of the waterline museum, the Fort *bij Vechten* (built in 1880) that surrounds more than twenty buildings and one archeological site (*castellum*). The staff is composed by ten elements.

The museum presents the story of water in its role as an ally, protecting the Netherlands against enemies for the last four centuries. The story focus on the New Dutch Waterline (build between 1815–1939) and also features other defense Lines.

Inside the museum, the exhibit “Strong Water” was designed in alignment with the museum’s philosophy: organised in three parts, “*when, now and I do*”, it presents a fusion of education and entertainment. *When* relates to information on the past, *now* offers information about the present, and *I do* implies an interactive participation of the visitor.



We can identify an hybrid approach of tangible and intangible heritage, indoors and outdoor locations, analogic and digital, which intends to connect culture, nature, education, and leisure, bridging man with nature (see Fig. 2). Although objects (artifacts and buildings) are central, the visitors are also invited to participate in interactive designed situations focused on experience. Here, the use of digital media integrates the outside environment in Virtual Reality and maintains the visitor connected to the sense of place: the visitor experiences a parachute jump in immersive multisensory VR (using a head-mounted device and taking one of the moving chairs) (see Fig. 2 – *right*) – there's a virtual rise through the museum window on to great heights and a simulated fall during which the visitor can overview the entire Waterline while hearing audio explanation and the simulated sound of wind and birds.



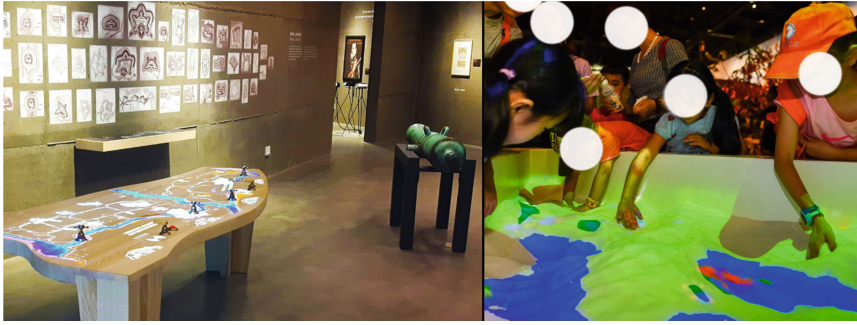
**Fig. 2.** Waterline Museum, The Netherlands: the outdoor bridge to access Fort bij Vechten (*left*) and visitors (of different ages), experimenting full immersive VR in the exhibit “Strong Water” (*right*). Courtesy of the Waterline Museum.

The digital technology and tools which are integrated in the museum experiences indoors are: Mixed Reality experiences; VR with head-mounted device (glasses); interactive displays/totems and interactive Kiosks; interactive wall, table projections; interactive table touch screens; and codes/visual cues to access digital information. But the museum also invests on digital media outside its doors: a website and active presence on social media.

Although digital tools are used to present descriptions and captions, their main use explores storytelling/narrative techniques in fictional but also real-world environments. Some of them created with the help of a VR immersive system, which constitutes a multi-sensory experience (see Fig. 2), but also by inviting the visitor to do and manipulate things like interactive objects and participate in gaming experiences (see Fig. 3 – *left*).

Majorly, the digital media in this museum is designed to: present content otherwise inaccessible, and additional interpretative material, but simultaneously to provide information that enhances the museum experience and create emotional experiences.

They mostly consider digital media in this museum to be highly valuable for the museum experience and a vital part of the museum's identity.



**Fig. 3.** Exhibition “*when, now and I do*” with interactive objects/projection on table, inside the Waterline Museum, The Netherlands (*left*), and children playing with interactive malleable surface, “creating” rivers and lagoons at The Changjiang Civilization Museum (*right*). Courtesy of the: Waterline Museum, The Netherlands (*left*) and The Changjiang Civilization Museum (*right*).

## 5 Discussion

In both museums there is a clear objective in designing the visitor experience as educational and pleasurable. The main purpose of the use of digital media in the museum, identified by each one and common to both is: to allow access to otherwise inaccessible contents; to provide access to additional interpretative material; and to offer additional information to enhance the museum experience. The distinctive main purposes are: for The Changjiang Civilization Museum, the use of digital media to better captivate the audience during the visit and engage them in the museum experience, and also to provide possibility of shared experiences between visitors; while for the Waterline Museum, the creation of emotional experiences.

Similar to both, the digital media main use explores: storytelling/narrative techniques in fictional but also real-world environments (in dark rides and VR immersive experiences – the case of The Changjiang Civilization Museum; and in VR immersive experiences – the case of Waterline Museum) creating multi-sensorial experiences; doing and experimenting (manipulating interactive objects); gaming experiences; and also literal descriptions and captions to identify pieces.

Digital interaction seems to be a central presence in both museums, inviting the visitors to engage in floors, wall, tables or with interactive objects in a Mixed Reality setting (see Fig. 3 – *right*) or interactive malleable surfaces exploring haptics. In both cases, depicted in Fig. 3, the use of interactive Mixed Reality is applied with a similar strategy: invite the visitor “to do” in order to achieve (in a activity that can be collaborative also) an understanding of the mechanism of water circulation and concentration (each case with different level of complexity). This is a good example of learning and entertainment simultaneously.

The digital media in use in The Changjiang Civilization Museum seems more targeted to children: the graphics, lights/colors and type of interaction are more playful (for example: jumping in the interactive floor projection; see Fig. 1 - *left*), which might



be less appealing to older visitors. While in the Waterline Museum, there's an intended sobriety and, although the same technology is present (full immersive VR experience), the participation of different demographics might be achieved. Personal and cultural differences between visitors are aspects that need to be considered in further research (which will include interviews to visitors).

In terms of digital presence online – in each museum's website, we have identified that, in both cases, English language information is scarce.

## 6 Final Considerations

There are similar digital technologies and tools present in both case studies, but different forms of integrating them in each museum's scale, context and mission. The importance of cultural tourism and the diversity of potential visitors, justifies attention to multilingual information in museums websites and other online platforms.

The importance of educating for a water sustainable life reinforces the value of incorporating water museums with engaging experiences that attract the audiences and motivates them to actively participate in their mission. Taking into account that today's museums audiences are technological driven, in particular young audiences, designing pleasurable and educational experiences with digital media appears to be a promising direction. Interactive and immersive experiences seem to carry large potential and interest by museums and their audiences.

Further research should follow, to identify *in situ* and in articulation with curators and visitors, new findings. And future research spectrum will encompass other water museums.

**Acknowledgments.** We wish to thank: Eriberto Eulisse, Coordinator of the WAMU-NET; Philippe Pypaert, Programme Specialist for Natural Sciences UNESCO Office in Beijing, China; the Waterliniemuseum Fort bij Vechten, in Bunnik, The Netherlands; The Changjiang Civilization Museum, Wuhan, China; Professor Luís Chicharo from UNESCO Chair in Ecohydrol-ogy of University of Algarve, Portugal; and also the Research Centre for Architecture, Urbanism and Design, Lisbon School of Architecture, University of Lisbon, Portugal.

## References

1. Global Water Museum Network. <https://www.watermuseums.net/>
2. Mortensen, M.F.: Designing immersion exhibits as border-crossing environments. *Mus. Manag. Curatorship* **25**, 323–336 (2010)
3. Malraux, A.: *La Musée Imaginaire*, Gallimard, Paris (1996). [orig. 1947]
4. Rivière, G.H.: *L'Ecomusée, Histoire, Définition, Organisation*. MNATP GHR Archives, Paris (1978)
5. Shelton, A.: Critical museology: a manifesto. *Mus. Worlds Adv. Res.* **1**, 7–23 (2013)
6. Martínez-Sanz, R.: Estrategia Comunicativa digital en el museo. *El profesional de la información* **21**, 391–395 (2012)
7. Falk, J.H., Dierking, L.D.: *The Museum Experience Revisited*. Left Coast Press, Walnut Creek (2013)

8. Myrczik, E.P.: Satisfying personal needs at the museum: the role of digital technologies. *MedieKultur* **57**, 176–196 (2014)
9. Light, B., Bagnall, G., Crawford, G., Gosling, V.: The material role of digital media in connecting with, within and beyond museums. *Convergence* **24**, 407–423 (2018)
10. Janes, R.R.: The mindful museum. *Curator* **53**, 325–338 (2010)
11. Watkins, C.: *The Young and the Digital*. Beacon Press, Boston (2008)
12. Da Costa, B., Kinsell, C., Nasah, A.: Millennials are digital natives? An investigation into digital propensity and age. In: Information Resources Management Association (ed.) *Digital Literacy: Concepts, Methodologies, Tools, and Applications*, vol. 1, pp. 103–119. IGI Global, Hershey (2013)
13. Black, G.: Remember the 70%: sustaining ‘core’ museum audiences. *Mus. Manag. Curatorship* **31**, 386–401 (2016)
14. Grenier, C.: *La Fin des Musees?*. Editions du Regard, Paris (2013)
15. Norman, D.: *Emotional Design*. Basic Books, New York (2004)
16. Norman, D.: *The Design of Everyday Things*. Basic Books, New York (2013)
17. Douek, J.: Music and emotion: a composer’s perspective. *Front. Syst. Neurosci.* **7**, 82 (2013). <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3832887/>
18. Lessa, J.: Dimensão Visual em Música Clássica. In: Raposo, D., Neves, J., Pinho, J., Silva, J. (eds.) *Investigação e Ensino em Design e Música*, pp. 269–278. Edições IPCB, Castelo Branco (2017). <http://convergencias.ipcb.pt>
19. Design, Use, Build Vimeo Channel: Nathan Shedroff Talk - Designing Meaningful Experiences. <https://vimeo.com/120207557>
20. Smeds, K.: On the meaning of exhibitions – exhibition epistèmes in a historical perspective. *Des. Learn.* **6**, 50–72 (2012)
21. Styliani, S., Fotis, L., Kostas, K., Petros, P.: Virtual museums, a survey and some issues for consideration. *J. Cult. Herit.* **10**, 520–528 (2009)
22. Abawi, D., Arcos, J., Haller, M., Hartmann, W., Huhtala, K., Träskbäck, M.: A Mixed Reality museum guide: the challenges and its realization. In: *Proceedings of the 10th International Conference on Virtual Systems and Multimedia, VSMM 2004* (2004)
23. Sardo, J., Pereira, P., Veiga, R., Semião, J., Cardoso, P., Rodrigues, J.: Multisensorial portable device for Augmented Reality experiences in museums. *Int. J. Educ. Learn. Syst.* **3**, 60–69 (2018)
24. Dal Falco, F., Vassos, S.: Museum experience design: a modern storytelling methodology. *The Des. J.* **20**, S3975–S3983 (2017)
25. Kočí, J.: What do czech ninth-graders drink to stay hydrated? *Acta Salus Vitae.* **6**, 23–30 (2018)



# A Human-Computer Interaction Framework for Interface Analysis and Design

Sónia Rafael<sup>1(✉)</sup>, Victor M. Almeida<sup>1</sup>, and Marco Neves<sup>2</sup>

<sup>1</sup> Faculdade de Belas-Artes, Centro de Investigação e de Estudos em Belas-Artes (CIEBA), Universidade de Lisboa, Largo da Academia Nacional de Belas-Artes, 1249-058 Lisbon, Portugal

{s.rafael, v.almeida}@belasartes.ulisboa.pt

<sup>2</sup> CIAUD – Research Center for Architecture, Urbanism and Design, Lisbon School of Architecture, University of Lisbon, Rua Sá Nogueira, Pólo Universitário, Alto da Ajuda, 1349-055 Lisbon, Portugal  
mneves@fa.ulisboa.pt

**Abstract.** Digital device ubiquity increased the need for HCI's analysis. The establishment of a structured body of knowledge is essential for the development of more efficient interfaces and interaction experiences.

The methodical analysis of interaction's possibilities requires models fostered by robust classification systems. Its development is vital for the establishment of a common language between researchers and designers, towards praxis and innovation (clarifying the relationships between entities and interaction solutions).

We propose an HCI Model, supported in agents positioning neutrality, as well as the required concepts and processes' deconstruction.

HCI is constructed on a succession of goal-related communicational events, here termed Interactive Processes. We propose an analytical classification system determined by the relation that Interactive Processes establish with each other within an HCI, as well as the ones established between the Interactive Processes of different HCIs, and also by the number of Interactive Processes' Conjugated Pairs developed within an HCI.

**Keywords:** Human-computer interaction · Classification systems · Interaction design · User interface design

## 1 Introduction

We propose a functional representation model that encompasses both the analysis and the development of HCIs, adopting a research-centred approach and conceptualization with a focus on interactive processes.

Parting from a classic conception of interfaces, recapped by the simple intermediation between humans and machines, towards an evolutionary perception of transparent interfaces capable of increasingly spontaneous and natural relationships, one focus on the need to overcome the human dominance paradigm that contaminates HCI theory. The proposed framework is backed by a top-down model with the following hierarchical levels:

- (1) HCI incorporates Interactive Processes;
- (2) Interactive Processes are developed through the use of Modalities;
- (3) Modalities support themselves in Information Dimensions.

## 2 Classification: A Requirement

The methodical analysis of interaction's possibilities between humans and computerized systems requires models fostered by robust classification systems. Its development and usage are vital in the establishment of a common language between researchers and/or developers, towards praxis (merging practice and theory) and innovation (clarifying the relationships between entities and interaction solutions) [11].

Classification assigns entities into groups or classes from a similarity point of view, searching for the smallest variations inside each group and the maximum variations between different groups, establishing itself as a prerequisite for advanced conceptualization, reasoning, language, or data analysis [2].

## 3 Classical HCI Models: The Human Dominance Paradigm

Interfaces are mediators at the core of the bidirectional communication in which users and computerized systems engage, requiring from both the comprehension of the processes and communication mechanisms between the parts that are intrinsic to the interface, and the comprehension of the information received from the counterpart [5].

Irrespective of human development or whatever technological constraints might exist at the time of their inception, interfaces must undertake the intermediate role between the two agents, as each of them unavoidably hold incomplete information about the other and his or its natural communication ways.

The development of increasingly intelligent interfaces, capable of promoting interaction's efficiency and naturality, and to congregate the benefits of adaptability, context suitability and support for task development, is a well-established HCI's goal [8], as is the transparency of the interface (as an immediacy feature; i.e., the absence of mediation or representation, towards more natural and realistic interactions) [3].

It's essential to bear in mind the interface's structure and goal, establishing the relationship between the user and the functional core of the computer system, through the integration of software and hardware [9], as portrayed in Nigay's fundamental HCI model (Fig. 1).

The interface is positioned as a mediator of relations, but the model's simplicity doesn't reveal the nature of the processes occurring between the two agents. Hence, [9, 10] propose an extended model – the Pipe-Lines Model (Fig. 2).

The Pipe-Lines Model highlights a functional equivalence between the transformations carried out by the user and the ones carried out by the computer system, representing the interpretation function and the rendering function (the former supported by the input interface and the latter by the output interface).

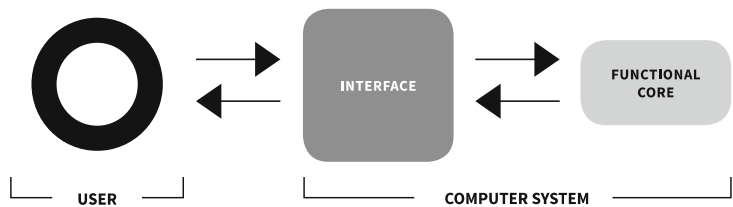


Fig. 1. Relation between a computer system and a user

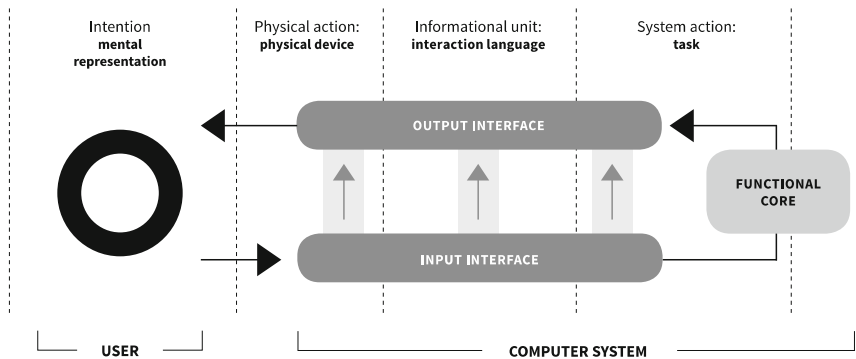


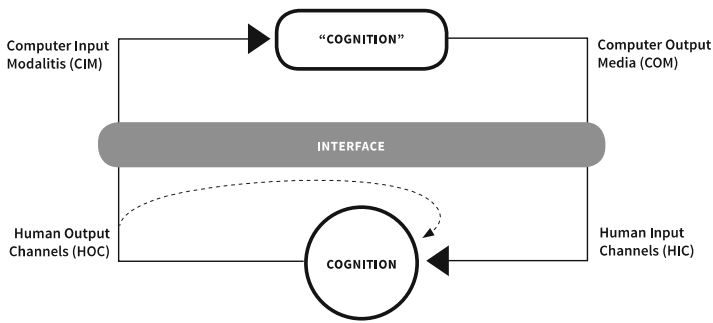
Fig. 2. Pipe-Lines Model for HCI

Nevertheless, the interface is envisioned in the restricted world of the computer system and [9, 10] don't consider the associative and congregational character of the several input and output channels used by both the computer system and the user; i.e., the interface is considered a computerized element. Additionally, the positioning of each agent establishes conceptual role differences for the two agents of the HCI: the user emits a request that is acquired and processed by the computer system, and the computer system provides an answer to the user. Hence, the action sequence puts the user in control of the HCI and the functional nucleus of the computer system has a reactive role.

Another classical example of an HCI model is the [12] general model for the analysis of human-computer communication processes (Fig. 3).

A visual analysis of the model fosters the idea of not being one so strongly anchored in the human's standpoint, as it appears not to give him a complete domain of the interaction. It presents a functional and cognitive parallel between the computer and the human, with an interesting schematic positioning choice of the computer over the human.

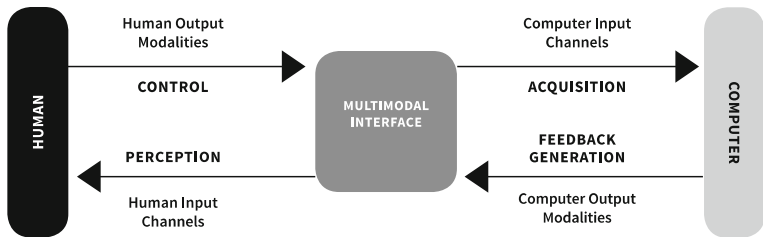
But the model's description deflates those impressions. The HCI is prompted with a human's request action and is followed by the computer bestowed answer [12]. HCI conception remains as an event-sequence in which the human controls and manipulates the computer and the highlighted processes (perception and control) develop at the human's level.



**Fig. 3.** A model for the identification of basic processes in human-computer interaction

Conversely, and notably, it is argued in [12] that similar cognitive or computational processes occur within both agents and it is declared that a human’s process perspective is adopted in the analysis. Also, of note, the interface is no longer presented as a computer element.

The introduction of computer processes’ perspective [6] expands the model’s scope (Fig. 4), highlighting the occurrence of acquisition and feedback as symmetric processes of control and perception.



**Fig. 4.** The multimodal human-computer communication process

Symmetric, although not equivalent, as the different processes terms suggest. Moreover, the noted differences direct us to a human’s dominance, with the request being inevitably part of the user’s prompted process (the input flow) and the response as part of the computer’s prompted process (the output flow).

Nevertheless, some of the terms adopted in [6] further the functional and cognitive proximity between the acquisition and the emission processes developed by the human and the computer (e.g., in [12] we saw the concepts of *human output channels versus computer output media* and in [6] we see the concepts of *human output modalities versus computer output modalities*).

The human dominance paradigm in HCI analysis is common in academic research but the degree to which it is portrayed isn’t homogeneous or undisputed.

In [4], there is the stipulation of equal importance to human and computer in HCI model analysis (Fig. 5), with both user and computer information transmission,

acquisition and interpretation processes receiving identical label. It’s a conceptual decision that promotes the perception of equivalent roles and functional capabilities.

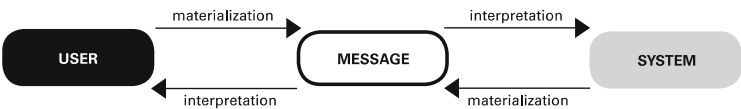


Fig. 5. User-system multimodal dialog

Nonetheless, the classic western world’s “top-to-bottom and left-to-right” reading process promotes the idea of the user requesting and the computer answering, highlighting a residual bias of the human initiating and dominating the HCI.

The academic human dominance paradigm in HCI arises from historical and contemporary technological and perceptive limitations of computer systems (as if academic analysis capitulated to engineering constraints); but academic analysis should disturb conceptual and technological implementation options, and challenge contemporary psychosomatic and sensorimotor limitations of both humans and computers.

4 Towards a Neutral Positioning HCI Model

The classic Shannon-Weaver communication model (Fig. 6) reveals the basic concepts of technological communication processes and should be adopted in HCI analysis [7].

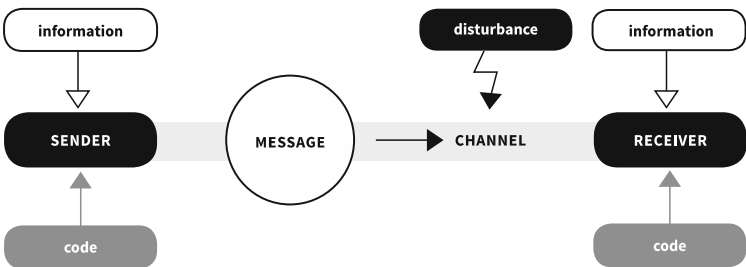


Fig. 6. Shannon-Weaver Model

The Shannon-Weaver Model carries an immediate advantage over classic HCI models: the use of non-restrictive concepts, evading the automatic attribution of a sender and a receiver role to, respectively, the Human Agent (HA) and the Computer Agent (CA). The CA is defined as a computerized system capable of assuming, at least, one of the following interaction roles:

- (i) the agent that acquires information, conveying a request, from an external entity and processes it (whether it came from an HA, from another CA, from the

environment, from an animal, etc.), and, subsequently, emits information back to the external entity as an answer;

- (ii) the agent that emits information, conveying a request, to an external entity and, subsequently, acquires and processes the information that the external entity emits towards him as an answer.

A fully advanced CA has the ability to engage on both of the described interaction roles.

Additionally, being originally conceived to describe the communication processes developed between humans, the Shannon-Weaver Model doesn't discriminate between agents.

However, this model reflects the vision of a classic unidirectional communication process, not revealing the dynamics of an interaction that occurs in a sequence of two events (request and answer). An immediate restructuring option [11] was the representation of a two-flow sequence experience (Fig. 7).

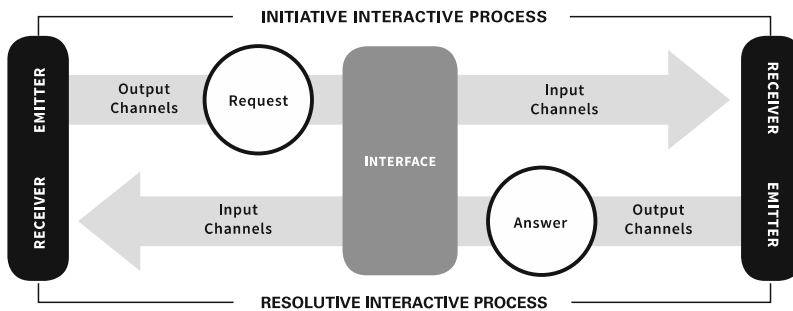


Fig. 7. Basic HCI model

The Basic HCI Model's positioning neutrality manifests itself in the refusal of role assignments to HA and CA, preventing the supposition of an HA's control over the developed HCI. It conveys the notion that either agents are able to present a request and receive the expected answer or to acquire a request and present an answer.

HCI is the product of a sequence of communicational events, termed Interactive Processes (IP), occurring in opposite directions:

1. First, the Initiative Interactive Process (IIP), where the emitter presents a request (resorting to one or more output channels) that is acquired by the receiver (resorting to one or more input channels);
2. And next, the Resolutive Interactive Process (RIP), where the receiver of the previous request takes the role of an emitter and presents an answer (resorting to one or more output channels) that is acquired by the original emitter that, now, takes the role of a receiver (resorting to one or more input channels).



4.1 Simple and Complex HCIs

A Simple HCI is one that accomplishes its interaction’s goals through the development of a pair of a single IIP and a single RIP, termed Interactive Processes’ Conjugated Pair (IP’CP); i.e., a sequence of a single request event by the emitter agent followed by a single answer event promoted by its counterpart (an HCI such as the one portrayed in Fig. 7). A Complex HCI (Fig. 8) requires the development of two or more IP’CPs; i.e., the interactions goals aren’t immediately achieved through the development of a single request and answer sequence, requiring the occurrence of a back-and-forth message exchange flow sequence.

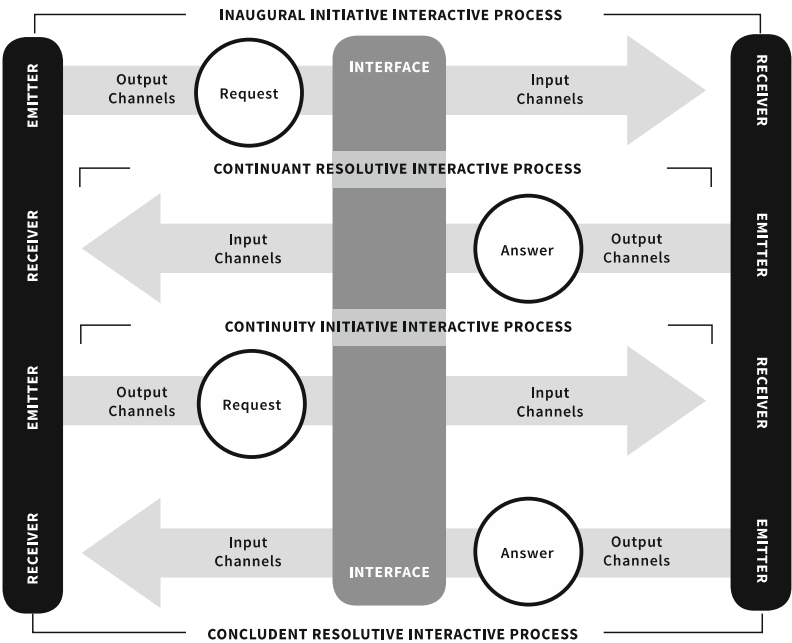


Fig. 8. Complex HCI, comprising two IP’CPs

During this exchange flow sequence of IPs, interaction’s goals will be step-by-step erected, with each of the involved IP’CPs accomplishing a set of functional sequenced goals. The first IIP, termed Inaugural IIP, sets the HCI in motion, but the RIP that follows, termed Continuant RIP, isn’t sufficient to accomplish the interaction’s goals.

Thus, the emitter of the Inaugural IIP presents another or a sequence of several others IIPs, each termed Continuant IIPs. The receiver of the Inaugural IIP follows with the same number of RIPs, all of which are termed Continuant RIPs, except for the last that is termed Concluent RIP.

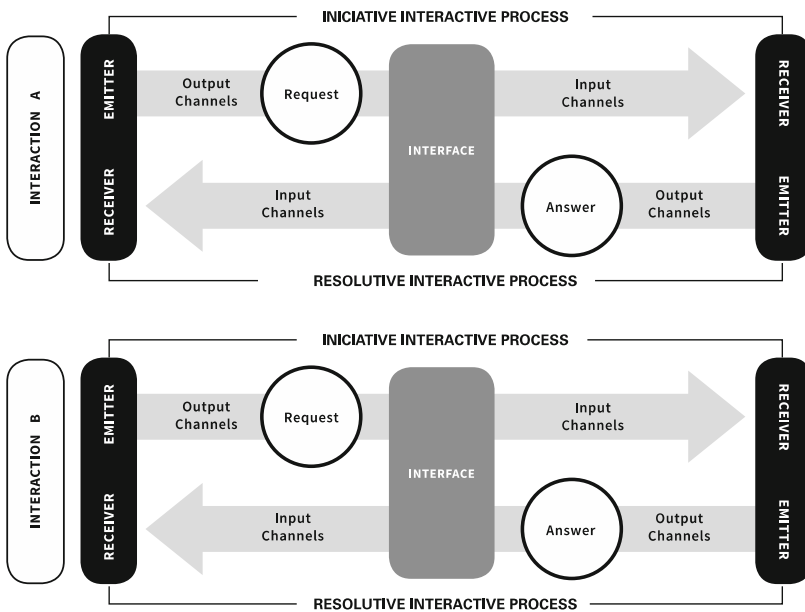
## 4.2 Complex HCI versus Sequence of Autonomous HCIs

Digital devices ubiquitous reality promotes an ever-growing HCI continuous routine. Hence, an HCI is frequently followed by another, and another, and so on, fostering the need for constant analysis of the actual contexts in which HCI is being developed.

First, a reminder: all that glitters is not gold. A sequence of several IP'CPs between an HA and a CA isn't necessarily a single Complex HCI (such as the one portrayed in Fig. 8) and is frequently a sequence of autonomous HCIs, with each promoting the achievement of its own interaction's goals. Such a sequence of autonomous HCIs could either integrate Simple HCIs or Complex HCIs, or even an assortment of both.

Additionally, with the recognition of the possibility of total equivalence between the HA's and the CA's cognitive and technical abilities in HCI development (e.g., with either being able to initiate an HCI, or to define the interaction's goals), two possibilities should be considered:

- (1) A sequence of autonomous HCIs initiated by the same agent (Fig. 9);



**Fig. 9.** A sequence of two autonomous Simple HCIs initiated by the same agent

- (2) Or a sequence of autonomous HCIs initiated by different agents.

If the autonomous HCIs of the sequence are initiated by different agents, we still need to discern between:

- (1) A full-fledged IP's autonomous development (Fig. 10);
- (2) Or a partial entanglement of IP's, with IPs execution overlap (Fig. 11).

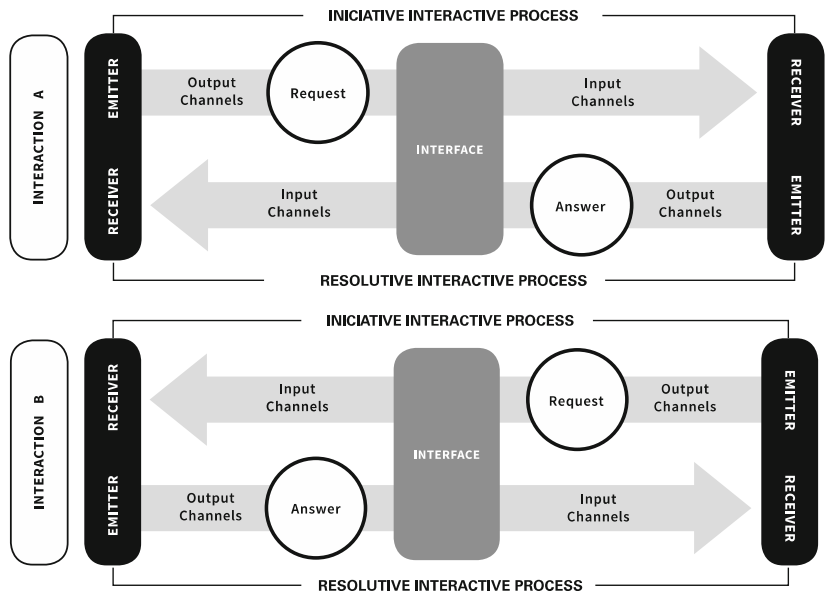


Fig. 10. A sequence of two autonomous Simple HCIs initiated by opposing agents

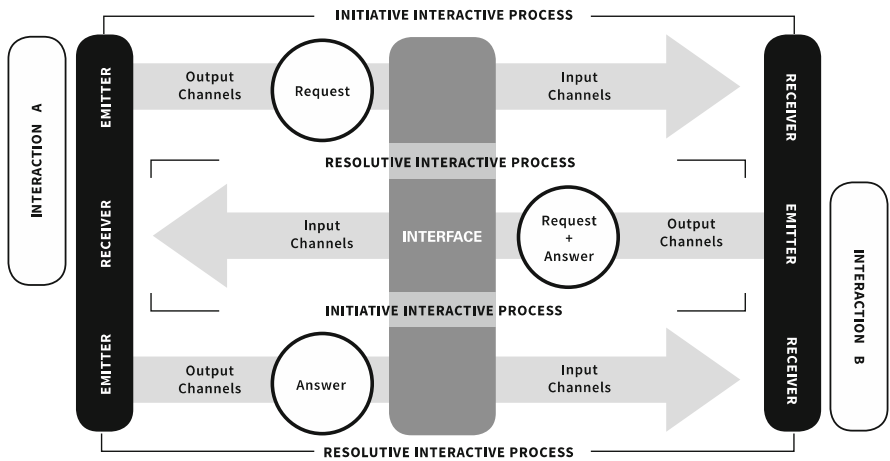


Fig. 11. A sequence of two autonomous entangled Simple HCIs, with IPs overlap

Both possibilities portray the occurrence of two autonomous HCIs, with each one possessing its own set of interaction's goals, but the entanglement in the latter reveals the possibility for the assumption of two simultaneous roles in a single communicational event; i.e., a message takes the simultaneous role of an answer and of a request.

## 5 Conclusion

HCI has long parted from a strictly human's initiative set of events. The emergence of AI, coupled with quantic computing, sets the prospect for computers' playfield leveling, and a clear reminder of humans' biological weaknesses. It's not a question of *if* computers will be our equals (or even surpass us), but more of a *when* question.

This paper presents an HCI Neutral Positioning Model, parting from the prevailing human dominance paradigm, and is part of an ongoing research effort for the development of HCI analysis tools, towards a comprehensive Multimodal HCI framework.

The proposed model focus on Interactive Processes, specifically on the relations they establish internally and externally, recognizing their role as the fundamental blocks of the HCI structure.

## References

1. Bailey, K.D.: Typologies and Taxonomies: An Introduction to Classification Techniques. Sage University Paper Series on Quantitative Applications in the Social Sciences, Series No. 07-102. Sage, Thousand Oaks (1994)
2. Bailey, K.D.: Methods of Social Research. FreePress, New York (1994)
3. Bolter, J.D., Grusin, R.: Remediation: Understanding New Media. The MIT Press, Cambridge (2000)
4. Caschera, M.C., Ferri, F., Grifoni, P.: Multimodal interaction systems: information and time features. *Int. J. Web Grid Serv.* **3**(1), 82–99 (2007)
5. Chignell, M.H., Hancock, P.A.: Intelligent interface design. In: Helander, M. (ed.) *Handbook of Human-Computer Interaction*, pp. 969–991. Elsevier Science Publishers, Amsterdam (1988)
6. D'Ulizia, A.: Exploring multimodal input fusion strategies. In: Grifoni, P. (ed.) *Multimodal Human Computer Interaction and Pervasive Services*, pp. 34–57. IGI Global, Hershey, New York (2009)
7. Emsenhuber, B.: Scent marketing: making olfactory advertising pervasive. In: Müller, J., Alt, F., Michelis, D. (eds.) *Pervasive Advertising Human-Computer Interaction Series*. Springer, London (2011)
8. Maybury, M., Wahlster, W.: Intelligent user interfaces: an introduction. In: Maybury, M.E., Wahlster, W. (eds.) *Readings in Intelligent User Interfaces*. Morgan Kaufmann Publishers (1998)
9. Nigay, L.: Conception et modélisation logicielles des systèmes interactifs: application aux interfaces multimodales. [Software design and implementation of interactive systems: a case study of multimodal interfaces]. Ph.D. thesis. Université Joseph Fourier – Grenoble 1 (1994)
10. Nigay, L., Coutaz, J.I.: Multifeature systems: the CARE properties and their impact on software design. In: *Intelligence and Multimodality in Multimedia Interfaces*. AAAI Press (1997)
11. Rafael, S.: Para uma Taxonomia da Multimodalidade na Interação Homem-Computador. Proposta Aberta de Classificação Pluridimensional. [Towards a taxonomy of multimodality in human-computer interaction. An open and pluridimensional classification proposal]. Ph. D. thesis. Lisbon University of Lisbon, Portugal (2015)

12. Schomaker, L., Nijtmans, A.J., Camurri, F. Lavagetto, P., Morasso, C., Benoit, T., et al: A taxonomy of multimodal interaction in the human information processing system. Multimodal Integration for Advanced Multimedia Interfaces (MIAMI). ESPRIT III, Basic Research Project 8579 (1995)
13. Shneiderman, B.: Designing the User Interface: Strategies for Effective Human-Computer Interaction. Addison-Wesley Publishing Co., Reading (1987)
14. Zaphiris, P., Ang, C.S. (eds.): Human Computer Interaction: Concepts, Methodologies, Tools, and Applications, xxxv–lvi. Information Science Reference, New York (2009)



# Collaboration: Critical Roles of Academia-Business Partnerships and Challenges the Workforce Must Face

Sara Antunes<sup>(✉)</sup> and Rita Almendra

REDES – Research and Education in Design, CIAUD – Research Centre for Architecture, Urbanism and Design, Lisbon School of Architecture, University of Lisbon, R. Sá Nogueira, Alto da Ajuda, 1349-063 Lisbon, Portugal  
sara.a.antunes@campus.ul.pt, almendra@fa.ulisboa.pt

**Abstract.** During the last few decades successive technological advances have brought innovation that facilitates our day-to-day life but also induces business transformation, bringing employment instability and constantly changing required skills. The intent of this paper is to help understanding what challenges workforce must face, which core skills must be mastered and what has been done so far. Reflecting about past challenges, present difficulties, and solutions found along the years may help us in preparing for the future. We first reflect on the changes caused by increased technological advances in every sector of activity during the last decades; then we analyze existing approaches in defining future challenges, present and future critical skills and solutions implemented by policy makers, universities and industry. We also analyze the most common barriers to that implementation, how to overcome them, and how may we prepare to those future challenges.

**Keywords:** Collaboration · Academia-business · 21<sup>st</sup> century · Education · Skills · Economic growth

## 1 Introduction

In the last decades successive technological breakthroughs have occurred, causing profound changes in our societies and in our economies, transforming the way we live, learn, work and do business.

In our modern every-day life, we are constantly using, and surrounded by, some form of technology. In school, at home or at work, many of our activities are increasingly dependent on the use of diverse forms of computing devices or machinery. In general, the effects of these technology-related changes have brought a beneficial contribution:

“The diffusion of digital technologies has encouraged a higher level of connectivity between people, opening new opportunities for meaningful social activism and effective peer-to-peer collaboration... People, ever more connected, can collaborate to improve their lives” [11].

But the non-stop and increasingly fast technological advances also induce disruptive transformation on businesses and professions, creating new jobs, changing

traditional ones, and even eliminating some, thus occasionally having a negative impact on employment and putting pressure on economies. That kind of business and professions transformation also requires the workforce of today to constantly adapt to the changing business needs, by acquiring and updating the required critical skills.

The future workforce, the students graduating every year from Higher Education Institutions (HEI), being in some way more familiar with new technologies than previous generations, have less difficulties in dealing with that change; but on the other hand, they need to face the challenge of entering an almost new world, a world where they need not only keep on learning, but especially apply the acquired knowledge in carrying out their jobs. The bigger the gap or divide between the education and working environments, the greater that challenge will be, hence the important role that a closer connection between industry and universities represents.

As one of several generic approaches within a PhD thesis where we study how to prepare future designers for increasingly collaborative workplaces, this article analyzes the challenges faced by the workforce of today and tomorrow, the importance of preparing future graduates to a real-world multidisciplinary environment and the role played by business-university collaboration in that process. It briefly describes types and levels of already established collaboration processes, in developed and developing countries. It lists some existing barriers to its implementation and improvement, and why they are harder to overcome in less developed nations or where Higher Education (HE) institutions-industry collaboration is not yet a common practice. And it further suggests a path to initiate and gradually improve those relationships.

## 2 Understanding Collaboration

In the 21<sup>st</sup> century economies have become more and more knowledge-based and the need for the education of highly skilled graduates, ready for the challenges of a global world, has greatly increased. “Today, much success lies in being able to communicate, share, and use information to solve complex problems, in being able to adapt and innovate in response to new demands and changing circumstances, in being able to command and expand the power of technology to create new knowledge” [1].

“Universities call on technology and curricula to drive the next generation of innovation” [12].

To meet their needs, successful businesses often collaborate with several universities and there are also universities collaborating with each other to provide better prepared graduates; but to keep up with the needs of modern economies that will likely demand employees with a broad and continuously changing skillset, an enterprise-like education concept, based on collaborative education and collaborative research needs to spread and exist in every higher education institution.

In *A Review of Business–University Collaboration* [2], Professor Tim Wilson refers to universities as being “an integral part of the skills and innovation supply chain to business” (preface) and stresses the fact that this supply chain multi-dimensional attributes (sustainability, strength, quality and resilience) may only be guaranteed by close collaboration between business and universities.

We have stated that modern global business has a knowledge-based nature, thus characterized by a growing need of knowing how to communicate, share and use information, and that business success, which in turn promotes economic growth, depends on the capacity of universities to supply highly skilled graduates; when describing the skills those graduates need, we will recognize that among those required skills lies one of utmost importance – the ability to quickly adapt to diverse work environments that will most likely have a multidisciplinary and collaborative nature.

We also recognize the need for business and universities to collaborate with each other. Collaboration is therefore seen as a key feature that is crucial both in the business-university relationship and in the multidisciplinary work environments of today.

But what is in fact collaboration? In an effort to understand and define collaborative design, Kvan [3] analyzes the Latin roots and meaning of the word ‘collaboration’, as defined in the “Oxford English Dictionary: ‘to co-operate, especially in literary, artistic or scientific work’ deriving from the Latin words ‘*col labore*’, to work alongside one another” [3]. Kvan proceeds his own pursue in defining collaboration – “can be thought of as a joint problem solving. It means working with others with shared goals for which the team attempt to find solutions that are satisfying to all concerned.” [3] - and alerts readers for the distinction between collaboration, cooperation and coordination. Using Mattessich and Money definitions in *Collaboration: What makes It Work* [4], stressing that collaboration requires a greater commitment to a common goal and a higher level of trust, as well as it implies an increase in risk.

In accordance with those definitions, the relationships that characterize cooperation are informal, as opposed the formal relationships that exist in coordination and to the even stronger and widely spread relationships in collaboration. In cooperation there is not a commonly defined mission, while in coordination a compatible mission is assumed, and in collaboration there is definitely a commonly accepted commitment to a defined mission.

As far as structure and authority, similar guidelines apply: structure is undefined in cooperation, where information is shared as needed and authority, as well as resources, is retained by each organization, risk being low or inexistent. In coordination, structure involves establishing communication channels, dividing roles, and sharing resources while authority is retained by each organization. On the contrary, in collaboration, the authority rests or is defined by the collaborative structure, increasing the risks [3, 4].

In *Teaching Collaboration Skills from Cradle to Career* [5], a similar approach is that of Emily Lai, Director of Formative Assessment and Feedback for Pearson, who says we all have a general idea of what collaboration is, in its basics: it could be simply defined as the act or capacity of working with others to achieve a common goal.

Emily Lai further considers that collaboration may be composed of ‘Interpersonal communication’, ‘Conflict resolution’ and ‘Task management’. The first refers to communication between team members, either verbally or non-verbally; the second describes the ability to efficiently deal with any conflict within the team having in mind its common goals, and lastly, task management includes defining goals and tasks and managing how the team accomplishes those tasks to attain the defined goals [5].



In our constantly changing world, collaboration is then a crucial tool for organizations and also an essential part of the future workforce skillset; what can be done to encourage collaboration, both at organizational and individual levels?

### **3 The Roles of Education and Industry in Globally Competitive Economic Societies**

“Ideally, every full time undergraduate student should have the opportunity to experience a structured, university approved undergraduate internship during their period of study” [2] – Professor Wilson says. Do existing collaborations include those opportunities? Are they similarly used in most countries and diverse knowledge areas?

While it may appear that in science-related areas of knowledge different types of work-like experiences are more commonly used than, for instance, in arts, we will see that the real difference is more closely connected to the technological and economic development conditions of the country itself – developed countries having a longer and deeper tradition of introducing those work experiences than developing countries. For those situations where experiences like internships, apprenticeships and placements are less common, perhaps other types of working experiences could be tried with relative success, even if implemented only within their academic environment.

Let’s revise the challenges faced by today’s and tomorrow’s workforce, and then visit some existing academia - HEI collaborations and what benefits both sides may get.

#### **3.1 Challenges Faced by the Workforce**

##### **3.1.1 Adaptation to the Work Environment**

As previously outlined, while technology is, for the existing workforce, what originates the stronger need to update their skills and acquire new ones, for recent graduates the biggest challenge is instead their entrance in the working arena, varying a little with the path they follow.

In fact, after concluding their academic career, HE students follow different paths to initiate their professional careers. Some will start their own businesses, others will join existing industry organizations; a reasonable number of them will be working in multidisciplinary and multi-generational groups requiring a variable period of time to adapt.

Indeed, adaptation is always needed in any kind of working environment, as they are leaving the university world and entering the real day-to-day working life; because their learning path is usually focused in specific fields of knowledge, and multidisciplinary working experiences introduce a level of collaborative need that they were not used to face in university, they need some time to adapt.

Even in situations where they join a company which has a specific core business, they will be required to collaborate with others in some level of diversity environment.

As an example, imagine a graphic designer joining an existing ‘design-only company’, in which there are no professionals from fields other than design; he or she will still need time to adapt; adapt to that new (working) life and also to their design colleagues who will probably have different specific design backgrounds, having in

common not much more than basic design concepts. Consider a design firm that has its core business focused in fashion design: it will probably need designers from other specific fields, such as graphic, multimedia, web, product and many others; most will know little or nothing about each other's very field-focused concepts and methods.

Transposing the situation to another possible scenario, a large health services provider will include not only doctors and nurses, but a large variety of professionals with diverse background and fields of knowledge, to include designers of several fields, such as communication, web, product, etc.

They will all need a certain amount of time to learn a common language, how to work together in a common task or project; that period may vary, depending on several factors, one of them being the level of previous experiences each of them might have had in working with people coming from other fields. Adaptation will probably take longer for a professional that had just got his university/college degree and suddenly finds himself working with a few colleagues from a very different area, as for instance a newly graduated graphic designer just joining in an IT company.

### 3.1.2 Getting the Right Skills

In *21<sup>st</sup> Century Skills for Students and Teachers* [1], a bridge is established between traditional education models (focused on learning identified content for subject areas) and the desired 21<sup>st</sup> learning framework that would still include the traditional subjects while emphasizing several core areas, ranging from civic, health, environmental and visual literacies to global awareness. It is important to note that global awareness is there defined as “the need for students to be able to learn from, and work collaboratively with, individuals from diverse cultures, religions, ideologies, and lifestyles, in an environment of openness and mutual respect” [1].

It also worth to point out that the same study characterizes communication and collaboration (that can be learned through a variety of methods) as critical learning and innovation skills for the 21<sup>st</sup> century. It then refers that collaborate with others includes to be able to work effectively with diverse teams to accomplish a common goal, showing respect, flexibility and will to compromise, while valuing individual contributions and assuming shared responsibility for collaborative work.

This ‘ability to collaborate’ is again referred to as a crucial capacity, when the authors describe other categories of skills for the 21<sup>st</sup> century—Life and Career Skills and Information, Media and Technology Skills—, stressing out the diversity that characterizes today's global nature of learning and working environments [1].

The above-mentioned needed skills are then reasonably identified and include the ability to use and share information through communication, having creative thinking and an open-mind, being capable to adapt to new and evolving environments and ready to take advantage of the power brought by the digital era: “The North Central Regional Education Laboratory and the Metiri Group have also identified a framework for 21<sup>st</sup> century skills, which is organized into four categories: digital age literacies, inventive thinking, effective communication, and high productivity” [1].

We cannot be sure of what the labour market will look like in the future decades and are, consequently unable to predict which will be the ideal employability skills; what we know is that the pace at which labour market evolves is strongly connected to

technology advances that grow almost exponentially and cause disruptive impact on jobs.

Not long ago, the concept of a single, field-focused education leading to a working career in a certain specific activity carried out on a typical 9-5 time schedule was broadly accepted as a standard and a full pension expected everyone at the end of that easily predicted working journey; some kind of pension is still expected today, but not as certain and predictable, as a single full working career has become uncommon; the workforce is now multi-generational as people keep working until an older age, multi-cultural as a result of globalization and the agility brought by easier travelling; jobs and organizations have become fluid as disciplines are converging due to the increasing connectivity brought by technology; in the uncertainties of today, individuals work on a full time basis, being constantly connected regardless where they are; moving from project to project, they need to acquire a diverse skillset that includes collaboration, flexibility and resilience to maintain ability to respond to continuous change.

“Technological growth, and the accompanying changes in business models, make the continuous adaptation of skill sets absolutely fundamental for successful participation in the labour market” [9].

In a very interesting evidence-based approach to investigate what will the UK future jobs will look like in 2030, Siemens HR Director and UKES Commissioner Toby Peyton-Jones examines the trends that are shaping the future and outlines some possible scenarios that may have implications such as [9]:

- Increasingly agile and hybrid core business skills, based on collaborative business models and increasing project-based employment, as well as entrepreneurship as a lifestyle;
- Converging technologies and disciplines causing business opportunities to make innovation happen at a faster pace and where the multi-national and multi-disciplinary nature of the working teams demand a crucial ability to collaborate;
- Automation brought by Information and Communication Technologies (ICT) influences all sectors of activity, transforming online education and creating new jobs that may be carried out remotely by a so-called virtual workforce — which mean that knowledge in ICT and sciences is a basic skill for innovation.

### **3.1.3 How and When Are the Required Skills Acquired**

We know the essential requirements for communication to take place include an emitter, a receiver and a common language; the first described component of collaboration (interpersonal communication) would then require that a common language (verbal or non-verbal) must exist, to allow team members to collaborate.

That might not always be the case, when newly graduates join a multidisciplinary team. Even among professionals with similar backgrounds the use of specific technical terminology may initially impair the desired level of communication, which in turn jeopardizes successful collaboration.

Similarly, to achieve desirable abilities of conflict resolution or task management, the team would require an adaptation time that may vary with several factors such as the previous collaborative experiences of each of its members, the complexity of the working environment and which collaboration skills learning tools are made available.

The answer to how and when the skills required to facilitate adaptation and quickly fulfill business needs are acquired lies closely related to the individuals previous background; a simple answer would be as early as possible, preferably during the education phase and as much work-related as it could be.

Previous collaborative work experiences might occur during undergraduate studies; in some countries, HEI often have partnerships with industry, providing placements and internships of variable duration. Among others, the US and UK examples are indicated as having a very well structured, regulated and monitored higher education, where several kinds of partnerships with industry exist and are constantly reviewed and optimized. Besides the advantages for graduates, both universities and business have their rewards. By collaborating with those education institutions, business participate in defining the curricula and internship programs that will provide graduates with adequate skills to fill their needs; in turn, universities will benefit from that collaboration, as having enterprise requirements reflected in the taught subjects will attract applicants to the courses they offer. Economy as whole will grow as a result of this synergy.

The challenges faced by current and future workforce raise further questions that need to be addressed:

What kinds of collaboration exist between academia and universities? Do those relationships help students to acquire the critical business required skills of the modern and future enterprise world and facilitate their entry in those work environments?

Where that collaboration is little, inadequate or non-existent, is it important to introduce some work-like experience within the academic journey of future graduates? Would that facilitate their entry into the real-life working world? Will that also help to provide them with the adequate skills to better fulfill their employers' needs?

## 4 Paths and Levels of Business-University Collaboration

The importance and need for collaboration between academia and industries have been recognized several decades ago; several developed countries have been implementing this collaboration and getting the benefits both for their education institutions and their industries, contributing simultaneously to the nation's economic growth.

The constantly changing economic environments of the present not only confirm the need for this collaboration to exist, but also show it has become a critical component to innovate, to be ready to face frequent events that are disruptive to the way we do business "...the rise of a global knowledge economy has intensified the need for strategic partnerships that go beyond the traditional funding of discrete research projects" [6].

The degree of business-university collaboration varies with the type and intensity of the links created in each case; it can exist for short or longer periods and be formal or informal. The desired benefits are usually the generation of skills and knowledge and the transfer of that knowledge to promote entrepreneurship. In long-term intense relationships, strategic partnerships are created; industry gets access to knowledge generated by universities and these institutions, traditionally known as teaching and researching organizations, acquire a new entrepreneurial nature, driving economic growth.

In *Promoting University-Industry Collaboration in Developing Countries* [7], José Guimón presents a typology for university-industry links, ranging from high to low intensity relationships, describing the type of interactions in each case in some detail (Table 1):

**Table 1.** A typology of university-industry links, from higher to lower intensity.

High (relationships)	Research partnerships	Inter-organizational arrangements for pursuing collaborative R&D, including research consortia and joint projects
	Research services	Research-related activities commissioned to universities by industrial clients, including contract research, consulting, quality control, testing, certification, and proto development
	Shared infrastructure	Use of university labs and equipment by firms, business incubators, and technology parks located within universities
Medium (mobility)	Academic entrepreneurship	Development and commercial exploitation of technologies pursued by academic inventors through a company they (partly) own (spin-off companies)
	Human resource training & transfer	Training of industry employees, internship programs, postgraduate training in industry, secondments to industry of university faculty and research staff, adjunct faculty of industry participants
Low (transfer)	Commercialization of intellectual property	Transfer of university-generated IP (such as patents) to firms (e.g., via licensing)
	Scientific publications	Use of codified scientific knowledge within industry
	Informal interaction	Formation of social relationships (e.g., conferences, meetings, social networks)

According to Guimón [7], as the link between industry and universities increase in intensity and relationships evolve from short-term to long-term, the mission and roles of universities also evolve from teaching to research and entrepreneurial nature.

However, as stressed by the author, “the priorities and scope of university-industry collaboration differ significantly between developed and developing countries”.

Having insufficient funding capacity, universities in developing countries are often unable to join industry in long-term innovation-related projects that would intensify their links and bring the desired mutual benefits. Relationships tend to be informal and collaboration limited to occasional participation of industry representatives in conferences held by universities and some university graduates recruited by companies for internship, staffing or consulting. Eventually that kind of relationship will improve to a more mature state, becoming more innovative and formal and including other types of

collaboration, from joint curricula development to entrepreneurship education and business incubation services.

#### 4.1 Promoting and Stimulating Industry-University Collaboration

Before analyzing what can be done to promote and stimulate collaboration between industry and academia, in terms of principles, policy or other actions, it's worth mention that most measures are harder to implement in developing countries, where the economic situation often translated by low income, implies restricted budgets that impair proper funding and adequate infrastructures. Universities will lack resources (both human and financial) to conduct adequate research projects that may attract industries, which in turn may not have enough technological capability and the financial stability needed to outsource the required innovation knowledge.

Apart from economic constraints, other barriers that will limit effective collaboration regardless the developing status, may exist in any country and these are related to the mission of each side or participant and to the benefits they expect from the process:

- Universities are usually concerned with the access to public and/or private funding (the private funds that industry may provide), and interested in sharing industries' empirical data and ultimately in enhancing teaching and reputation; industries are interested in accessing the universities innovation knowledge to complement that obtained internally by their Research & Development (R&D) departments and in influencing teaching and learning processes to later obtain high-skilled employees;
- Universities want to publish research results to enhance reputation, while industries prefer to delay that publication before having guaranteed the research-related products and/or patents; the ownership of Intellectual Property (IP) rights is also a typical hard to agree item;
- There is a conceptual difference in university and industry values that influence their approaches to innovation-related research projects; while academia is concerned with the cultural values brought about with the research, industry values most the commercial results, and the faster the better "The academic community, including students, tends to place a higher value on cultural achievement than on commercial success" [8].

Needless to point out that both sides, as well as policy makers, should foster negotiation to eliminate any mission conflict, realize the mutual benefits resulting from joint research, agree on the joint exploitation of IP rights, and focus on the provision of funding that will assure long-term partnerships.

Governments may develop regulatory policy and/or implement measures to promote or stimulate academia-business collaboration, as outlined below [7]:

- Provide public funding to R&D projects;
- Provide infrastructure such as science parks, incubators and technology transfer offices;
- Provide support services to facilitate partner search;
- Provide grants to entrepreneurs and tax-incentives to R&D projects;

## 4.2 Successful Industry-University Collaboration Examples

The ultimate desired level of business-academia collaboration is reached when both sides can establish long-term strategic partnerships and become able to promote innovation and economic growth, bringing successful transformation to industries and to the role of universities. This strategic level of collaboration is not easy to attain and according to the 2012 Science|Business Innovation Board AIBL report, “Most European academics are not engaged at all in collaboration and only a few cooperate with business to a high degree...” [6]. Giving the example of Silicon Valley as a result from more than five decades of long-term collaboration, that report indicates that some world-class research universities consider strategic collaboration a top priority, having recognized that benefits at that level include “substantial streams of external funding, enhanced opportunities for professors and graduates to work on groundbreaking research, vital inputs to keep teaching and learning on the cutting edge of a discipline and the impact of delivering solutions for pressing global challenges” [6].

As a result of a detailed analyses of several success cases where the views of both senior industry executives and university officials where the main contribution to the findings, the report in question outlines the reasons why strategic long-term partnerships are so fruitful. Most, if not all the interviewed agreed that only long-running partnerships provide the ingredients for the establishment of deep professional relationships, based on trust building, acceptance of culture differences and mutual understanding of the shared benefits. Several success cases classified in 3 categories according to the impact brought to universities are then described in detail. From all those collaboration examples we will mention just a few that seemed appropriate to illustrate each of those categories.

Partnerships that had a significant impact on teaching and learning – those that especially contribute to develop new skills for the future workforce:

- Partnership between Microsoft, Cisco Systems, Intel and the University of Melbourne, initiated in 2008. Partners, along with 60 research institutions, also involving OECD and UNESCO, were set to identify skills for the 21<sup>st</sup> century and methods to teach and assess those skills. They identified collaborative problem-solving and digital literacy as two discrete skill sets and successfully created assessment tools that were tested by 5.000 students from six countries. Results were presented at the 2012 Education World Forum and incorporated the 2015 OECD Programme for International Student Assessment.
- Partnership initiated in 1995 between the University of Art and Design of Helsinki, the Helsinki School of Economics and the Helsinki University of Technology and later the Finnish Industry. The three universities joint to create a new field of multidisciplinary study, giving students an open and innovate mindset by using collaborative cross-disciplinary problem-solving. They started a programme that was offered in any of the three institutions – International Design Business Management. The great success of the programme in promoting multidisciplinary learning led to the merger of the three institutions in the present Aalto University and attracted the Finnish industry. During the one-year programme, teams composed by multicultural and multidisciplinary students deal with real-

world problems posed by companies and present innovative solutions. Participating companies pay the university an agreed fee per each project. This programme has transformed teaching and learning while enhancing collaboration between the university and industry.

Partnerships that develop new funding for university – those from which the main result was the creation of significant funding streams to the university:

- Partnership between the Imperial College London and Imperial Innovations Group PLC. This company was initially (1986) a technology transfer office for Imperial College London that has become a subsidiary of the university in 1997. The handling of technology transfer to a separate and wholly owned subsidiary that retained the IP rights of university developed technology has attracted other industry investors; the result was a huge multiplication of funding for the university.

Partnerships that reinvent the role of the university – intend to transform the university culture and mission and intensify its role in supporting economy:

- Partnership between the University of California (UC) and now hundreds of private R&D firms – resulted from UC's Industry-University Cooperative Research Program (IUCRP), that would promote and increase collaboration between faculty, students and companies using a special kind of funding: Discovery Grants "Research partnerships with industry help speed commercialization of important new technologies in the state. From 2009–11, matching funds from the UC Discovery Grants supported partnerships between UC researcher and more than 120 California companies developing agricultural, biomedical and alternative energy technologies" [10]. These grants oblige companies participating in research projects to match the funding provided by the university.

### 4.3 Other Collaboration Perspectives

New technologies also enable collaboration between the educational service (teachers, administrators) and students, as well as their families. Improved ways to communicate allow all of them to actively and collaboratively contribute to improve the learning process, to bring innovation to the education service. The possibility the end-user possesses to bring a citizen-centered approach to the educational services is now easier to put to practice, as a result on a higher level of connectivity.

In several countries such as the US, UK, Denmark and Australia several initiatives are in place, both in public and private education sectors, like establishing design-innovation offices that encourage public engagement. By integrating citizens feedback, needs and motivation, a broader variety of views and perspectives is brought to education services. Shared goals are made easier to achieve and citizen-focused services are improved [8].



## 5 Conclusion and Proposed Practices

Advances in technology brought forms of innovation that facilitate our day-to-day life; but the technological evolution also transformed business and economies, jobs and its required skills, adding new challenges to the existing and future workforce. Education systems must adapt their methods in prepare students for their working careers which demand a broader spectrum of skills. Ideally, during their period of study, every graduate should have the opportunity to experience some work-like training where those skills could be developed. What can be done to encourage collaboration, both at organizational and individual levels, in order to improve that preparation?

By understanding what challenges today's and tomorrow's workforce must face, which core skills must be mastered and what has been done so far, by policy makers, universities and industry we conclude that those actors must engage in a level of collaboration that, among other benefits, allow students to have those opportunities to acquire the required core skillsets.

For better results, long-term strategic academia-business collaboration needs to be established and must include most HE systems where possible. That should be the ultimate goal, even where collaboration is little, inadequate or non-existent, as is it important to introduce some work-like experience within the academic journey of future graduates, to facilitate their entry into the real-life working world, and because that will also help to provide them with the adequate skills to better fulfill their employers' needs.

Do existing collaborations provide those opportunities? Are they similarly used in most countries and diverse knowledge areas? That is, in fact, the case of some partnerships that are in place, mostly in developed countries, where funding and technologically advanced companies are available and willing to collaborate with universities, sharing both the expenses and the benefits and promoting economic growth. However, even in those countries, other barriers to collaboration may limit that effort, such as the differences in mission and expected benefits of the participants. In developing countries, the main barriers are the lack of resources, both in funding and in the companies and universities capabilities to engage in innovation research projects.

A step-by-step approach is advised in those situations, where universities shall start with easier to implement ways to collaborate, and gradually build mutual trust, increase benefits for both parts, having in mind that ultimate goal – long-term strategic relationships, where the benefits for each participant and the contribution to economic growth are maximized.

As initial collaborative steps, occasional exchanges of staff between and industry may be established (inviting company executives to teach in the universities and professors to participate in company events). A group of universities may also engage in multidisciplinary projects where a mixed group of students tries to solve a real challenge posed by an invited industry or company.

## References

1. Pacific Policy Research Center: 21<sup>st</sup> century skills for students and teachers. Kamehameha Schools: Research & Evaluation Division, Honolulu (2010)
2. Wilson, T.: A review of business-university collaboration. Department for Business, Innovation and Skills. Crown, London (2012)
3. Kvan, T.: Collaborative design: what is it? *Autom. Construct.* **9**, 409–415 (2000)
4. Mattessich, P.W., Monsey, B.R.: *Collaboration: What Makes It Work*. Amherst H. Wilder Foundation, Saint Paul (1992)
5. Teaching collaboration skills from cradle to career. <http://www.pearsonlearningnews.com/>
6. Edmondson, G., Valigra, L., Kenward, M., Hudson, R.L., Belfield, H.: Making industry-university partnerships work: lessons from successful collaborations. Science|Business Innovation Board AISBL, Belgium (2012)
7. Guimón, J.: Promoting university-industry collaboration in developing countries. Policy Brief, The Innovation Policy Platform (2013)
8. Higher Education Academy Art Design Media Subject Centre (ADM-HEA): National Endowment for Science, Technology and the Arts (NESTA): What are the barriers to effective collaboration? In: *Creating Entrepreneurship: Entrepreneurship Education for the Creative Industries*. ADM-HEA and NESTA (2007)
9. Centre for Research in Futures and Innovation, Foresight Company: The future of work: jobs and skills in 2030. UK commission for employment and skills, United Kingdom (2014)
10. UC innovation awards. <https://ucop.edu/research-initiatives/programs/innovation-opportunities/index.html>
11. Public & Collaborative NYC. <http://nyc.pubcollab.org/>
12. Intel Corporation: Collaborating with universities to create career-ready graduates. Intel Foundation and Intel Corporation, USA (2015)



# The ‘Place’ that Shows the Title of a TV Series: What to Name It and How It Has Evolved

Ricardo Maia Pestana<sup>(✉)</sup> and João Brandão

CIAUD – Research Centre for Architecture, Urbanism and Design,  
Lisbon School of Architecture, University of Lisbon, Lisbon, Portugal  
ricardo.pestana@edu.ulisboa.pt, joaobrand@gmail.com

**Abstract.** Nowadays, television series occupy a significant part of broadcasting time, particularly in paid channels. In this communication we present a reflection about the terminology used in English, French, and Portuguese to designate the filmic object that helps identify the TV series’ episode by presenting the series name and who made it. This discussion of the different words and expressions and their meanings is followed by a brief account of the evolution of these objects from the beginnings of their production until the 21st century.

**Keywords:** Graphic design · Motion graphics · Main title ·  
Main title sequence · Television series

## 1 The ‘Place’ that Shows the Title: What to Name It

An image is worth a thousand words. If that was to be true, then one second of moving images would worth more than twenty thousand words (in cinema and TV, the standard is 24 images per second –24 fps). However, more important than how many images or how many words can fit in one second of moving images is what kind of information is conveyed in that second.

In movies and TV series there are a few seconds, and sometimes more than just a few, with information that does not belong to the storyline, which helps to identify what we are seeing and who made it. This information is usually presented at the beginning or close to the beginning of the movie or the TV series episode and includes the names of the people involved in its production, namely the leading actors, the writers, the production team, and the director.

While many times the information about the authorship is displayed alongside images of the movie/episode, often it is presented in a motion graphics composition introducing the story – or at least it helps to set the tone of the movie/episode.

In order to understand why these seconds are spent in a motion picture or in a TV episode, we also have to know what to name this filmic object. In the English-speaking world, there are as many names as there are different ways of showing this information. But, in French and European Portuguese there is only one single word to identify it: *générique* and *genérico* respectively.

In these two languages, these terms refer to both the information presented at the beginning of the movie/episode as well as the full list of participants that appear at the

end of the movie/episode. In addition, both *générique* and *genérico* are antonyms of specific (as is the word ‘generic’, in English), depicting a less individualized sense of authorship [1].

In *Vocabulaire du Cinema*, Marie-Thérèse Journot [2] says that the term *générique* refers to the sequence that contains the reference to the title of the film and to those participating in the making of it. For a long time, this information was located solely at the beginning of the film. Nowadays, with the increased number of credits, we can often find this information at the start and at the end of the movie/episode [2]. Furthermore, Jaques Aumont and Michel Marie say that the term *générique* refers that ‘place’ on the movie that contains inscriptions showing its title and the names of those who made it [3].

In other languages, we often find, for the information at the beginning of the movie/episode, the notion of the place where the titles are shown: e.g. in Spanish (Castilian) it’s called *títulos*, in Catalan *titols de crèdit* and in Italian *titoli di testa* [4].

Why must we mention these linguistic differences? If in French and Portuguese we have only one word to name the information at the start and at the end of the movie/episode, in English we have one expression for each of these different objects (e.g. *opening credits*, *end credits*).

Nevertheless, in the French dictionary *Dictionnaire de l’image* [5], we can find the distinction between *titles* (at the presentation/introduction) and *credits* (the list at the end) as two categories of the *générique*.

Therefore, in English we find more specific (less generic) definitions as the ones presented in *The Film Encyclopedia*, by Ephraim Katz:

1. “**Titles:** Written matter inserted into a film for introductory or explanatory purpose. In modern films, titles appear most often in the form of the opening and closing credits. The title spelling out the name of the picture is known as ‘main title’. The others are simply known as ‘credit titles’ or ‘secondary credit titles’. The title announcing the end of the film is naturally called ‘end title’” [6].
2. “**Credits:** A list of the names of the principals involved in the production of a motion picture with their functions – e.g., the stars, the featured players, the director, the producer, the screenwriter, the director of photography. The list appears as titles, usually at the beginning or end of a film, or both” [6].

In these definitions Katz & Nolen refer to other terms used in this context, each with its own meaning: *opening credits*, *closing credits*, *main titles*, *credit titles*, *secondary credit titles* and *end titles*. Alexandre Tylski, author of one of the few books exclusively on this subject (*Le générique de cinéma - Histoire et fonctions d’un fragment hybride*), adds some more terms: *title sequence*, *opening title sequence*, *head credits* and *tail credits* [4].

Another author that has written on this subject is Éric Vêrat. In his book *Génériques! Les séries américaines décryptées*, he says that in English we can find several terms to nominate these objects, each with a precise meaning. In addition to the terms already listed, he adds *intro* and *outro*, a neologism that means an exit – as *intro* means an introduction [7].

Explaining each one of the terms, the same author says that *main title* is the most used expression to identify these objects, being the one used in the awards given by the

Academy of Television Arts & Sciences since 1997: the *Emmy for Outstanding Main Title Design* [7].

According to Vérat, *main title* is a designation filled with meaning, as it includes two words (*main* and *title*), which presents an important piece of information by naming the movie/series [7].

However, for Vérat, *Opening Title Sequence* is a most precise way to describe those objects because there we have three words: *Opening* – referring to where it belongs in the movie/episode; *Title* – referring to the importance of its name; *Sequence* – giving us the notion that it has a start and an end, possibly independent from the movie/episode and reinforcing the importance of the *Opening Title Sequence* [7].

*Opening Credits* is also an expression mentioned by the aforementioned authors. Another author, Laurence Moinereau, in the book *Le générique de film – De la lettre à la figure* expresses that, when standing alone, the term *credits* refers to the written roles/names of the different participants in the making of the film/episode [8]. Therefore, adding the word *Opening* to the word *Credits*, forming the expression *Opening Credits*, will not be the best way to name the filmic object where the title is included. It seems to us that Vérat is right when he says that *Opening Credits* has mainly the legal function of naming some of the authors of the movie or episode.

Though, in TV series, due to the reduced length of the time slots, it is impossible to show all the credits in the *end credits* of an episode – as occurs in movies, where even the drivers of the stars are credited. Therefore, the few identified by name in the credits of an episode have a high degree of importance in the production hierarchy and have achieved a higher level of prestige or importance [7].

As such, *Opening Credits* reflects more a contractual need to highlight selected names than to introduce what we are about to see or are already seeing – or even to present us the movie/series title. For the introduction, we have other objects, namely the *title sequence*, with its own narrative and that interrupts the movies/episodes, and the *intro*, without title or credits, which exists only to introduce what we are about to see. Similarly, *outro* provides closure to the movie/episode [7].

As we can see, it is not easy to find (in English, or even in French or in Portuguese) one single term to name the object that contains the information about the authorship and/or the title of the movie/series, precisely because it is not always the same kind of object, especially in the TV context.

In the French and Portuguese languages, when we talk about the *générique* or the *genérico* we must declare if we are talking about the start or about the end of the movie/episode. Even then, if we must be precise, as in academic context, the selected term must be followed by a description.

However, in English, the use of more specific expressions to name the objects might be misleading. For instance, when the expression *Opening Title Sequence* – the one preferred by Vérat – is used to refer to objects that appear several minutes after the start of an episode, the word *Opening* is deceptive, since it is no longer an “opening” to the episode. Nevertheless, *Title Sequence* is still meaningful when the object names the movie/episode with a sequence, with its own narrative, independent of the movie/episode.

To prevent these kinds of misinterpretations, we propose using the expression *Main Title Sequence* instead of *Opening Title Sequence*. Although, when the object only

shows nothing more than the title in an “isolated” form preceded and/or followed by superimposed credits on the episode images (therefore not a sequence), the expression *Main Title Sequence* should be replaced by the expression *Main Title*.

It is worth noting that, at least since the year 2000, the *Emmy for Outstanding Main Title Design* has been attributed to *Main Title Sequences*. Nevertheless, and since there are two major ways of constructing these objects [1], both expressions should be used – since the beginning of the 21st century the percentage of *main titles* has increased, and the percentage of *main title sequences* has decreased [1].

## 2 The ‘Place’ that Shows the Title: How It Has Evolved

In order to understand what this “place” is, it is not enough to know its definition, as well as the terminology used in different languages. It is also important to know, even briefly, a little of its history. We will limit ourselves, however, to show how it has evolved in the twentieth century, referring to striking examples of some series that became famous.

In the beginnings of television broadcasting, we can only speak of *main title sequences*, since the programs were not recorded, being emitted live, following the models of radio programs. Even entertainment programs were broadcasted directly from the studios where they were being performed, and only some accounts of their identification arrived to us. From them, it’s possible to infer that most often there were almost no title sequences for those programs [7]. Actually, Vêrat points out that, due to the technical conditions existing until the middle of the 20th century, it is unlikely that these sequences were more than simple cards with the names of the programs accompanied by a musical theme [7]. Possibly, a speaker could announce the title and/or the name of the sponsor (usually only one) of the program that paid most of the production, and, in fact, often had a direct influence on its contents.

The number of television sets in private houses was still very small until the middle of the century, but it grew exponentially in the following decade, covering more than 90% of the US homes in less than ten years [7]. The existence of a growing public, the possible target of advertisement to many and varied products, made it profitable for many companies to invest big amounts of money sponsoring large audience programs.

At the same time, the development of technology related to the production and broadcasting of television programs introduced great changes in all the processes involved in this industry. The programs had no more the need to be broadcasted live; they could be recorded and broadcasted later, and this allowed significant changes in the formal structure of the programs, particularly in their presentation.

These two changes in the production and diffusion of television programs had a very relevant impact in the main title sequences of the programs. A well-known example of these sequences is that of the series *I Love Lucy*, one of the first entertaining programs with a large audience in the United States, running from 1951 to 1957.

This show was sponsored by Philip Morris cigarettes and this kind of funding allowed the producers to hire professional designers that created, for the introduction of the program, an animated sequence where stylized figures/caricatures of the two main characters of the show climbed a giant pack of cigarettes [9]. The credits related to the

episode were integrated into this animation sequence that was preceded by a small sequence announcing the series, filmed by a static camera focusing the face of a young bellhop yelling "*Call for Philip Morris*" and zooming out, giving place to the animated sequence. A long advertising film followed the animation film, where an actor/speaker talked about the advantages of the cigarettes while smoking, inhaling and expelling smoke that could be seen in volutes surrounding the face of the actor. Only after that, the show started.

This was the original introduction of the show, which, over the time, was replaced by others, depending on the sponsors. Actually, Philip Morris cigarettes were not the only sponsors of the series *I Love Lucy*. The series, which lasted until 1957, had other sponsors namely the "*squeeze comb Lilt*" a liquid for home hair permanents, or Sanka coffee (General Foods, later acquired by Kraft Foods) and the main title sequences were then replaced by other animated sequences [10]. The Philip Morris *main title sequences*, as well as all other advertisements to cigarettes, were banned when the series was aired on syndication and edited in DVDs but were recently restored and appeared in YouTube as referred in New York Post [11].

After 1957 the series was reformulated, continuing until 1961. From 1962 to 1968 a sequel of this series titled *The Lucy Show* was produced, firstly in black and white, and in color from the second season. Initially, the *main title sequence* was of the same type of those of the original series but was gradually modified. In the last seasons, and later on syndication, the *main title sequence* was known as the "*kaleidoscope opening sequence*", as fragmented clips of previous episodes, images and credits were shown turning around as in a kaleidoscope image [12].

Another example that must be mentioned is the *main title sequence* of *Alfred Hitchcock Presents* (1955–1962), nowadays seen as a cult series, which actually is an anthology of independent suspense films of about 25 min each. Hitchcock himself directed only about 10% of the more than 250 episodes. The common feature of the series is the *main title sequence*, the same in all the episodes [13].

Every episode starts with the showing of a grey card with a caricature of Hitchcock, drawn by him [7]. Then, from the right side of the screen, his figure starts to appear, sliding slowly until it covers completely the caricature. Hitchcock then says "*Good evening*" and presents a monologue of about one minute in which he introduces the episode that will follow. At the end of the episode, Hitchcock returns and presents some conclusions with irony and wit, according to morality and good manners.

Hitchcock always says the initial and final monologues. For each episode there are two alternate versions – one for the broadcasting in the USA, commenting sarcastically the sponsors and another one for diffusion in Europe in which he used to make some comments about Americans [13].

This model of a spoken *main title sequence*, although usually much shorter, repeated in every episode at least of each season, was used in several other series. As an example, the series *Dragnet* (1951–1959) presents, in the opening sequence, first the image of a police badge reinforced by a strong musical theme, then a short monologue follows "*Ladies and gentlemen: the story you are about to see is true. The names have been changed to protect the innocents*" [14]. Eventually, the name of the series *Dragnet* appears superimposed on the image of the badge, which starts fading out leaving only the name of the series that fades out just after that of the badge.

Another famous series, which was aired between 1959 and 1973 with more than 400 episodes in 14 seasons, is *Bonanza* [15]. The colorful introduction, punctuated by a very strong opening musical theme worked as a real call for the public to reunite in front of a TV screen to watch the Sunday night episode that presented the various stories occurring in Ponderosa Ranch, near Virginia City.

The initial images correspond to a map that locates the series in the South USA. Then, the name of the series, in big capital letters, zooms in superimposed to the map, then zooms out and fades away, and a fire starts near the center of the map, referring to the American Civil War, the period in which the series occurs. The fire spreads, producing a large hole in the map, from where, through the smoke, four cowboys approach, and the starring actors are announced. Then the main actors are identified one by one by their names and the episode starts.

The *main title sequence* remained almost unchanged along all the seasons, except in what related to the order of the presentation of the four main actors that changed in all the episodes, and in the presentation of the guest stars, always identified by the name and the photograph of the character performed [16].

Another cult series, *The Twilight Zone*, created by Rod Serling began to be aired by 1959, being the first relevant television production in the field of Science Fiction. This series (*The Twilight Zone*, 1959–1964) is also an anthology of unrelated episodes having as a common feature the presentation by Serling himself of a spoken opening monologue [17]. This spoken introduction is not the same in all seasons, although maintaining the same general mood. The images shown while the text is said are very different in each season, some totally abstract, others inspired by op art or surrealism. This *main title sequence* somewhat creepy was accentuated by the sound themes [18, 19]. The graphic presentation of the title of the series also changed from season to season.

In the following decade, 1960–1970, some of the series initiated previously continued to be produced, with no changes or only small changes in their *main title sequences*. Yet, in other series, the evolution of technology used in cinema or television had significant influence. Actually, the increase in the audiences of television made the *main title sequences* of the series more important, as they could be an important factor in the loyalty of the public to the channel. And the audiences of a television channel – and of a series – are fundamental, from an economic standpoint, because of the associated advertisement income. It should be noted, that by that time, the TV sets didn't have remote controls and so changing the channel was much less practical.

The money resulting from advertising allowed investments in more sophisticated technologies, and that affected positively the quality of the *main title sequences*. It also made possible and financially appealing to produce more series, changing significantly all the industry and the work market related to these productions. Still, the increased quality of these *main title sequences* did not depend only on the existence of better (and more expensive) equipment, but also on more, and better, professionals trained in cinema and graphic design.

All these factors produced a qualitative change in the *main title sequence* of the series, also associated with the increased number of series produced, especially after the middle of the decade.



The TV series produced in the Fifties of the 20th century may be considered pioneers and, in a way, constituted a model for a kind of television programs that proved to be successful. This is why we chose to examine with some detail these examples since they represent some of the biggest successes in viewers' numbers and international reach. These series have also different kinds of *main title sequences*, which are, by themselves, examples that were followed in subsequent years.

However, it would be too long to present here with the same detail an overview of the universe of the series produced since 1960. Only some examples considered more relevant by their specific characteristics or because they correspond to series with greater audience and/or longevity (what usually is associated) will be referred.

As mentioned above, technological innovations were reflected more or less significantly in the production and also in the broadcasting of the series and in their *main title sequences*. And so, color started to be used more and more extensively, although the change to color implied great investments for the production studios not only in equipment but also in the materials and their treatment.

At the beginning of the Sixties many series were still produced in black and white. In the case of *The Adams Family* (1964–1966), this was quite adequate to the style of the series where the macabre and comical interconnect. Actually, the expenses of the transformation of the production into color were perhaps in the roots of the cancellation of the series, after only two seasons (64 episodes) as the audiences were not very high, in particular in the second season [20, 21].

Also with a short duration, the series *Batman* (1966–1968) had a great success among its target young audience. It had three seasons with a total of 179 episodes broadcasted twice a week [22]. The *main title sequence* deserves a mention as it is directly inspired by the corresponding comic books, maintaining its particular esthetical aspects in an animation sequence.

Totally different is the presentation of the title card and initial credits of the series *Bewitched*, although also included in a very short animation film. This *main title sequence*, that states the mood of the series, presents a charming witch mounted on a broom, circling the screen and doing some magic by the simple twitch of her nose, which is accompanied by the sound of the ringing of a small bell. The series that lasted from 1964–1972 with more than 250 episodes in seven seasons had a huge success not only in the United States but also in many European countries [23]. The series, initially in black and white, switched to color in the third season, and the colorful *main title sequence* became more attractive.

The emblematic series *Mission Impossible* aired from 1966 to 1973, with a total of 168 episodes in seven seasons was targeted for a different public, interested in action series and movies. It is about "impossible" covert operations carried out by an elite team knowing that in case of capture or failure there will be official denial. At the beginning of each episode the super-secret mission is explained and after that introduction, which is the real beginning of the episode, the *main title sequence* starts with the lighting of a match which, in turn, lights a fuse that is seen burning horizontally in the screen, along all the whole main title sequence, accompanied by a strong musical theme easily identified [24]. While the fuse is burning, some small clips of relevant scenes of the episode are shown, followed by the presentation of the credits corresponding to the actors with images of their characters, and by the remaining credits of

the episode. This *main title sequence* changes in each episode, what is still uncommon in television series, but the fuse burning and the musical theme are maintained almost unchanged, being even used some years later when the thematic of the series is recovered in a set of six movies (for now).

During the following decade 1970–1980, several series like *Dragnet*, *Bonanza*, *Bewitched*, or *Mission Impossible* continued, as well as many others not mentioned here.

In what concerns new series, *M\*A\*S\*H* (1972–1983) should be pointed out. It is a series about a medical team helping on the battleground during the Korean War. The *main title sequence* shows crude images of the rescue of soldiers wounded in combat and their subsequent transportation to the field hospital that contrast cruelly with the beautiful musical theme with its strange lyrics (*Suicide is painless*) that accompanies the images [25]. As a side note, this kind of approach to the violence of war is explored by Pablo Ferro in the *main title sequence* of the 1974 movie *Dr. Strangelove or: How I Learned to Stop Worrying and Love the Bomb* by Stanley Kubrick, which has a contrast between the threat of an atomic war and the subtleness of the music *Try A Little Tenderness* that accompanies the images.

Several other series started during this period, but the *main title sequences* are usually not very relevant, although their technical and cinematographic quality may have had some interesting evolutions, namely the use of split screens—that means the use of different sequences of images running simultaneously in separate parts of the screen.

Among the series that used this technique in the *main title sequence*, it is worth mentioning *Dallas* that started in 1978 and lasted until 1991, with more than 350 episodes in 14 seasons [26]. The series was broadcasted in many countries in the whole world and had an audience of many millions of very interested viewers [26]. It had a *main title sequence* that, with a very recognizable musical theme over images a split screen, showed the faces of the main cast alongside with the places where the action ran. This *main title sequence* was later recovered for the 2012 sequel that had the same name.

In 1981 the series *Hill Street Blues* started to be aired in prime time. This series, that lasted until 1987 had 146 episodes in seven seasons, made a deep change in the format of police drama series, as it intended to show with objectivity the daily life in a police station in an unnamed American big city [27]. The *main title sequence* that is preceded by a short sequence corresponding to the distribution of tasks specific for each episode is very concise. It is initiated with the title superimposed on the image of a police car, followed by the departure of all police cars from the police precinct with sirens ringing, still with the title superimposed to the images, and finally the credits are presented, with the names of the actors associated to the characters played [28]. The musical theme that accompanies this sequence and actually the whole series should also be highlighted.

Contrasting with *Hill Street Blues*, *Cheers*, a comedy series which action is passed in a bar where the residents of the neighboring quarters meet to drink and talk started in 1982 also became famous, lasting until 1993. The *main title sequence* is interesting using animation of antique photos and drawings accompanied with a cheerful musical theme that identified the show [29].

A very special series, *The Simpsons* (1989), which celebrated in 2018 its 30th anniversary of consecutive exhibition, with more than 600 episodes aired in prime time [30], is an animation sitcom for adult audience satirizing the middle class American lifestyle, having a legion of fans [31]. The *main title sequence* although maintaining usually a common structure, varies in each episode, usually not much, although in special cases the changes are more significant [32, 33].

The end of the 20th century and beginnings of 21st century saw the start of production of medical series like ER or Chicago Hope, and of crime scene series like the CSI “galaxy”, characterized by the use of images of scientific instruments and/or scientific techniques.

However, considering that the number of series has been rising dramatically from year to year since the middle of the last decade of the 20th century and there is no time distance that can allow a correct appreciation of the evolution of the *main title sequence* of these series, we will not discuss them in detail.

We will only refer that 3D animations were introduced in some *main title sequences* produced in the last years of the 20th century but this innovation became more obvious only recently. The *main title sequence* of Black Sails (2014–2017) presents an interesting 3D animation [34], but the more striking example is that of the *Game of Thrones*, series initiated in 2011, with a tremendous success and that is presently running [35, 36].

In this brief overview only American series were mentioned, leaving aside those produced in the rest of the World, particularly the U.K. series where main title sequences of great graphic quality, namely for the care in the use of typography can be found.

### 3 Final Remarks

In order to answer the questions of how to name the graphic identification of a TV series and how it has evolved, we started to show the different terms that are used in different parts of the world. These different terms reflect different approaches to the subject, mainly between the English and the French.

Having explained many of the terms by which it is known, we arrived at the conclusion that *Main Title Sequence* and *Main Titles* are the best terms to name that ‘place’ on the movie/episode that contains inscriptions showing its title and the names of those who made it.

From there, we showed how the main title sequences evolved in the 20th century, presenting examples of these objects, namely from several emblematic TV series that represent models followed since the beginnings of TV.

**Acknowledgments.** 1. CIAUD – Research Centre for Architecture, Urbanism and Design, Lisbon School of Architecture, University of Lisbon, Portugal; 2. FCT – Fundação para a ciência e Tecnologia, Portugal

## References

1. Pestana, R.: Design Gráfico para Televisão - Proposta de Classificação de Tipologias de Estruturas de Genéricos de Séries. Master's thesis, Faculdade de Arquitectura, Universidade de Lisboa (2014)
2. Journot, M.T.: Vocabulário de Cinema. Edições 70, Lisboa (2005)
3. Aumont, J., Marie, M.: Dicionário Teórico e Crítico do Cinema. Edições Texto & Grafia, Lisboa (2009)
4. Tylski, A.: Le Générique de Cinéma: Histoire et Fonctions d'un Fragment Hybride. Presses Universitaires du Mirail, Toulouse (2008)
5. Goliot-Leté, A., et al.: Dicionário de Imagem, Edições 70, Lisboa (2011)
6. Katz, E., Nolen, R.D.: The Film Encyclopedia. HarperCollins Publishers, New York (2012)
7. Vérat, E.: Génériques: Les Séries Américaines Décryptées. Les Moutons Électriques, Éditeur, Lyon (2012)
8. Moinereau, L.: Le Générique de Film: De la Lettre à la Figure. Collection «Le Spectaculaire», Presses Universitaires de Rennes, Rennes (2009)
9. IMDb.com, Inc.: I Love Lucy. TV Series produced by Desilu Productions, Columbia Broadcasting System (CBS), USA, Trivia – IMDb (1951–1957). [http://www.imdb.com/title/tt0043208/trivia?ref\\_=tt\\_ql\\_2](http://www.imdb.com/title/tt0043208/trivia?ref_=tt_ql_2). Accessed 20 Dec 2018
10. The Classic TV Database: I Love Lucy, TV Series Info. <http://www.classic-tv.com/shows/i-love-lucy>. Accessed 20 Dec 2018
11. Lumenick, L.: Lucille Ball hawks Cigarettes in Newly Restored Ads. The New York Post, 24 May 2014. <http://nypost.com/2014/05/23/lucille-ball-hawks-cigarettes-in-newly-restored-ads/>. Accessed 20 Dec 2018
12. IMDb.com, Inc.: The Lucy Show. TV Series produced by Desilu Productions, Columbia Broadcasting System (CBS), USA, Trivia – IMDb (1962–1968). [http://www.imdb.com/title/tt0055686/trivia?ref\\_=tt\\_ql\\_2](http://www.imdb.com/title/tt0055686/trivia?ref_=tt_ql_2). Accessed 20 Dec 2018
13. IMDb.com, Inc.: Alfred Hitchcock Presents. TV Series produced by Revue Studios, CBS, USA, Trivia – IMDb (1955–1962). [http://www.imdb.com/title/tt0047708/trivia?ref\\_=tt\\_ql\\_2](http://www.imdb.com/title/tt0047708/trivia?ref_=tt_ql_2). Accessed 20 Dec 2018
14. The Classic TV Database: Dragnet. TV Series produced by Mark VII Ltd., National Broadcasting Company (NBC), USA, Dragnet @The Classic TV Database (1951–1959). <http://www.classic-tv.com/shows/dragnet>. Accessed 20 Dec 2018
15. The Classic TV Database: Bonanza TV Series, Bonanza@The Classic TV Database (1959–1973). <http://www.classic-tv.com/shows/bonanza>. Accessed 20 Dec 2018
16. IMDb.com, Inc.: Bonanza. TV Series produced by National Broadcasting Company (NBC), USA (1959–1973). <http://www.imdb.com/title/tt0052451/>. Accessed 20 Dec 2018
17. Stanyard, S.T.: The Twilight Zone Archives – the Internet #1 Twilight Zone website. <http://www.twilightzone.org/index2.html>. Accessed 20 Dec 2018
18. The Classic TV Database: The Twilight zone, TV Series, The twilight zone @ The Classic TV Database (1959–1964). <http://www.classic-tv.com/shows/the-twilight-zone>. Accessed 20 Dec 2018
19. IMDb.com, Inc.: The Twilight zone, TV Series produced by Cayuga Productions, CBS Television Network, USA, IMDb (1959–1964). <http://www.imdb.com/title/tt0052520/>. Accessed 20 Dec 2018
20. The Classic TV Database: The Addams Family - TV Series Info. <http://www.classic-tv.com/shows/the-addams-family>. Accessed 20 Dec 2018

21. IMDb.com, Inc.: The Addams Family. TV Series produced by Filmways Television, American Broadcasting Company (ABC), USA. IMDb (1964–1966). <http://www.imdb.com/title/tt0057729/>. Accessed 20 Dec 2018
22. The Classic TV Database: Batman. TV Series produced by 20th Century Fox Television, American Broadcasting Company (ABC), USA. TV Series Info (1966–1968). <http://www.classic-tv.com/shows/batman>. Accessed 20 Dec 2018
23. The Classic TV Database: Bewitched. TV Series produced by Ashmont Productions, American Broadcasting Company (ABC), USA. TV Series Info (1964–1972). <http://www.classic-tv.com/shows/bewitched>. Accessed 20 Dec 2018
24. The Classic TV Database: Mission Impossible (1966–1973), TV Series, produced by Desilu Productions, (1966–1968), Paramount Television (1968–1973). TV Series Info. <http://www.classic-tv.com/shows/mission-impossible>. Accessed 20 Dec 2018
25. The Classic TV Database: M\*A\*S\*H, TV Series, produced by 20th Century Fox Television, Columbia Broadcasting System (CBS), USA. M\*A\*S\*H @ The Classic TV Database (1972–1983). <http://www.classic-tv.com/shows/mash>. Accessed 20 Dec 2018
26. The Classic TV Database: Dallas, TV Series, produced by Lorimar Productions, Columbia Broadcasting System (CBS), USA. Dallas @ The Classic TV Database (1978–1991). <http://www.classic-tv.com/shows/dallas>. Accessed 20 Dec 2018
27. The Classic TV Database: Hill Street Blues, TV Series, produced by MTM Enterprises, National Broadcasting Company (NBC), USA. Hill Street Blues @The Classic TV Database (1981–1987). <http://www.classic-tv.com/shows/hill-street-blues>. Accessed 20 Dec 2018
28. IMDb.com, Inc.: Hill Street Blues. TV Series, produced by MTM Enterprises, National Broadcasting Company (NBC), USA, IMDb (1981–1987). [http://www.imdb.com/title/tt0081873/awards?ref\\_=tt\\_ql\\_4](http://www.imdb.com/title/tt0081873/awards?ref_=tt_ql_4). Accessed 20 Dec 2018
29. The Classic TV Database: Cheers, TV series, produced by Charles/Burrows/Charles Productions, National Broadcasting Company, USA. Cheers @The Classic TV Database (1982–1993). <http://www.classic-tv.com/shows/cheers>. Accessed 20 Dec 2018
30. IMDb.com, Inc.: The Simpsons, TV series, produced by Gracie Films, Fox Network, USA. IMDb (1989). <http://www.imdb.com/title/tt0096697>. Accessed 20 Dec 2018
31. IMDb.com, Inc.: The Simpsons (TV Series). Trivia – IMDb. [http://www.imdb.com/title/tt0096697/trivia?ref\\_=tt\\_ql\\_2](http://www.imdb.com/title/tt0096697/trivia?ref_=tt_ql_2). Accessed 20 Dec 2018
32. Scott, J.: The simpsons opening credits guide. Simpsons crazy (2014). <http://www.simpsonscrazy.com/opening>. Accessed 20 Dec 2018
33. Leonard, T.: The Simpsons Opening Sequence Changes. The Telegraph, 17 February 2009. <http://www.telegraph.co.uk/culture/tvandradio/4682314/The-Simpsons-opening-sequence-changes.html>. Accessed 20 Dec 2018
34. IMDb.com, Inc.: Black Sails (2014–2017), TV Series, produced by Film Afrika Worldwide, Starz!, USA. IMDb. <http://www.imdb.com/title/tt2375692/>. Accessed 20 Dec 2018
35. IMDb.com, Inc.: Game of Thrones, TV Series, produced by Home Box Office (HBO), Home Box Office (HBO), USA. IMDb (2011). <http://www.imdb.com/title/tt0944947/>. Accessed 20 Dec 2018
36. Perkins, W.: Game of Thrones Art of the Title (2011). <http://www.artofthetitle.com/title/game-of-thrones/>. Accessed 20 Dec 2018



# Communication Design and Medical Procedures: Inform Citizens to Act in Emergency Situations

Marco Neves<sup>1(✉)</sup> and Ana Rafaela Poças<sup>2</sup>

<sup>1</sup> CIAUD – Research Center for Architecture, Urbanism and Design,  
Lisbon School of Architecture, University of Lisbon, Rua Sá Nogueira,  
Pólo Universitário, Alto da Ajuda, 1349-055 Lisbon, Portugal  
mneves@fa.ulisboa.pt

<sup>2</sup> Lisbon School of Architecture, University of Lisbon, Rua Sá Nogueira,  
Pólo Universitário, Alto da Ajuda, 1349-055 Lisbon, Portugal  
aarafaelaa@gmail.com

**Abstract.** Emergency situations are unpredictable and happen very quick. They require citizens to be able to act to help victims until they are stable or until emergency entities arrive. Acting in these situations is crucial to save someone's life. However, the average citizen does not always know about first aid. Communication for this matter is important as it allows a set of information to be transmitted in a variety of ways, such as verbal, non-verbal or pictographic. Therefore, first aid procedures should be communicated in a simple and objective way, to motivate citizens to act in emergency situations. We present a set of analog and digital media as part of a design project developed as a solution for these circumstances, where we explain basic life support and recovery position. We undertook an evaluation of project outcome, through questionnaires. Perception and effective learning of techniques to deal with emergency situations was improved.

**Keywords:** Communication Design · Emergency · Information design · Medical procedures · Basic life support and recovery position

## 1 Introduction

The connection between text and images is a common way for medical specialists to communicate with ordinary citizens, e.g. citizens outside medical context and without training in first aid. When it comes to health issues, visual communication in most media makes use of visual instructions to allow knowledge acquisition. For an acceptable level of literacy to prevail, someone needs to develop communication media with graphic elements and to take advantage of features related to information and interaction design.

The average citizen has access to a lot of information and in various media, but even if he or she recognizes the importance of being proactive in an emergency, it is most likely there will be no training acquired before. Consequently, communication directed towards this can be beneficial, so that basic medical procedures can be transmitted to the

public. By fostering greater public involvement and its relationship with designers and health care entities, addressing these issues places the emphasis on use of information and how it can be a design issue. Information design is intended to simplify information through visual elements, in which images, illustrations or icons can be used to complement text, color and other shapes [1–3]. Also, interaction design may be suggested to encourage public participation, whether on analog or digital media [4].

Our main goal is to develop communication media that reaches a diversity of groups not trained in and with little knowledge of first aid. For this purpose, we created a set of analogue and digital interventions and objects with an informative and didactic intent for the territory of Portugal.

## **2 Design Project: Development of Communication Media to Inform Citizens to Act in Emergencies**

A high amount of information about medical procedures was based on digital media available from INEM (Portuguese National Emergency Medical Institute) website and from several meetings with representatives from INEM and from the Portuguese Red Cross. While collecting those materials, we realized there is a process and several factors to verify if the victim needs resuscitation. This process begins with a fallen victim: if she responds and/or breathes, we will have to place her in recovery position. If she does not respond and/or breathes, we will have to proceed to cardiopulmonary resuscitation. These steps made us realize that various first aid issues would be represented: evaluation of consciousness, evaluation of breathing, contact with 112 (European emergency number) and the Portuguese Anti Poisons Information Center, basic life support and recovery position.

Throughout research, we sketched several schemes which were often used to clarify the amount of information to be transmitted. These schemes and idea generation were very important throughout the process. For this research, sketch functioned as a tool, allowing a better study, analysis, perception and planning of each media and its relationship with the human being and with the environment in which every media is to be placed. The sketch phase allowed, first, a focus on solving the situation, and, then, rapid and free exploration of ideas and possibilities [5].

### **2.1 Definition of Requirements**

Medical language is not obvious to the average citizen. Therefore, we considered appropriate to direct all media to non-medical people without first aid training, who in emergency situations need to make decisions and need to act quickly. This choice relates to the project goals, which are to make knowledge on these topics more transversal and more comprehensive.

It was our intention to develop objects that would allow common citizens to be prepared with basic life support and recovery position procedures. Due to stress caused by emergencies, these procedures may be harder to remember. We envisioned common citizens should be able to easily consult steps for both procedures, in an emergency context and outside it.



In terms of visual language, we used a straightforward approach with illustrations to escape a more heavy or serious understanding, which some materials related to first aid usually present and thus capture public attention through a more instructional way.

## 2.2 Definition of Materials

After collecting information on emergency, knowing the factors involved in this context and defining audience approach, we defined the materials to use. All media objects were intended to integrate people's daily lives, exactly because of the need to make them feel safe and more prepared, so that difficulty in acting and taking decisions appropriate to the situation would be attenuated.

In this way, materials perform informative functions, presenting steps that must be followed. One of the objects requires intervention: it is a public use board, placed in establishments and public places. Therefore, it was important to know where and how other similar objects were strategically placed, such as defibrillators and fire extinguishers. Regarding this, it was also important to realize that both are properly signaled and that defibrillators may only be use by qualified people. Therefore, our public board would be accessible to people outside health areas and without training in first aid. We also considered, it is not possible to equip all places and to have the plate constantly present because emergencies can be spontaneous. So, we tried to make it adaptable to a personal and smaller object, which could accompany citizens in their day-to-day.

Thus, another object was developed, which is a small folding and portable guide. To complement the board and the guide, we also developed a website, to foster an interactive approach, that would encourage the use of the remaining objects.

## 2.3 Design and Prototyping

Throughout the design process, several low and high fidelity prototypes were developed for every object within the scope of the project. We based visual messages in a distinction between two characters in an emergency context: rescuer and victim. Being that the object is destined to the rescuer, all highlights go to his actions. This distinction is done through different colors. Farina, Perez & Bastos [6] state that the human being experiences visual sensations, influencing him on a physical, psychological and emotional level. Colors create these visual sensations, causing their choice and adequacy to communication materials to help in understanding of messages and working as a mechanism to capture people's attention and interest. Therefore, Farina, Perez & Bastos [6] reinforce the impact of color, which influences the areas of "(...) Education, Accident Prevention, Decoration, Medicine, Communication, Production, Fashion, Art, Traffic and many others".

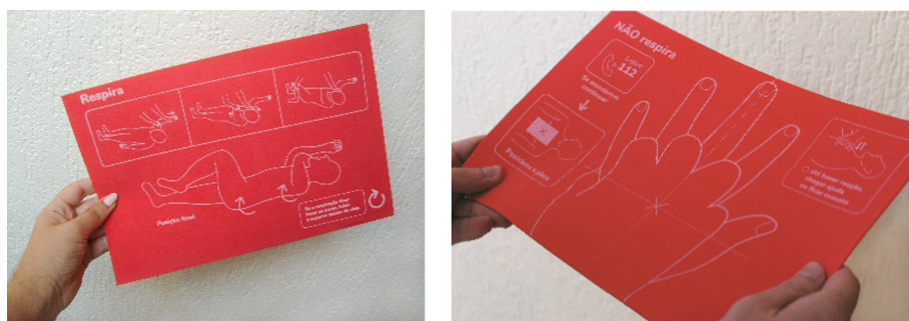
Our color palette is presented in Fig. 1. It was complemented by three type fonts used throughout the project: Gill Sans, Montserrat and Nunito. Typography has its importance in the project, since it influences readability and consequently, understanding of all content. In the case of the public board, only Nunito font was chosen, because it is simple and rounded, contributing to a quicker and easier reading.





**Fig. 1.** Color palette for the project.

**Public Intervention Board.** This object derives from the difficulty in correctly reasoning in a moment of emergency and from the consequent difficulty in acting, related to the bystander effect [7]. It was designed to be used exactly at the time an emergency occurs and it includes basic life support and recovery position procedures separately on front and back sides (Fig. 2). While the recovery position side serves only for consultation and visualization of the necessary steps, the basic life support side allows, when placed at the center of the victim's chest, to obtain the correct location for rescuers to have their hands to perform compressions. Together with simple and not very detailed illustrations, text would be short, because the action must be quick and there is no time to interpret complex and extensive elements.



**Fig. 2.** Two sides of the public board.

Red was chosen as the background color, because it is a contrasting color and, as in mentioned examples, it is associated with emergency situations. In addition, Farina, Perez & Bastos [6] consider it a warm color that transmits energy and proximity while also being associated with movement, dynamics, action and energy. Something important for our goal of entice people to act. Both illustrations and text appear in white.

We used satin vinyl foam as material because of its malleability, resistance and lightness. The board dimensions follow A4 format ( $210 \times 297$  mm;  $8.3 \times 11.7$  inches), arranged horizontally, as it is a standard format for production and presents appropriate measures for rescuer hands to be on the victim's chest. The hand placement

zone followed dimensions presented in Panero & Zelnik [8], where average dimensions of various body parts are compiled, including female and male hands (Fig. 3). The board in public exhibition along its signage can be seen on Fig. 4.



Fig. 3. Simulation of board use.



Fig. 4. Board public exhibition with signage.

**Basic Life Support and Recovery Position Guide.** The second object follows an informative approach and treats the same issues with more detail, using illustrations and text. It is a small and personal guide, portable and can be consulted when necessary. It gives users the possibility of extensive detail when compared to the board, because citizens will more time to analyze and consult it. We considered everyday objects to match our requirement of it being portable. Our guide could be included and carried in objects such as wallets, suitcases, bags and pockets.

We applied the basic dimensions of plastic cards (Portuguese citizen card, ATM cards and business cards were observed). According to the Portuguese Agency for Administrative Modernization [9], citizen card size is 86 mm  $\times$  54 mm (3.4  $\times$  2.1 inches). The idea was to develop a folding object, which, when handled, assumed larger dimensions, but, folded, followed the measurements of the citizen's card. When the guide is placed inside a wallet, a fraction is still visible (Fig. 5), as it happens with other cards. This guarantees the title is always visible.



**Fig. 5.** Guide on a wallet.

Like the board, this guide has two sides as well, so we took advantage of it to follow the same logic and distribute each procedure on just one side. In the front side, basic life support procedure (Fig. 6) and, on the back side, recovery position and a list of emergency contacts (Fig. 6). The presence of this list is meant to always accompany citizens and includes the 112 and the Portuguese Anti Poisons Information Center number. An explanation of when to call them is also provided.

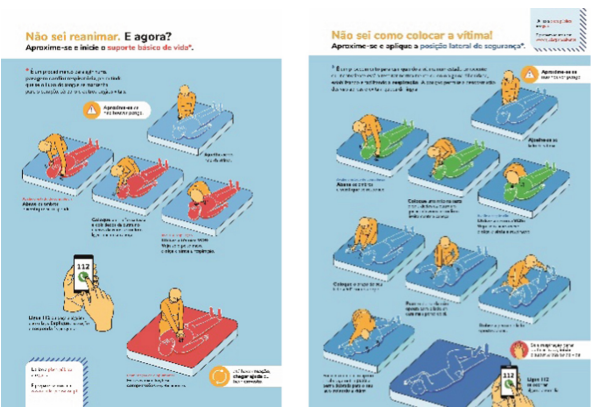
We used three different colors for three different subjects (basic life support, recovery position and contacts). One color distributed for each one: red for basic life support, blue for recovery position and yellow for contacts.



**Fig. 6.** Guide: Basic life support (red) and recovery position (blue).

**Campaign.** A campaign was conceived with the purpose of informing society at large about situations in which basic life support (specially for cardio-respiratory arrest) and recovery position (specially for unconsciousness) should be applied and for reinforcing importance of ordinary citizen action. This campaign consisted in 2 infographics, 2 posters and a website.

Two infographics were developed, where each one treats individually basic life support procedure (Fig. 7) and recovery position (Fig. 7). As done previously in the guide and on the board, each step is presented individually and with its importance. Each step is illustrated and accompanied by a textual explanation. Figures in red indicate there is no reaction and, in green, the opposite. The format allows them to easily adapt to a poster version, to be exhibited in public places and near the public board. In both infographics, such as in the following posters, we designed a small window, which shows the use of the board, the guide and the website. In this way, we establish a link between all materials.



**Fig. 7.** Campaign infographics for basic life support and recovery position.

In addition to promote necessary procedures, we also considered important to inform population of what is a cardiorespiratory arrest and a state of unconsciousness, why they happen and why ordinary citizens action is crucial to stabilize or save the victim until medical help specialist arrives. For that reason, 2 posters were developed: one about cardiorespiratory arrest and another about the state of unconsciousness, as can be seen in Fig. 8, respectively.

The campaign also comprises a website (Fig. 9), which serves as a repository where guide, infographics and posters are available for download and sharing on social media. Therefore, if people have not yet had contact with any campaign materials, they have an opportunity to save and print them, give someone or just distribute them. They are available so anyone can download and place them on a public space. In this way, it is possible to reach even more people and request their participation in the process of dissemination of materials, creating an idea of analog and digital sharing. The website presents a brief form in which people can send suggestions for communication materials.



Fig. 8. Campaign posters.

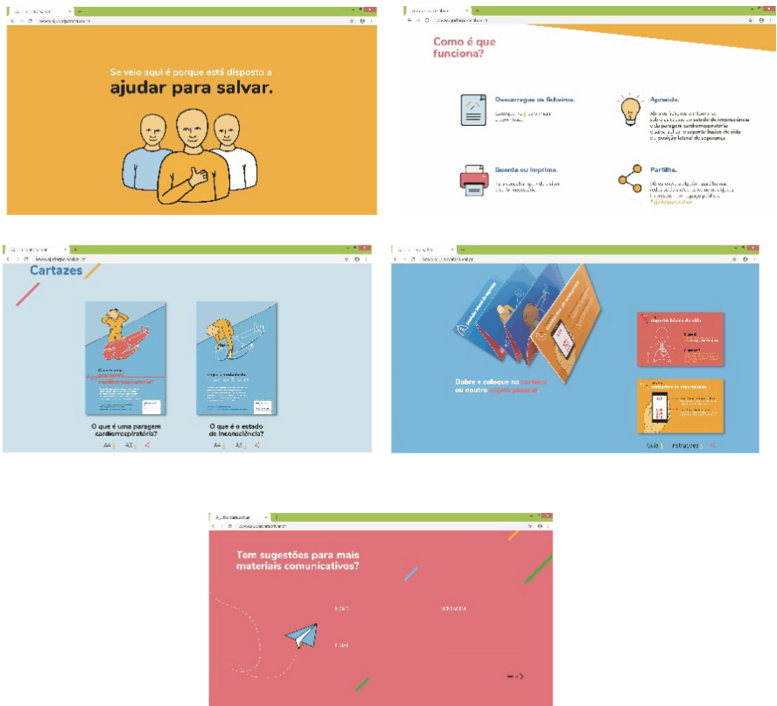


Fig. 9. Website screens.

2.4 Evaluation

After design and prototyping stages, we carried out an evaluation of all materials produced. To evaluate our design project, it was essential to run a usability test, in which the following points were addressed: length of each session, objectives of the

test, purpose of evaluation, profile of chosen individuals, applied methods and data to be collected. We intended to understand if the design project is relevant and effective in relation to the defined problem and understand if users can interpret information presented in all produced objects. For this, 2 medical specialists of the Portuguese Red Cross School of First Aid were selected as representing a profile of people with knowledge in the area and 15 persons without first aid training, as representing a profile of people without training in the area. Those 15 were selected by convenience, as they were students from the 2nd year of the Master's Degree in Communication Design, Faculty of Architecture, University of Lisbon, academic year 2018/2019. Tests were conducted in a controlled and calm environment, so that attention was focused on explanations and presented objects. Each session lasted about 25 min, where questionnaire were distributed to collect information on usability, effectiveness, objectivity and relevance of the project.

The results of the specialists group, regarding the general evaluation, using a SUS scale, were 87.5%. This proves effectiveness and satisfaction towards the project. Both subjects also considered presented objects to be useful for people without training in first aid and that used language is not complex.

The group of non-specialists, in a general evaluation, in which a SUS scale was also used, resulted in 70%. This result shows the project as efficient and effective.

The project had a very positive evaluation in remaining questions, in comments made aloud and in observation notes. Relevance and usefulness were mentioned several times and the contribution it brings to communication and learning of procedures to deal with emergency situations.

### 3 Conclusion

Our design project attempts to prove a relation between design and communication of medical procedures. It contributes to make medical information, complex in its nature, as something simple and accessible for the average citizen.

Information design can effectively contribute to a better representation of medical procedures through strategies, which decrease the amount of visual and verbal information, allowing the public to understand easier and quicker, without losing any sort of motivation. The project was developed in a direct, straightforward way. Visual language included an interventional and informative goal, so all produced materials could disclose the necessary procedures and, consequently, promoted greater knowledge and preparation to act and help someone else. It is important to emphasize the relevance of interdisciplinary in accomplishing such a project, both in connecting different areas, and in including emergency entities. Partnership with these national entities was a very positive experience, as they reviewed technical aspects and gave suggestions about emergency contexts.

This research through a project practice showed how a design project, constituted by a set of informative objects, which require citizen's participation, can communicate medical procedures to act in pre-emergency. We expect this research will contribute to provision of first aid.

**Acknowledgments.** The authors would like to thank the funding support by the Foundation for Science and Technology of the Ministry of Science, Technology and Higher Education of Portugal under the project UID/EAT/04008/2013.

## References

1. Krum, R.: Cool Infographics. Wiley, Indianapolis (2014)
2. Coates, K., Ellison, A.: An Introduction to Information Design. Laurence King Publishing, London (2014)
3. Quispel, A.: Data for all. How professionals and non-professionals in design use and evaluate information visualizations. Ph.D. thesis, Avans University of Applied Sciences, Tilburg (2016)
4. Neves, M.: Enhancing user experience in graphic design: a study in (unusual) interaction. In: Rebelo, F., Soares, M. (Eds.) Advances in Ergonomics in Design. Advances in Intelligent Systems and Computing, vol. 485, pp. 801–810 (2016)
5. [https://doi.org/10.1007/978-3-319-41983-1\\_72](https://doi.org/10.1007/978-3-319-41983-1_72)
6. O' Grady, J., O' Grady, K.: A Designer's Research Manual: Succeed in Design by
7. Knowing your clients and what they really need. Rockport, United States of America (2006)
8. Farina, M., Perez, C., Bastos, D.: Psicodinâmica das cores em comunicação. Edgard Blücher, São Paulo (2006). [Psych dynamic of colors in communication]
9. Cherry, K.: How to Overcome the Bystander Effect. <https://www.verywell.com/how-to-overcome-the-bystander-effect-2795559>
10. Panero, J., Zelnik, M.: Las dimensiones humanas en los espacios interiores: Estándares antropométricos. Gustavo Gili, México (1996). [Human dimensions in interior spaces: antropometric standards]
11. Agência para a Modernização Administrativa, Projecto Cartão de Cidadão
12. <https://www.autenticacao.gov.pt>. [Portuguese Agency for Modern Administration, Citizen Card Project]





# Color and Interaction in Journalistic Infographics: The Case of Online Portuguese Media

Salomé Esteves<sup>(✉)</sup> and Marco Neves

CIAUD – Research Center for Architecture, Urbanism and Design,  
Lisbon School of Architecture, Universidade de Lisboa, Rua Sá Nogueira,  
Pólo Universitário, Alto da Ajuda, 1349-063 Lisbon, Portugal  
r.salome.esteves@gmail.com, mneves@fa.ulisboa.pt

**Abstract.** Infographics are an effective way to transmit messages, both as an information design artifact and as a journalistic piece. Its fundamental components are information, composition, typography and color. In this study, the main focus is the usage of color in infographics in online Portuguese media, particularly in generalist newspapers. We intend to discover if the color usage is different in interactive and static infographics or if color is applied to infographics unrelated to its interactive nature. The main method of research was a comparative case studies, based on the aggregation, organization and analysis of color samples of graphics, backgrounds and typography of static and interactive infographics in six newspapers. In this process, conversion of RGB samples to Natural Color System (NCS) was pivotal for the their effectual mapping in the color spectrum, according to luminance, saturation and tone. The study led to conclude that online infographics tend to have light and saturated colors in graphics, light colors or white in backgrounds, and saturated colors and black in typography. There were no significant differences between static and interactive infographics, neither in terms of number of colors applied or in aspects of luminance, saturation and tone. In both cases, there was a prominence of the tones of yellow, red and blue in the graphics and neutrals in backgrounds. In what concerns typography, the samples of colors where distributed in the spectrum, with no clear prominence of any tone.

**Keywords:** Information design · Interaction design · Journalism · Digital media · Color

## 1 Introduction

An infographic is consensually [1–5], described as the result of the transformation of complex data into a graphic composition with the intent of facilitating and promoting users' understanding of the message. Its main purpose is to be useful [4] and effective [6]. The primacy of the message traces back to the origin of the term infographics (information graphics), which is grounded in Journalism [7]. In this field, it integrates the discipline of visual journalism [8], because of its usage of visual languages (graphics, diagrams, illustrations, etc.) to convey messages otherwise expressed through words.



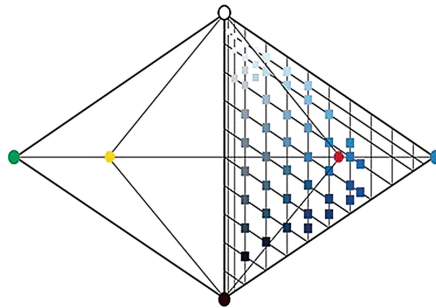
According to Wong [9] an infographic actually results of the combination of typography, design and color. This research focuses in the latter element. To Cairo [4], color is fundamental to unveil and distinguish important parcels of information, namely using contrasts of saturation, luminance and tone. Both authors agree that designers should use a limited and cohesive color palette to keep the reader/user focused on the information. But does this happens in practice? Do news outlets have specific color schemes or do they chose them according to themes of particular editorial choices. Then, the research question was raised: how are Portuguese media using color on the infographics published in their websites?

To answer the question, we took into account: the frequency of digital infographics' publication; trends and patterns in colors for backgrounds, typography and graphics; the relation between the visual identity's general color palette and the colors of each infographic; and the differences and similarities between news outlet (both daily, weekly and digital newspapers).

The analysis assayed the last 10 infographics published by the chosen generalist news outlets between 22nd of April 2017 and 22nd of April 2018. Our study focusses on the websites of the daily newspapers Público, Jornal de Notícias, Correio da Manhã and Diário de Notícias; the weekly newspaper Expresso and the digital Observador. Both I (daily) and Sol (weekly) were in the initial group, but were later removed due to the lack of infographics published in said period.

## 2 Methodology

In this study, we used a qualitative non interventionist methodology. First of all, we conceived a analysis sheet, to collect the following information: news outlet, author, data, title, theme, and the color samples of graphics, backgrounds and typography. The latter was accomplished with the collection of all the RGB color samples. Then, the samples were organized and classified according to NCS (Natural Color System) (Fig. 1). This system aims to identify colors the way they are perceived by the human eye [10], through the positioning of each sample in a three-dimensional space. This space is delimited by luminance, saturation and tone. On the other hand, it considers the six elementary colors perceived by humans: yellow (Y), red (R), blue (B), green (G), white (W) and black (S).



**Fig. 1.** The Natural Color System's color space

### 3 Case Study

The first step was the collection of the sample of analysis. We identified and labeled a total of 60 infographics, 10 from each of the eligible news outlets. Then, we collected the color samples from the infographics, and grouped them by news outlet. This process was repeated thrice, for backgrounds, typography and graphics. In total, we assembled and identified 367 color samples. Lastly, we organized the samples in the NCS plans according to our previous categorization (Fig. 2). The corporate identity color of each news outlet was added to each plan, because it was frequently used in infographics.

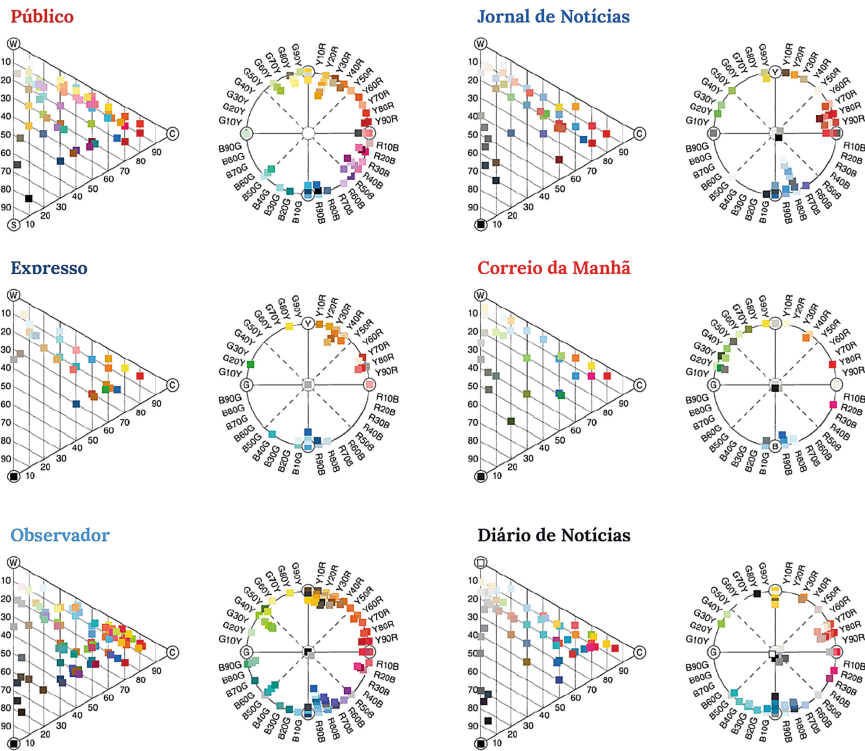
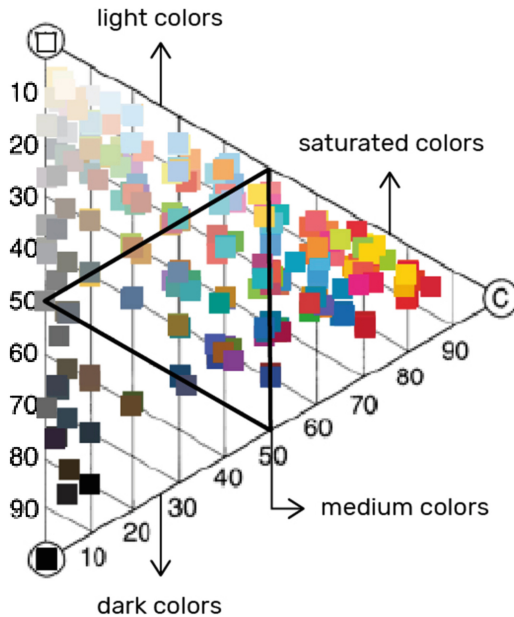


Fig. 2. All color samples, by news outlet

Since it became clear that colors tended to be applied repeatedly throughout the infographics, we gathered and analyzed all the samples together (Fig. 3). When looking at the big picture, it easy to identify a general preference for light and saturated color, instead of dark and medium colors. This pattern is clearly visible in the image below.



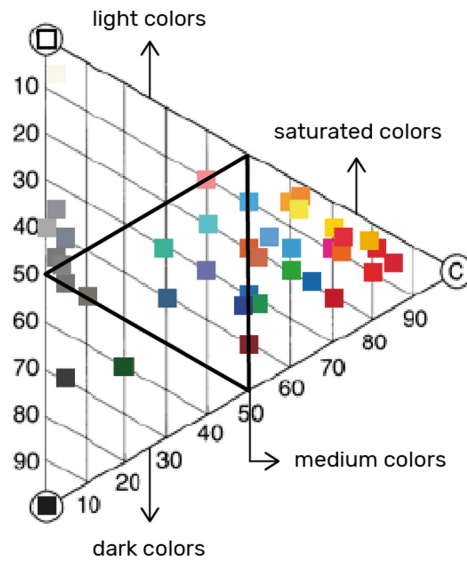
**Fig. 3.** All color samples, organized by luminance and saturation

The usage of light colors is also prominent when analyzing backgrounds. From the 60 infographics, 42 (70%) have white backgrounds, 13 (21%) have light colored backgrounds, and only 6 (10%) have dark backgrounds. The last 2 (3,3%) have photographic backgrounds. This phenomenon is more evident in *Diário de Notícias* and *Correio da Manhã*, which demonstrate a wide variety (8 and 7, respectively) of light colors in backgrounds.

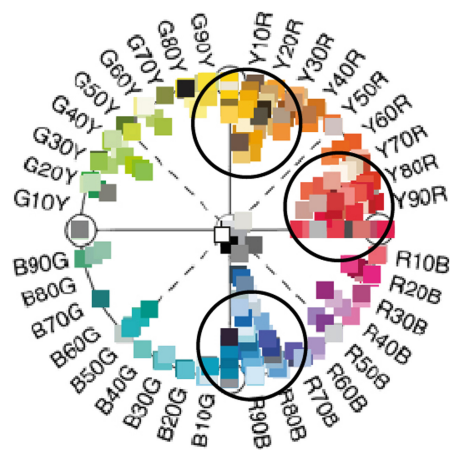
When looking into the typography (Fig. 4), there was also a clear preference for saturated colors, particularly in *Jornal de Notícias* (5 samples), *Correio da Manhã* (8 samples) and *Observador* (8 samples). These saturated colors are usually applied in light or white backgrounds. However, in 48 from the 60 infographics (80%), there is black text. White or light colored text is always found in saturated or dark colored graphics and backgrounds or over photography.

In terms of tone, there is also a clear color pattern across the 6 news outlets. When analyzing colors in graphics, the 290 color samples allowed us to unveil the preference for yellows, reds and blues. This is visible by the repetition of color samples in the codes Y-Y30R, Y70R-R and R80B-B (Fig. 5).

Then, it came the time to establish a comparison between static and interactive infographics. And, unlike thought previously, there were not any visible differences between the two groups. Among the 60 infographics in this analysis, only 14 were interactive, as opposed to 46 static infographics. This numbers only reflects in the



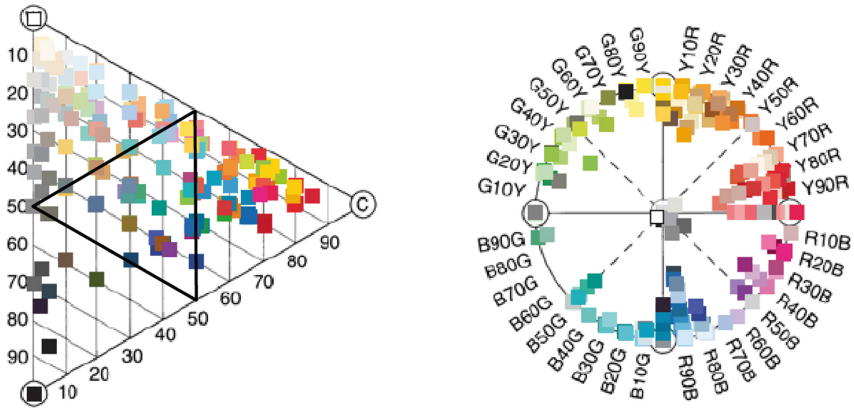
**Fig. 4.** All color samples in typography, organized by luminance and saturation



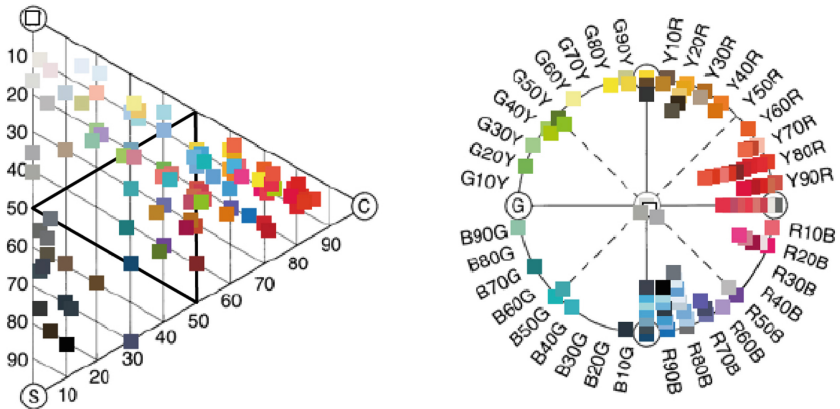
**Fig. 5.** All color samples in graphics, organized by tone

number of color samples collected, because even if the two groups aren't equally represented, they show similar patterns in usage of colors. Figure 6, static infographics, and Fig. 7, interactive infographics, clearly show the similarities between them. The one visible difference between them is that interactive infographics show a prominence of bright reds, which are less representative in static infographics.

During the analysis, the correlation between number of samples and frequency of publication became notorious. Later, we could attest that, in fact, the news outlet that publishes the least amount of infographics - Observador (with a frequency of,



**Fig. 6.** All color samples in static infographics



**Fig. 7.** All color samples in interactive infographics

approximately, 1 infographic in 29 days) - is also the one who uses a greater quantity of colors (81). On the opposite side, *Correio da Manhã* (10 infographics in 4 days) applied only 28 colors, in total. In general, and across all six news outlets, a smaller number of colors signifies a repetition in their usage, which strengthens the corporate visual identity. However, this last statement cannot be confirmed by the present research.

In terms of typography and backgrounds, this correlation between frequency and number of colors was non-existent. It is, nevertheless, possible to state that *Correio da Manhã* uses the same colors in both typography and graphics, which does not happen in any other news outlet.

## 4 Critical Assessment of Results

Considering the results of data collection and analysis, it is possible to distinguish the news outlets who chose the color palettes of their infographics according to its theme and the ones who do it according to the corporate visual identity. The first would be the ones who present a higher number of color samples, since each theme might require very different colors instead of perpetually applying the same colors. It should be natural that the news outlets with a lower number of samples would be the ones with a higher publishing frequency, since choosing colors takes more time than using a predefined palette. However, this research was not extensive enough to affirm that as a rule, neither in static nor interactive infographics. *Correio da Manhã* and *Expresso* are the news outlets which tend to repeat the same colors throughout all their infographics, while the rest (*Público*, *Jornal de Notícias*, *Observador* and *Diário de Notícias*) usually use a wider, more varied selection of colors, that are interchangeable according to thematic.

*Observador* is the news outlet with the biggest number of color samples in general and the highest quantity of colors in each individual infographic, alongside *Público*. As all of their infographic contents are created using an online tool - Infogram - it safe to say that colors are also predefined according to number of variables and contrast between them. This would explain why there are so many color samples for very similar shades and why they aren't coherent between them.

It is equally interesting the similarity of tones used by different news outlets. The curious phenomenon is that the bigger difference between the six news outlets is the number of colors not the colors per se. This pattern is evident in both hue, luminance and chroma and in both static and interactive infographics. Tufte [11] states that colors form nature - blues, greens and grays - allow for the creation of visual harmonies that are familiar and pleasant to the human eye. As the analysis uncovered, Portuguese media outlets tend to avoid greens in favor of other colors, which contradicts the author's statement. Years later, Cairo [4] asserted that saturated and bright colors are useful and appropriated to highlight more important parcels of information because they are immediately recognized by the human eye as something radically different. This would explain the preference of tones of red across all infographics in all news outlets. Cairo's statement also justifies why so many infographics present so many contrast by saturation: when bright or saturated colors appear next to or over lighter colors or white [12]. This kind of contrast is pivotal for digital legibility and readability, specially because reading in screens is more challenging to the human eye than it is reading in paper [13], which gets even more difficult as the size of screens diminishes. Color contrast is particularly important to readability and legibility in smaller screens, such as smartphones and tablets, because reading in these devices is expressly more difficult [14]. To ease this difficulty, Mills and Weldon [15] believe that text legibility is higher when the contrast between type and background is polarized, as it is in black and white. The authors affirm that luminance is the fundamental factor in the reading process. Furthermore, a pronounced contrast between graphic elements (graphics and text) and background can improve the reading experience of all users, but specially seniors and people with visual deficiencies [16].

However, Zuffi, Brambilla, Beretta and Scala [16] claim that a color contrast doesn't equal higher readability, if the difference between luminance in both colors isn't sufficiently high. Legge, Parish, Luebker and Wrum [17] state that contrast in tone and contrast in luminance play very different roles in legibility and readability and that both can be equally efficient when used right. Taking all this into account, it is not surprising that the vast majority of the infographics in this study presents black text over white background, once this is the most legible combination.

## 5 Conclusion

By the end of this research, we can affirm that Portuguese news outlets don't present much differences in the usage of colors in digital infographics in their websites, both in static and interactive. The six general color palettes were concordant in terms of saturation, luminance and tone. Every news outlet shows a preference for light colors for graphics and backgrounds, saturated colors for graphics and black for text. There is also a prominence of tones of yellow, red and blue across all static and interactive infographics. With red being a particular strong color in interactive infographics.

The fact that, regarding contrast between typography and background, there are not big differences between static and interactive infographics, leads to the conclusion that the choice of colors is more related to the pursuit of readability and legibility than to the interactive nature of infographics. And given that the comprehension of the message by users is the main objective of any news outlet it is justifiable that every decision revolves around it. It must not be forgotten that an infographic in a journalistic context is a piece of news and although it is also a design artifact, it isn't usually conceived as one. It must not be forgotten that journalists usually design infographics in news outlets and that they might lack design competences. Or that, even when designers or design teams conceive infographics, they usually follow colors, types of graphics or typography previously designed for the company, which forcibly limits choice.

However, these news outlet also differ in number of samples versus frequency of publication of infographics. In general, the newspapers that publishes the most infographics are also the ones with fewer color samples. The latter are also the ones who tend to repeat the color scheme of their visual identity in their infographics. This leads to the perception of a stronger corporative image. On the other hand, more complex infographics - with particular color schemes - have the feel of a design project, with builds the credibility of the content in itself.

In future investigations, it would be interesting to include sports and economic newspapers, as well as weekly news magazines. It would also be pertinent to test with users how the repetition of corporative colors in infographics and specific color schemes affect the overall perception of the brand in terms of trust and credibility. In what concerns Design, it could be pertinent to study the correlation between quantity of colors and complexity of infographics, in terms of composition, types of graphics and typography.

**Acknowledgments.** The authors would like to thank the funding support by the Foundation for Science and Technology of the Ministry of Science, Technology and Higher Education of Portugal under the project UID/EAT/04008/2013.

## References

1. Ellison, A., Coates, E.: *An Introduction to Information Design*. Laurence King, London (2014)
2. Tufte, E.R.: *Envisioning Information*, 14th edn. Graphics Press LLC, Cheshire (2013)
3. Petterson, R.: *Information Design: An Introduction*. John Benjamins Publishers, Eskilstuna (2002)
4. Cairo, A.: *The Functional Art: An Introduction to Information Graphics and Visualization*. New Riders, San Francisco (2012)
5. Simiciklas, M.: *The Power of Infographics: Using Pictures to Communicate and Connect with Your Audiences*. Que, London (2012)
6. Tufte, E.R.: *The Visual Display of Quantitative Information*. Graphics Press LLC, Cheshire (2007)
7. Krum, R.: *Cool Infographics: Effective Communication with Data Visualization and Design*. Wiley, Hoboken (2013)
8. Farnsworth, A.: What is visual journalism? BBC News (2013). <http://www.bbc.com/news/blogs-the-editors-22483705>
9. Wong, D.M.: *The Wall Street Journal Guide to Information Graphics: The Dos and Don'ts of Presenting Data, Facts, and Figures*. W. W. Norton, New York (2010)
10. Pernão, J.C.: *A cor como forma do espaço definida no tempo. Princípios estéticos e metodológicos para o estudo e aplicação da cor em arquitectura e nas artes*. Faculdade de Arquitetura da Universidade Técnica de Lisboa (2012)
11. Tufte, E.R.: *Envisioning Information*. Graphic Press, London (1990)
12. Itten, J.: *The Elements of Color*. Van Nostrand Reinhold Company, New York (1970)
13. Nielsen, J.: *Why Web Users Scan Instead of Reading*. Nielsen Norman Group (1997). <https://www.nngroup.com/articles/why-web-users-scan-instead-reading/>
14. Góczy, Z., Gazdik, R.: *Contrast Rebellion* (2011). <http://contrastrebellion.com/>. Accessed 21 May 2018
15. Mills, C.B., Weldon, L.J.: Reading text from computer screens. *ACM Comput. Surv.* **19**(4), 329–358 (1987). <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.513.2691&rep=rep1&type=pdf>
16. Zuffi, S., Brambilla, C., Beretta, G., Scala, P.: Understanding the readability of colored text by crowd-sourcing on the Web. Hewlett-Packard Development Company, L.P. (2009). <http://www.hpl.hp.com/techreports/2009/HPL-2009-182.pdf>
17. Legge, D.E., Parish, D.H., Luebker, A., Wurm, L.H.: Psychophysics of reading. XI. Comparing color contrast and luminance contrast. *J. Opt. Soc. Am. A Opt. Image Sci.* **7**(10), 2002–2010 (1990). [https://www.researchgate.net/publication/20925172\\_Psychophysics\\_of\\_reading\\_XI\\_Comparing\\_color\\_contrast\\_and\\_luminance\\_contrast](https://www.researchgate.net/publication/20925172_Psychophysics_of_reading_XI_Comparing_color_contrast_and_luminance_contrast)





# Information Design in Presentation, Interpretation and Dissemination of Natural and Cultural Heritage

Cristina Santos<sup>1,2(✉)</sup>, Maria João Pereira Neto<sup>1</sup>, and Marco Neves<sup>1</sup>

<sup>1</sup> Lisbon School of Architecture, CIAUD – Research Center in Architecture, Urbanism and Design, University of Lisbon, Lisbon, Portugal

{mjoaopneto, mneves}@fa.ulisboa.pt

<sup>2</sup> Polytechnic Institute of Beja, Beja, Portugal

cristina.santos@ipbeja.pt

**Abstract.** It has been established that an attractive heritage presentation is crucial for successful media coverage of natural and cultural heritage. New infographic technologies and audiovisual languages can accomplish this by communicating complex processes in simple, understandable information, thus providing a high-quality cultural experience to visitors. This study highlights the importance of information design in interpretation, presentation and dissemination of heritage, and in prompting visitors to direct their attention more closely to singularities and distinct heritage aspects of a place. Through a theoretical reflection and presentation of several examples, we strengthen guidelines that we think are determinant for way heritage is perceived and informed to public, further improving systems and processes used for integrating infographics into communication materials. We argue that an attractive and functional heritage presentation is crucial for its successful media coverage and we highlight the importance of infographics and graphic identity in heritage information and in preserving its memory.

**Keywords:** Information design · Infographics · Natural and cultural heritage · Wayfinding systems · Cultural tourism

## 1 Introduction

Many municipalities see tourism as an opportunity for development in their region, and make a significant investment in media and publicity to attract tourists. However, it is often placed too much emphasis on the tourism product itself and too little attention to goals and desired effects that users seek to achieve when visit a place. Therefore, there should be a clear and conscious initial planning, which establishes relationship between goals, content, graphic design and physical location. There are still many examples of “poor” information about heritage sites, which can be decisive for success of a tourist destination. We need to communicate, inform and make heritage accessible to an audience that sometimes is completely unaware of what they are visiting.

Having these previous premises as a starting point, we aim with this study: to use information design to benefit tourism, more specifically cultural tourism and to find

effective solutions in presentation and communication of its natural and cultural heritage; to relate some theoretical foundations underlying heritage and cultural tourism, information design and graphic design areas; to demonstrate how visual information can contribute to a deeper knowledge of specific peculiarities of a certain region/location and present solutions that have an accessible and high quality information, aiming to have a greater perception and dissemination to a wider audience; to study and clarify the importance of graphic identity in heritage sites presentation and promotion in order to reinforce their differentiation, as well as the experience visitor has on location; to emphasize information designer role as informational message decoder using a visual language that aims to present a complex information message in an accessible and simple way without losing its content.

It is important to mention that some of the considerations and examples presented in this article are the result of a deep research that took place previously and that interconnected information design with cultural and natural heritage.

Having the following hypothesis as initial premise: information design may be indispensable for a greater perception and comprehension in communication of heritage messages by presenting visually and exclusively, information that disseminates unique aspects of natural and cultural heritage of a place, we defined a qualitative study based on a methodology justified by literature we find most relevant considering the proposed objectives in the cultural tourism, heritage and information design areas; we observed and described specific examples and conducted a visual survey of infographics about heritage through a website where we compiled these references.

## 2 Heritage Presentation, Interpretation and Promotion

According to Hernández and Tresserras [1], heritage role is now seen as socio-economic facilitator and as a privileged agent of local development. Besides, according to authors, cultural heritage is one of the basic resources for setting up a tourist destination. The way heritage is communicated, the experience in a certain region, the customs of a local community, is, therefore, very important to attract potential tourists who wish to escape standard mass tourism circuits and are interested in more specific issues of a certain region. Cultural tourism manifests itself as a way of consumption of realities that refer to heritage of a population, a nation or a continent, which someone wants to know and understand to be able to enjoy its meaning and contemplate it fully [2]. Queirós [3] emphasizes that, nowadays, cultural tourism has become a “mass tourism”, especially of middle class; and the “taste” of this class is a concept that must be considered together with the voyage “motivation”, identifying itself more with the products of culture in its double dimension, aesthetic and ethical. Same author also states that cultural tourism incorporates content and matters from culture and scientific culture fields, particularly museology and heritage sciences, but adjusted to the dynamics and the tourism economy goals, in the management of their value chains. Emmendoerfer and Ashton [4] state that tourism can be an efficient way to (re)define and (re)value culture and local/regional identity in territories and that tourism promotes the consumption of identity, culture and what is produced and lived locally, influenced by the atmosphere and ambience of the local cultural capital. Authors conclude that tourism can be considered as one of the

development sources that take into account the consumption of cultural goods and services. Previously, Guerreiro [5] reinforced the idea that we should pay more attention to environmental, cultural and historical heritage of each region, therefore, being necessary to emphasize regional and local specificities, because this is the only way that each of these regions should assert and stand out in the competition panorama between regions and the European context we are inserted. Besides, European Union, in 1993, already had reinforced the idea that cultural tourism contributes to strengthen cultural identity of the community, allowing to establish differences and similarities between the member countries [1].

According to Fernández and Ramos [6], cultural heritage of a country, region or city is comprised of all those elements, tangible or intangible manifestations produced by societies, the result of a historical process where the reproduction of ideas and materials constitute factors that identify and differentiate that country or that region. For Alves [7], heritage encompasses the specificities of a culture, population quotidian, in its form of conviviality and expression, not being imposed, created and transferred, but that represents values attributed to works of art, buildings or any other object that has a special meaning for individuals and communities.

Therefore, we can state with conviction that information is an essential component of heritage - for example, to know how, when and by whom a musical instrument was played, enriches our knowledge of the human context that proceeds it - and the transmission of this information turns out to be as important as the object itself [6]. According to Hernández and Tresserras [1], the interpretation facilitates the presentation and social use of heritage, and allows us to offer different interpretations and options for an active use of it. Alves [7] states that the reasons and motivations of tourists when they are choosing a location to travel, are carried through their symbols and signs and the constant coming and going of tourists, they are processed by symbolic exchanges through colors, shapes, ways, smells and techniques. The tourist destination to meet needs and desires of your visitors, encompasses several informations of its space, senses and symbolic meanings attributed to tourism between the different social actors [7]. Mental image formed of destination to be visited, is part of motivation that drives the individual to travel to the location to be visited [8]. Gallarza, Saura and García [9] corroborate this statement by saying that the image of the tourist destination is important because it affects the individual subjective perception and thus the behavior and choice of destination. Yázigi [10] highlights the need to consider the existence of *"place's soul"*, stating that soul is the best part that remains of a place and therefore transcends time. Same author points to an interaction of people who nourish feeling towards their place of living, demonstrating that there is soul when there is passion of people for the place. For Norberg-Schulz, the term *"place"* is much more than one location: *"In general, nature forms an extended comprehensive totality, a 'place', which according to local circumstances has a particular identity"* [11].

So that heritage presentation can meet a series of assumptions in order that visitor has a cultural experience of quality, this presentation will have to go through dissemination of speech to a diversified audience sectors, by an attractive communication speech using necessary and possible means to stimulate a visit of quality, by using new technologies and audiovisual languages to communicate complex processes [1]. According to Hernández and Tresserras [1], heritage presentation must include

publications that make available various levels of information to public, such as leaflets with general information of the institution and services it provides, maps and infographics to facilitate orientation of visitor, well-illustrated pocket guides, educational books and games for children and parents to visit it with their children, monographs on specific contents and specialized guides for teachers. It is important to take into account the design of strategies for presenting heritage to all audiences. However, this heritage presentation shouldn't be limited to the direct contact between the public and heritage, but should also have as main purpose a greater understanding and communication of what is exposed [2]. According to Silvan [12], heritage presentation must be done in an attractive way, stimulating visually and causing reflection, while maintaining the historical accuracy and respecting the heritage integrity.

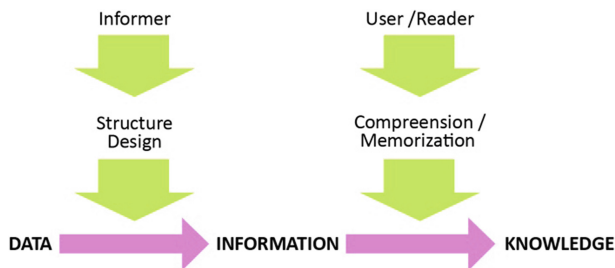
In the same way that presentation "*in situ*" allows the contact between visitor, places and monuments, besides helping to promote the heritage among general public, there are other means, such as television, press, radio and new technologies, which contribute positively to making it more accessible. New technologies enabled enormous possibilities of heritage diffusion, by allowing incorporation of texts, images and sounds that offer a more effective reading of information. Through interactivity, users can manage the information freely, having a large database on which results of work in the field of a general or specific heritage can be concentrated [2]. When we talk about new technology, we are also talking about new forms of heritage media coverage; Ioannides et al. [13] refer the benefits of exploitation the modern technological advances, in the electronic restoration, preservation and documentation of any kind of cultural heritage. A feature mentioned often in this matter is the increasing use of 3D digital modeling in cultural heritage field as a very effective and intuitive form of communication [14]. According to Manferdini and Remondino, in the last few years, the use of 3D technology has represented a fundamental shift of our cognitive model - the availability of 3D digital replicas, compared with the usual photos, videos or drawings, enables to communicate scenes or objects that have intrinsic three-dimensional features more effectively. This form of representation has changed the way we access and exchange knowledge, expanding possibilities of interpretation and analyze of the past, helping to simulate the reality more objectively and reliably [14].

Heritage divulgation integrates necessarily graphical definition of materials in which the information is presented, and therefore, the definition of trademarks or logos associated with these communication materials. The brand will be composed by the region cultural identity and must transmit the product concept, attributes and benefits [15]. According to Lopez [16], brand has the idea of distinction implicit, with the aim of distinguishing one thing from another; *branding* is to highlight one thing to be distinguished from another. The same author states that something "branded" is highlighted, belongs to someone or means something.

For Brizzola [15] in the positioning there should be a careful consideration of the message and the amplitude value of cultures that are being promoted. Images and phrases used must stimulate the imagination of the tourist, motivating the tourist to travel - promotion of a destination must reflect region reality, avoiding that culture becomes only a commercial show devoid of any meaning and significance (for example, *Santiago de Compostela - the Pilgrims City*).

### 3 Information Design in Heritage Information Developing

According to Wildbur and Burke [17], information design as a discipline, has efficient information communication as the main task, and this implies responsibility for content presentation to be both precise and impartial. Unlike advertising or marketing, in which the main purpose is to persuade user to perform a certain action, information design tries to present all objective data required to allow user to make some kind of decision. According to Sless [18], the main focus of interest in information design is the dynamic interaction between people and information that exists in the action, in what people do with information and the way appropriate meanings for actions are constructed. Horn [19] defines information design as the art and science of preparing information, so, it can be used by humans easily and with the purpose to serve as a tool to guide actions of users/readers. According to the same author, the very word “design” implies structure: the work of information designer is, precisely, to shape what by nature seems chaotic and incomprehensible due to its great complexity. By this process, data (which by themselves have no informative value) are transformed into information (i.e., give data meaning through its organization), which user can understand, memorize and transform into knowledge (Fig. 1). It is necessary to clarify that in this scheme, “data” isn’t restricted to what is quantitative, but refers to the discrete result of any observation of reality [20].



**Fig. 1.** The process of information visualization (adapted from Cairo [20]).

According to Mijksenaar [21]: “*images provide a different view of things and motivate the user*”. Lester [22] says that visual messages are a powerful form of communication – they stimulate both emotional and intellectual responses and therefore make us think as well as feel.

When an information designer is designing an infographic, will have to consider some aspects such as, facilitate attention, perception, information processing and memorization. One of the first issues of an information designer is to capture the attention of his/her audience. So, it is up to the designer to retain audience attention [23] and to that purpose, it is important that information materials facilitate human attention. According to Pettersson [23], the concept of “*perception*” is a collective designation for different processes in which an animal or a person obtains information about the outside world. We organize and analyze information we pay attention. Colors, illustrations, photographs, lines, images, sounds, symbols, texts and words

must be integrated so that they can be meaningfully interpreted as a whole rather than a number of individual elements. Perception of two-dimensional or three-dimensional representations implies a rapid, parallel, simultaneous and holistic process. Another important consideration is the fact that memorization is greater when a verbal and visual code are activated at the same time instead of only one.

### 3.1 Examples of Information Design in Interpretation, Presentation and Dissemination of Heritage

Next, we present some case studies that aim to justify and illustrate the role of the information designer in decoding information and in the interaction of the mentioned areas, contributing to the conclusions seek to answer the initially proposed goals.

**New Maia Language by Frida Larios.** Frida Larios studied how she could adapt the Maia writing through a use more contemporary, and the results of her six-year research is a graphic system called the *New Maya Language*<sup>1</sup>. Larios has redesigned some ideograms of this culture to communicate concepts and complete sentences, revealing how these symbols can be interpreted and combined [24–26]. In this project, we consider that heritage is reinterpreted and its memory reinvented and preserved through a modern graphical approach as part of a heritage site of UNESCO World Heritage, *Joya de Cerén* in El Salvador<sup>2</sup>. In the museum of Joya de Cerén, Frida made a statement of her own on the walls, using some of the “*pictoglyphs*” that are in her book “*Nuevo Lenguaje (Visual) Maya*”. “*Pictoglyphs*” narrative of the New Maia Language tells the story of archaeological place of UNESCO World Heritage Site, named “Pompeii of the Americas” because it was preserved under five meters of volcanic ash for almost 1400 years [27]. The “*Pictoglyphs*” almost tell the story by themselves and Larios has taken a big step farther and created a trilingual (Spanish-English-Maya) children’s book, “*The Village that Was Buried by an Erupting Volcano*” [26] also assuming an educational role for the younger generations, in order to make them aware of the heritage that also belongs to them.

It is also important to highlight the importance of design area in reinventing heritage and in the conservation of its memory, its capacity to summarize, prepare, interpret and create realities, being a powerful tool to represent and revive the past. Artists and designers prove to be decisive for more public enjoy and preserve the patrimonial heritage and the work of Frida is a good example of this principle [27].

**Stamps of the Battle of Trafalgar by Peter Grundy.** Peter Grundy (in partnership with Tilly Northedge), has developed works in information design for the most diverse areas; the work that we highlight is once again an example of the simplification that Grundy always sought; this collection of stamps of the Battle of Trafalgar, contains a large amount of data through a highly simplified visual language, which gives us

<sup>1</sup> *The New Maia Language*, a 115 pages book, created and designed, during the Master Degree in Communication Design of the University of the Arts London.

<sup>2</sup> *Joya de Cerén* was commemorating 20 years of being designated a UNESCO World Heritage Site. To celebrate this historic date, the Culture Secretariat of the Presidency of El Salvador order some murals to Frida Larios in 2013.

information about food of sailors, location of the Battle of Trafalgar, how many men crew had and their home countries among many other data. We find this example interesting due to graphic simplified form that Peter Grundy tells us this episode history. Peter Grundy describes his work as “*making visually complex things simple*” [28]. By examining the simplicity of Grundy work, it is useful to divide its work into three main categories - pictograms, diagrams and narratives. All exhibit a certain primitivism (influences of Egyptian hieroglyphics, Aztec symbols and moments of modern art) and where we can establish some common guidelines with the work of Frida Larios already mentioned previously [28, 29].

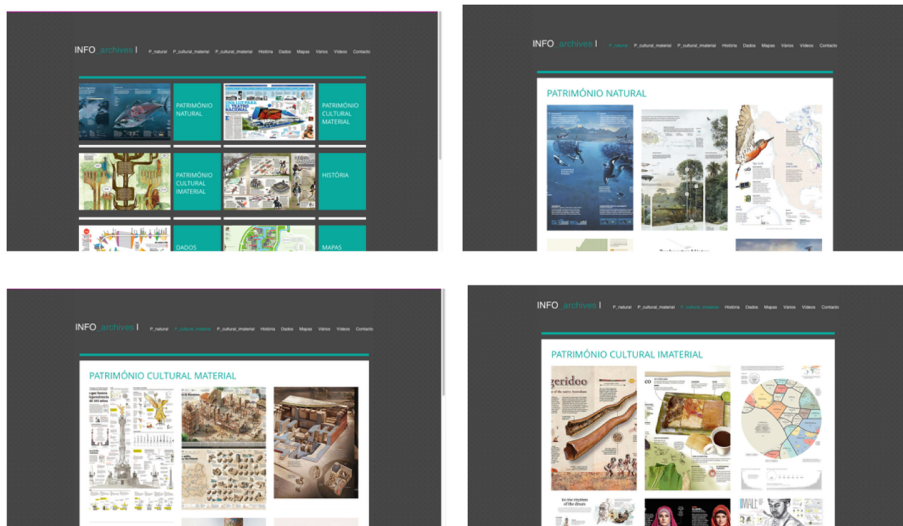
***Flyers for Sintra City Parks (Portugal) by Anyforms.*** Cultural Landscape of Sintra was classified as a World Heritage Site in 1995. In the beginning there were only 5 flyers with local infographics (*Moorish Castle, Pena National Palace, Monserrate Palace, Convent of Capuchos* and a general flyer with the location of the four monuments, contacts and useful information about Sintra city), but recently they were reissued and were added three additional monuments, *Sintra National Palace, Chalet of the Countess of Edla* and *Royal Palace of Queluz* [30, 31].

This is an example of high quality of infographics use, contributing greatly to the increased awareness of existing and protected natural and cultural heritage - according to what Luis Taklim (company owner) said in an interview, these flyers have increased the flow of visitors and contributed to a greater guidance and exploration of places [32]. Still in this interview, Taklim emphasized the importance of designer understands the use of abstraction. If sometimes in infographic is essential to simplify representation of reality, so, that crucial details to understand information can stand out from background (transport maps are the best example of this fact: most of land details are eliminated and pathways are drawn with thick lines and dominant colors - as is the case of London underground map) [33]. On the other hand, the flyers developed by Anyforms for Sintra Parks demonstrate that sometimes a visual representation more faithful to reality may be more useful to access information. So that infographic also has a promotion function it needs to be appealing, so that attract people and arouse curiosity; by fulfilling this crucial goal, Taklim highlights the use of several illustrations and 3D representations, in order to create certain environments that arouse the curiosity of people [32].

**Visual Research of Several Infographics Examples Representing Natural and Cultural Heritage.** One method used for this study consisted in developing a website that compiles the infographics examples researched considered relevant to presentation of information in natural and cultural heritage area (tangible and intangible). In Fig. 2, we can see some pages of the website *INFO\_archives* [34], where we can observe these infographics examples.

***Wayfinding Design for Downtown Brooklyn (New York, USA) by Two Twelve.*** We believe that wayfinding designs are important examples for the objectives of this study as they often combine graphic identity with guidance of the places to visit, using infographics as a key resource to help people find the right direction. Berger [35] emphasizes that if information presented to visitor is simple, clear and consistent,





**Fig. 2.** Some website *INFO\_archives* pages: Home page, Natural Heritage page, Tangible Cultural Heritage page, Intangible Cultural Heritage page (Figure translation: Patrimônio Natural = Natural Heritage; Patrimônio Cultural Material = Tangible Cultural Heritage; Patrimônio Cultural Imaterial = Intangible Cultural Heritage).

visitor will perceive the place in a true and welcoming way. To achieve this goal, should be developed a comprehensive and integrated signage plan.

We highlight the project developed by information design american company, *Two Twelve*. We consider this project important as a reference because it was created the brand *Downtown Brooklyn* and the end result was provided by a long research that involved residents, tourists and business people, so that territory and opportunities were better understood. Logo and slogan “*You Can See the World from Here*”, were the starting motto to define design position, wayfinding strategy and signage design [36].

## 4 Results

According to the analyses performed in this study, it can be justified that an attractive heritage presentation can be crucial for the successful media coverage of natural and cultural heritage.

New infographic technologies and audio-visual languages can accomplish this by communicating complex processes into simple, understandable information, thus providing a high-quality cultural experience to visitors.

Among new technologies, we highlight the use of 3D technology (example of Anyforms’s work) that allows communicating scenes or objects that have intrinsic three-dimensional characteristics more effectively.

In the examples studied, we can observe that some specific heritage features are more easily communicated through visual language and the use of visual resources,



such as 3d models or complex illustrations, accompanied by data - all together provide a better understanding of the presented heritage.

The information designer stands out here as a “transformer” by giving meaning to raw data, organizing it and consequently giving informational value, contributing to memorization and knowledge, being responsible to present a complex informational message in an accessible and simple way to be comprehensible without losing its content.

The way heritage is communicated can be crucial to give motifs and motivations for tourists to choose a place to visit, to communicate its symbols and signs, making the tourist to form a mental image connected to destination to be visited. It's important to highlight the importance of design area in reinventing heritage and in the conservation of its memory.

The definition or association of a brand to a heritage area contributes to the definition of its identity, transmitting content, images, ephemeral sensations that help to form psychological concepts about the place, reinforcing the “soul of the place”.

Through the examples studied and presented, we tried to justify all these premises.

## 5 Final Remarks

Cultural and natural heritage are basic resources for setting up a tourist destination to an audience that is increasingly demanding and that seeks to know distinctive and specific aspects of a place that characterize the heritage.

For this reason, information design as a discipline, is essential in the development of promotional and informational materials that seek to attract more public, that are interested in more particular issues of a region, contributing to its development, valuing important regional and local specificities to publicize, memorize and preserve particular natural and cultural heritage aspects.

## References

1. Hernández, J.B., Tresseras, J.J.: *Gestión del Patrimonio Cultural* [Management of Cultural Heritage], 9th edn. Ariel Patrimonio, Barcelona (2007)
2. Hernández, F.H.: *El Patrimonio Cultural: La Memoria Recuperada* [The Cultural Heritage: The Recovered Memory]. Ediciones Trea, Gijón, Asturias (2002)
3. Queirós, A.: Turismo Cultural e Economia do Património [Cultural tourism and heritage economy]. *Revista Turismo & Desenvolvimento* [Tourism Dev. Mag.] **4**(21/22), 107–117 (2014)
4. Emmendoerfer, M.L., Ashton, M.S.G.: Territórios Criativos e Suas Relações Com o Turismo [Creative territories and their relations with tourism]. *Revista Turismo & Desenvolvimento* [Tourism Dev. Mag.] **4**(21/22), 459–468 (2014)
5. Guerreiro, J.: A Valorização de Novos Produtos Turísticos Exige a Formação de Novas Parcerias [Valorization of new tourist products requires the formation of new partnerships]. In: *Encontro Técnico: Novos Consumos, Novos Produtos Turísticos* [Technical Meeting: New Consumption, New Tourist Products], pp. 99–107. Portuguese Tourism Institute, Lisbon (2003)

6. Fernández, G., Ramos, A.G.: Turismo, Patrimonio Cultural y Desarrollo Sustentable [Tourism, cultural heritage and sustainable development]. *Caminhos de Geografia - Revista on-line [Paths Geography - Online Mag.]* 3(7), 1–19 (2002). <http://www.seer.ufu.br/index.php/caminhosdegeografia/article/download/15297/8596>. Accessed Sept 2018
7. Alves, K.: O Turismo Pedagógico como Indutor de Lugares Identitários para Reconhecer, Interpretar e Reservar [Pedagogical tourism as inductor of identity places to recognize, interpret and reserve]. *Revista Turismo & Desenvolvimento [Tourism Dev. Mag.]* 4(21/22), 483–491 (2014)
8. Ramos, S., Ferreira, R., Gandara, J., Lima, J.: A Semiótica Utilizada no Marketing Turístico na Cidade de Curitiba – PR – Brasil [The semiotics used in tourism marketing in the city of Curitiba - PR - Brazil]. *Revista Turismo & Desenvolvimento [Tourism Dev. Mag.]* 1(13/14), 455–464 (2010)
9. Gallarza, M.G., Saura, I., García, A.H.C.: Destination image: towards a conceptual framework. *Ann. Tourism Res.* 29(1), 56–78 (2002). Quoted in Ramos, S., Ferreira, R., Gandara, J., Lima, J.: *Ibid.* 8, 455–464
10. Yázigi, E.: A Alma do Lugar. Turismo, Planejamento e Cotidiano [The Soul of the Place. Tourism, Planning and Daily Life]. Contexto, São Paulo (2001). Quoted in Alves, K.: *Ibid.* 7, 487
11. Norberg-Schulz, C.: *Genius Loci – Towards a Phenomenology of Architecture*, p. 10. Rizzoli, New York (1979)
12. Silvan, R.: The presentation of archaeological sites. In: de la Torre, M. (ed.) *The Conservation of Archaeological Sites in the Mediterranean Region*, pp. 51–59. Getty Conservation Institute, Los Angeles (1997)
13. Ioannides, M., Fellner, D., Georgopoulos, A., Hadjimitsis, D.G. (eds.): Preface. In: *Digital Heritage, Third International Conference, EuroMed*. Springer, Berlin (2010)
14. Manferdini, A.M., Remondino, F.: Reality-based 3D modeling, segmentation and web-based visualization. In: *Digital Heritage, Third International Conference, EuroMed*, pp. 110–124. Springer, Berlin (2010)
15. Brizolla, T.: Turismo Cultural- Orientações Básicas [Cultural Tourism - Basic Guidelines]. Ministry of Tourism of Brazil, Brasília (2006)
16. López, A.: *Manual de Marketing General y de Servicios Turísticos [Manual of General Marketing and Tourist Services]*. Editorial Síntesis, Madrid (1992)
17. Wildbur, P., Burke, M.: *Information Graphics – Innovative Solutions in Contemporary Design*. Thames and Hudson, London (1998)
18. Sless, D.: Theory for practice. *Clear - AIGA J. Inf. Des.* (2005). [http://www.aiga.org/resources/content/1/9/0/4/documents/AIGA\\_Clear\\_Sless\\_Theory.pdf](http://www.aiga.org/resources/content/1/9/0/4/documents/AIGA_Clear_Sless_Theory.pdf). Accessed Aug 2009
19. Horn, R.E.: Information design: emergence of a new profession. In: Jacobson, R. (ed.) *Information Design*, pp. 15–33. The MIT Press, Massachusetts (2000)
20. Cairo, A.: *Infografía 2.0 [Infographics 2.0]*. Alamut, Madrid (2008)
21. Mijksenaar, P.: *Visual Function: An Introduction to Information Design*, p. 36. Princeton Architectural Press, New York (1997)
22. Lester, P.M.: *Visual Communication. Images with Messages*. Wadsworth Publishing Company. A Division of International Thomson Publishing Inc., Belmont (1995). Quoted in Pettersson, R.: *It Depends: ID – Principles and Guidelines*, 4th edn. International Institute for Information Design (IIID), Austria (2012). <http://www.iiid.net/PublicLibrary/Pettersson-Rune-ID-It-Depends.pdf>. Accessed June 2018
23. Pettersson, R.: *It Depends: ID – Principles and Guidelines*, 4th edn. International Institute for Information Design (IIID), Austria (2012). <http://www.iiid.net/PublicLibrary/Pettersson-Rune-ID-It-Depends.pdf>. Accessed June 2018

24. Knight, C., Glaser, J.: Diagramas – Grandes Ejemplos de Infografía Contemporánea [Diagrams - Great Examples of Contemporary Infographics]. Editorial Gustavo Gili, Barcelona (2011)
25. Frida Larios. <http://www.fridalarios.com>
26. Shapiro, E.: The New Maya Language of Frida Larios. Printmag (2014). <http://www.printmag.com/design-inspiration/new-maya-writing-system/>. Accessed Jan 2019
27. Los Blogs de El Faro. Frida, el Lenguaje Maya y Joya de Cerén Frida, [The Maya Language and Jewel of Cerén] (2014). <http://losblogs.elfaro.net/elamigoimaginario/2014/08/frida-el-lenguaje-maya-y-joya-de-ceren.html/> . Accessed Jan 2019
28. Designboom. Peter Grundy (Grundini) Interview (2013). <http://www.designboom.com/design/peter-grundy-grundini-interview/>. Accessed June 2018
29. Grundini. <http://www.grundini.com>
30. Parques de Sintra [Sintra Parks]. <https://www.parquesdesintra.pt/area-profissional/imprensa/mapas-em-pdf-para-download/>
31. Anyform Design Mapas Ilustrados [Anyform Design Illustrated Maps]. <http://anyformsdesignmapas.blogspot.com>
32. Santos, C.: O Design de Comunicação na Área do Turismo Cultural. A Importância da Infografia em Suportes Comunicacionais de Divulgação e Informação, Aplicados a Percursos Temáticos na Cidade de Almada [The communication design in the area of cultural tourism. The importance of infographics in communicational media of dissemination and information, applied to thematic routes in the city of Almada]. Master's thesis. Faculty of Architecture - University of Lisbon, Portugal (2010, unpublished)
33. Cairo, A.: The Functional Art – An Introduction to Information Graphics and Visualization. New Riders – Voices that Matter, San Francisco (2013)
34. INFO\_archives. <http://crispirel.wixsite.com/info-archives>
35. Berger, C.M.: Wayfinding – Designing and Implementing Graphic Navigational Systems. RotoVision, Hove (2009)
36. Downtown Brooklyn – Wayfinding Systems – Two Twelve. <http://www.twotwelve.com/wayfinding-systems/downtown-brooklyn.html>

# **Virtual Reality**



# Evaluation of Behavioral Compliance with Safety Warnings at Different Levels of Cognitive Load in Warehouses

Ana Almeida<sup>1,2(✉)</sup>, Francisco Rebelo<sup>1</sup>, and Paulo Noriega<sup>1</sup>

<sup>1</sup> CIAUD, Centro de Investigação em Arquitetura Urbanismo e Design,  
Faculdade de Arquitetura, Universidade de Lisboa, Rua Sá Nogueira,  
Pólo Universitário, Alto da Ajuda, 1349-063 Lisbon, Portugal  
aalmalmeida.01@gmail.com

<sup>2</sup> CAPES Foundation, Ministry of Education of Brazil, Brasília - DF 70040-020,  
Brazil

**Abstract.** This study aims to evaluate the behavioral compliance with dynamic safety warnings, in different levels of cognitive load in warehouses. Participated in the study forty subjects between the ages of 17 and 47. Participants performed two simultaneous tasks, while compliance with safety warnings was evaluated. Cognitive load had three levels (neutral, low cognitive load, high cognitive load) modulated through difficulty of double task. Behavioral compliance was 77.1% in the condition where there was no double task (neutral condition), in the condition of low cognitive load, 90.7% were consonants, and in the condition of high cognitive load the percentage dropped to 45.7%. Results suggest that the presentation of safety information is sensitive to cognitive load. In a work environment, where the demand for cognitive resources is high, there is a need to design stronger warnings that can increase compliance.

**Keywords:** Virtual reality · Behavioral compliance · Safety warnings · Cognitive workload · Warehouses

## 1 Introduction

A fundamental characteristic of human cognition is the limited capacity to process information, especially about attention [1]. In practice, paying attention to one source of information can interfere with the processing of other information, such as the classic example, keeping your attention on driving while talking to someone using a mobile phone.

There are many studies that explore individual's responses to high cognitive load, particularly in dynamic driving or control situations. This number of studies can be explained by the seriousness that an error can have in dynamic situations like driving or air traffic control situations and the need to, for example, optimize performance by improving the interfaces or types of signals used.

Alongside this proliferation of studies in dynamic situations, there is a near absence of studies that assess the effects of manipulation of cognitive load in less dynamic work situations and where it is also necessary and useful for the safety of workers,

particularly in the identification and compliance with safety notices. Usually the evaluation of the design of safety warnings considers the normal situations where the participant is asked if the warning catches his attention, if he can understand it and what he would do if he saw it daily.

In this study, our focus was on the evaluation of dynamic safety warnings, through the behavior of participants at different levels of cognitive load: neutral, corresponding to a search task; low, corresponding to a search task and simple questions (name, date of birth) and high, with a search task and arithmetic subtractions. We chose a situation of work in warehouses because it is a place where many accidents occur, and we did not find studies in the scope of safety warnings associated with the manipulation of cognitive load.

We know that this type of research, using labor or real situations, may involve high risks and costs [2, 3] because:

- the participant should not be exposed to real risks due to ethical and safety issues;
- in a real scenario dangerous events are rare and unpredictable;
- build a scenario where there is a danger that looks real, but at the same time is safe, requires financial cost, time and effort.

The solution found to these limitations was the use of virtual reality (VR), because it allowed the simulation of almost real critical situations, without exposing the participant to real risks. The creation of a virtual environment made possible the repetition of the experience, how many times it was necessary and the manipulation of the characteristics of the environment without so great financial and time costs. Thus, a virtual reality simulator was developed that allowed to control a situation of cognitive load increase due to double task, which was close to a real situation, yet without compromising the safety of the participants.

The objective of this study was to evaluate the behavioral compliance with safety warnings in different levels of cognitive load, due to double task. This variable was measured by the observation of the participant during the simulation, if he/she complied with the warning even when performing double task.

## 2 Method

### 2.1 Participants

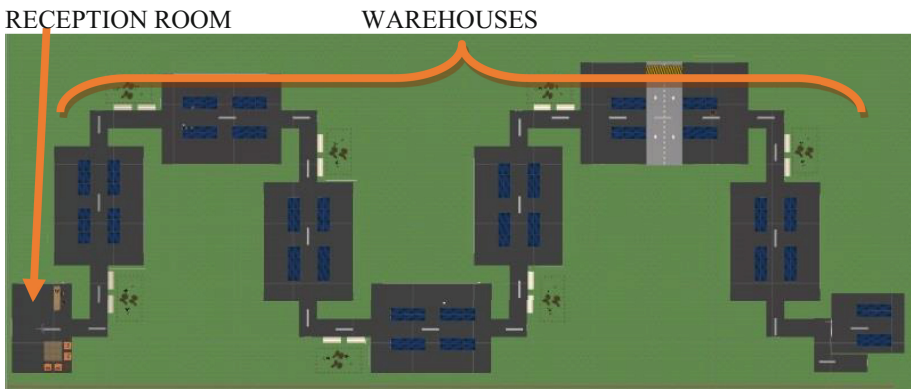
This study had the voluntary participation of 45 individuals, 22 males and 23 females between 17 and 58 years old ( $M = 29/SD = 10.8$ ). Five participants (11%) dropped out because of Cybersickness, two men and three women. The sample consisted of 20 men and 20 women aged 17 to 47 years ( $M = 27.7/SD = 9.6$ ). The educational level varied between the preparatory course and the full doctorate. Exclusion conditions in the study included having dizziness or conditions such as heart disease, depression, or pregnancy.

## 2.2 Apparatus

Tasks were performed on a Desktop Station with an Intel<sup>R</sup> Core<sup>TM</sup>i7 – 4790K CPU processor, 8 GB, NVIDIA GeForce GTX 980 video card. Virtual environment interaction was performed using a gamepad, Head Mounted Display (HMD), model DKII, OCULUS Rift (OLED display, resolution 960 X 1080 per eye, 100° field of view) and wireless PHILIPS earphones, model SHC5102/10.

## 2.3 Virtual Environment

The VE was created according to a desired workplace context. The prototype consisted of a reception room and eight warehouses (Fig. 1). In four of the warehouses there were warnings that were developed in consonance with the ANSI Z535.2 [4] standards, with respect to signal word, color, use of a pictogram and hazard nature, consequences and actions messages. Additionally, the location of the warning was also taken into consideration. Based on previous studies [5], the warning was placed in an uncluttered site and within the individual's field of view. Regarding the environmental modeling, the Unity 3D 4.3 software was used.



**Fig. 1.** VE floor plan

## 2.4 The Warnings

The warnings used in this study considered the common risks found in warehouses and the possibility of being deployed in the developed virtual environment. The four warnings used in the experiment were related to the risks: fall of goods, fall on the same level, vehicles movement and hazardous substances.

## 2.5 Procedure

Before starting the experimental session and after explaining the purpose of the experiment, participants were asked to sign the consent form and fill the demographic questionnaire. The consent form provided the explanation of the procedure as well as

the possibility of risks and discomfort, such as nausea, during the simulation, and stated the feasibility of quit the experience at any time. Participants were unaware of the real purpose of the experiment, it was only said that the aim was to evaluate the virtual environment for recording human behavior data. The experimental session was divided into 3 parts: (1) training session; (2) VR simulation session and (3) response to some questionnaires. The average total time was 30 min.

In the training session, participants were invited to explore a virtual environment and walk through rooms and corridors. They were introduced to the interaction devices to be used and the training session began. They were asked to read the posters they would find, to check the readability issues. The training environment consisted of a reception room and two storage rooms. At the reception was posted a placard with instructions on handling the navigation device in the virtual environment. Six more placards were added, along the warehouses, with instructions of directions to be followed by the participants. In the last warehouse, a trigger-activated script was used to display a message board with a positive or negative feedback depending on the behavior of the participant.

The experimental session began in the reception room where the participant received information, through the headphones, about tasks that would be performed during the simulation. This communication was activated by the investigator through the keyboard. In each warehouse the participant was asked to execute a type of task (i.e., go to the left corridor and say how many units a given box had). As they performed the tasks, they received new tasks until the simulation was complete. In the figures below, you can see the warehouses and the location of the warnings (Figs. 2, 3, 4, 5 and 6).



**Fig. 2.** Reception - beginning of the experience





**Fig. 3.** Warehouse 2 – risk of falling goods



**Fig. 4.** Warehouse 4 – risk of falling on the same level



**Fig. 5.** Warehouse 6 - risk of moving vehicles



**Fig. 6.** Warehouse 8 - hazardous substances

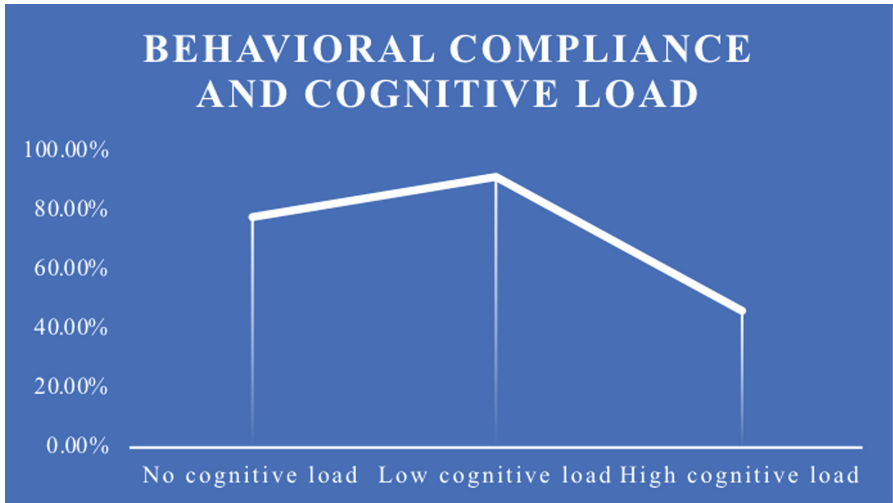
### 3 Results

Since our main study variable was the behavioral compliance with safety warnings in situations of high cognitive load due to double task, we realized that participants were not always in a double task. It was understood, therefore, to look at all observations independently.

A total of 160 observations were performed, of which 113 observations (70.6%) were considered valid and 47 (29.4%) were invalidated. These observations were invalidated when the participants were no longer in the experimental condition under evaluation. This occurred mainly in the condition of high cognitive load, because the participants, due to the complexity of the simultaneous execution of the tasks, stopped the execution of the secondary task in order to perform the main task. In this case, they ceased to be in a high cognitive load condition, so it was decided to invalidate these observations.

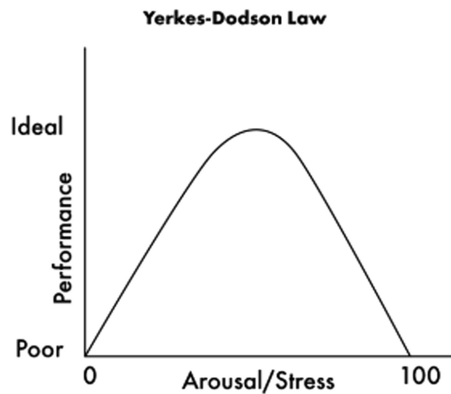
As a result, it can be highlighted that in overall terms, of the 113 valid observations, 73% of the cases were in accordance with the safety warnings. When looking at the behavioral compliance according to the cognitive load, it is verified that in the condition where there is no double task (neutral condition), 77.1% of the observations were in compliance with the warnings, in the condition of low cognitive load, 90.7% were consonants, but in the condition of high cognitive load the percentage dropped to 45.7%. The following chart illustrates these numbers (Fig. 7).

It is possible to verify that from the neutral to the low condition there is an improvement in performance in terms of compliance. However, when we look to the high cognitive load there is a great loss of performance. These results are compatible with the model that relates the level of activation to performance (Yerkes Dodson model (Fig. 8)). Thus, it is justified a rise in performance from the neutral situation to the low cognitive load, because in the neutral the activation is smaller. Probably the situation of low cognitive load causes a level of activation enough to make the participant more attentive and consequently the level of behavioral compliance is higher.



**Fig. 7.** Behavioral compliance in high, low and neutral cognitive load

It is also clear the loss of performance in the condition of high cognitive load because activation is too high and the cognitive resources are not sufficient to handle two tasks simultaneously and therefore we are already in the descending part of the Yerkes Dodson curve characterized by tunneling, where performance is lost in the area of peripheral vision or in the ability to perform tasks simultaneously [6]. In the present case, both the low sample size (because many of the observations were invalidated) and the low level of compliance obtained (probably because they did not see the warnings or did not process them) support this model.



**Fig. 8.** Yerkes-Dodson model

## 4 Discussion and Conclusions

The objective of this study was to evaluate the behavioral consonance with safety warnings at different levels of cognitive load, manipulated through double task. However, manipulation of the cognitive load may not necessarily have an immediate effect on performance deterioration. This is because the task that is used to increase the cognitive load may not be enough to significantly reduce the cognitive resources necessary for performance [7, 8]. On the other hand, if too much, the high load requires the individual to allocate additional resources that can reduce efficiency and performance [9]. Indeed, in the present study, individuals with a high cognitive load condition often placed attention in one task causing the other to deteriorate, which led to the invalidation of these specific data. Thus, with respect to the objective, the conclusion is when looking at valid data (dual task condition), the results achieved demonstrate the effects of the dual task cognitive load on the behavioral compliance with safety warnings. These results are consistent with the studies of Wogalter and Usher [10] in which in the condition of high cognitive load there was a decrease of the consonance with the instructions of safety and deterioration in a second arithmetical addition task.

It is concluded that this work draws attention to designers, safety engineers, ergonomists in general, all occupational health and safety professionals, that the cognitive load resulting from the work tasks affects the behavior of the worker in relation to behavioral compliance with safety warnings.

**Acknowledgements.** This work was co-financed by the Portuguese Foundation of Science and Technology under the project UID/EAT/04008/2013 (CIAUD) and by grants BEX 0660-13/2 to Ana Almeida from CAPES Foundation Ministry of Education of Brazil.

## References

1. Strayer, D.L., Drews, F.A.: Attention. In: Durso, F.T. (ed.) *Handbook of Applied Cognition*, 2nd edn, pp. 29–54. Wiley, Hoboken (2007)
2. Duarte, E., Rebelo, F., Teixeira, L.: Warnings research methods: where are we now and where are we headed? In: 5th UNIDCOM/IADE International Conference, Lisbon, Portugal, pp. 414–422 (2009)
3. Wogalter, M.S., Laughery, K.R.: Warnings. In: Karwowski, W. (ed.) *International Encyclopedia of Ergonomics and Human Factors*, 2nd edn, pp. 1367–1373. Taylor & Francis (2006)
4. American National Standards Institute: American National Standard for Environmental and Facility Safety Signs, ANSI Z535.2. National Electrical Manufacturers Association, Rosslyn, VA (2011)
5. Duarte, E.M.C.: Using Virtual Reality to Assess Behavioral Compliance with Warnings. Universidade Técnica de Lisboa, Portugal (2011)
6. Wickens, C.D., Lee, J.D., Liu, Y., Gordon, S.E., Becker, S.: *Introduction to Human Factors Engineering*, 2nd edn. Prentice Hall, Newark (2003)
7. Ho, C., Reed, N., Spence, C.: Multisensory in-car warning signals for collision avoidance. *Hum. Factors J. Hum. Factors Ergon. Soc.* **49**(6), 1107–1114 (2007)

8. Duffy, R.R., Kalsher, M.J., Wogalter, M.S.: The effectiveness of an interactive warning in a realistic product-use situation. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting, vol. 37, no. 14, pp. 935–939 (1993)
9. Galy, E., Cariou, M., Mélan, C.: What is the relationship between mental workload factors and cognitive load types? *Int. J. Psychophysiol.* **83**(3), 269–275 (2012)
10. Wogalter, M., Usher, M.: Effects of concurrent cognitive task loading on warning compliance behavior. In: Proceedings of the Human Factors and Ergonomics Society, 43rd Annual Meeting, pp. 525–529 (1999)



# Locomotion-in-Place and Teleport: Which Is the Best Technique to Be Used in Human Behavior Research Using Virtual Reality?

Inês Galvão<sup>(✉)</sup>, Francisco Rebelo, and Paulo Noriega

CIAUD - Research Centre for Architecture, Urbanism and Design, Rua Sá  
Nogueira, Pólo Universitário, Alto da Ajuda, 1349-063 Lisbon, Portugal  
inesgalrao.ciaud@fa.ulisboa.pt,  
frebelo@fmh.ulisboa.pt, pnoriega@campus.ul.pt

**Abstract.** In human behavior studies in critical situations, such as emergency situations, it's necessary for the participant to feel that is in danger and that behaves the same way as in the real world. For this behavior to be natural, the technique to control the avatar in the virtual environment should not distract users. A wrong choice of locomotion technique distracts users from their task and result in poor performance, frustration and cybersickness. In this context, the objective of this study is to know if a new technique (locomotion-in-place) is more efficient than the teleport, for human behavior studies. We evaluated collisions of the avatar with walls and objects in the virtual environment, the level of presence and cognitive maps. The results showed that Locomotion-in-place is a technique easier to control, regarding the number of collisions, but we didn't find differences in presence and cognitive maps between the two locomotion techniques.

**Keywords:** Virtual reality · Locomotion-in-place · Teleport · Avatar control · Virtual environments · Cognitive maps

## 1 Introduction

The main advantages of using virtual reality systems is that it allows to experiment different spaces and scenarios which users don't have access to and provide training in a safe controlled environment [1, 2]. A good virtual reality experience requires several features that must be harmoniously conjugated, namely, virtual objects, animations, sounds, textures, lights and a narrative to give the user a purpose inside the virtual environment [3].

In the study of human behavior in critical situations, such as emergency situations, it's necessary for the participant to feel that he is in danger and that behaves the same way as he would in the real world. For this behavior to be natural, the technique to control the avatar in the virtual environment should not distract the participant. In human behavior studies using virtual reality a natural locomotion technique is required, for tasks of wayfinding [2, 4], and following autonomous agents - social influence over wayfinding decisions [5]. A wrong choice of locomotion technique can distract the user from their task and result in poor task performance, frustration and cybersickness.

Several techniques have been developed for this purpose using, for example, the keyboard or the joystick to control the avatar [6–8]. However, interaction in virtual reality with these devices requires learning time and gives an unnatural control of the avatar, associated with high levels of motion sickness due tovection (illusory of self-motion) [1]. Some solutions that use omni-directional treadmills allow users to move very naturally in any direction [8, 9] but have a very high cost, making its use prohibitive. With the constant development of virtual reality equipment and the emergence of manual controllers, some affordable solutions have arisen, like the teleportation system. Teleportation is one of the best options to allow the user to move through the virtual environment without being limited by the physical space of the room where the activity takes place. This system is usually used, as it allows to place the avatar in a location chosen by the user, and avoids nausea caused byvection [7, 10]. In this context, it may be a promising technique for studies of human behavior in emergency situations.

The experience in our laboratory showed us that there are limitations in the use of this technique, such as the effective control of the avatar inside the virtual environment and possible effects in the sense of presence. Taking these problems into account, we developed a new technique, which we called “locomotion-in-place”, consisting in using the teleport system in a controlled way, where the user can only move in short distances, like taking a step forward. The “locomotion-in-place” technique could be suitable in experiments that need more controlled movements inside the virtual environment. In this context, the objective of this study is to know if our technique (locomotion-in-place) is more efficient than the teleport, for human behavior studies.

The hypothesis for the experiment was that the “Locomotion-in-place” technique will be more natural for the participants than the Teleport technique. Natural, in this context, means having an avatar displacement without collisions with walls or objects of the virtual environment and having a high level of presence, to not distract the participant with the avatar displacement. We are also interested in verifying if the locomotion technique used influenced the creation of the cognitive map of the virtual environment where the experience takes place.

## 2 Methodology

In this study we developed a virtual reality environment where the participants need to follow a path and do different tasks. Participants tried the same virtual environment twice, each time with a different locomotion technique (locomotion-in-place and teleport). The expected combined time of the experiment was 15 min (with questionnaires included).

The virtual environment was designed in the AutoCAD program, converted in .FBX format to Autodesk Maya program to be imported in Unity3D game engine, where the textures, lighting, animations and our interaction system (ErgoVR) were inserted (triggers, events and log records).

This study had 27 voluntary participants (17 men and 10 women) aged between 16 and 67, with education ranging from secondary education (9th grade) to master’s degree, with different backgrounds and careers. 15 participants (55.5%) are students.

18 participants (66.7%) do not often play first-person perspective videogames. All participants had minimal or none previous virtual reality experience.

The measures taken during the experiment were: collisions with objects and walls, spatial orientation (cognitive map) and presence.

The materials used in the experiment was the HTC VIVE. The tracking area was 3.64 m by 3.27 m. Our server computer had Intel® Core™ i7-6700 CPU @ 3.40 GHz and 16 GB RAM with a Graphics card NVIDIA GeForce GTX 1080. The implementation was done using version 2018.1.6f1(64-bit) of the Unity game engine.

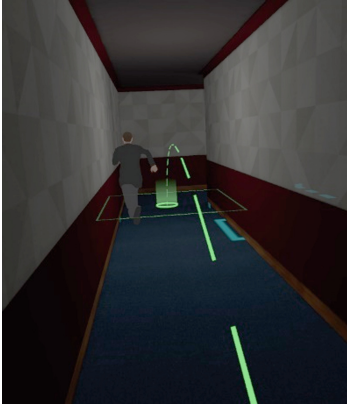
## 2.1 Experiment

In this experiment we compared the two locomotion techniques, which use different controller buttons, as well as their conjugation with the technique of moving objects (Fig. 2). In the “Locomotion-in-place” technique, the participant is standing in the room with the controller pointed to the floor and press the trigger button to move in the virtual environment, orienting the body towards the direction of the movement. This technique was developed to make locomotion look more natural using virtual reality, so that the user could have a better spatial perception of the virtual environment. The technique created in our laboratory was based on the simple teleporter script of the SteamVR package in its 1.0 version, where the user uses the controller’s trigger button to move in space. The reach of the displacement has been modified allowing only small increments relating to the place where the user is. If, for example, the user wants to simulate running, must press the trigger button of the controller faster so the movement will happen more frequently. The script is related to a specific area where we allow the user to move, with the tag ‘floor’, so the script will only work where the pavement is tagged as ‘floor’. If the user tries to walk to an area not tagged as ‘floor’, locomotion-in-place will not be triggered. Collision detection with walls happens every time the user teleports next to the walls of the virtual environment rather than moving in the center of the path. Whenever a collision is detected, the data is saved by the application.

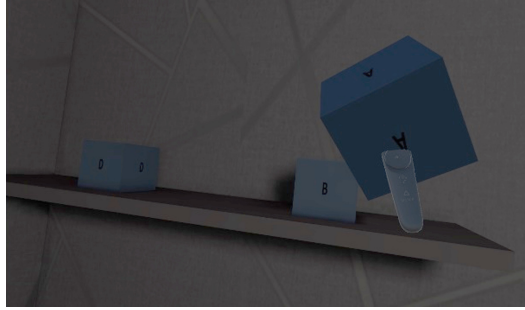
In the “Teleport” technique the movement is done by pressing the touchpad of the HTC VIVE controller and pointing to where the user wants to move, releasing the button next. To move objects, the user must press and hold the trigger button of the controller. In the implementation of this technique, we used the teleport system of the SteamVR package in its 2.0 version, available in the Unity Asset Store. In this technique the teleport area is designed in the virtual environment, where the pointer will appear green (Fig. 1). In our experiment the teleport area is the floor within the wall limit of the route. If the user during the teleport technique points to the walls or other location than the floor, the pointer will turn red, making it impossible to teleport. Pointing the controller exactly to the desired location requires some skill, and this may make it difficult to control. The main advantage of this technique is to be able to make long displacements in the virtual environment. With this system green circle is created in the place where the user can teleport in the virtual environment. This way, the user can easily understand where he is pointing and where he will be teleported. In addition, a laser beam appears from the controller and extends to the ring, forming an arc, which helps the visualization (Fig. 1). The beam color is the same as the ring the user is going to teleport to, i.e. green when teleportation is possible and red when it’s not allowed.



The space orientation of the user is maintained from the source during the teleport, so the user can change direction by turning the body after teleportation.



**Fig. 1.** Teleport technique used in the experiment.

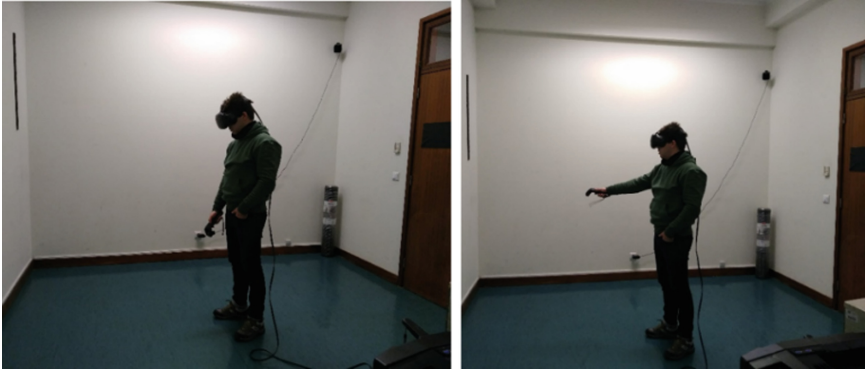


**Fig. 2.** Moving an object in the virtual environment.

## 2.2 Virtual Environment

The virtual environment consists of a set of corridors and a room where the participant must perform several tasks (Fig. 3). The first set of corridors have 2 m wide, allowing the participant to become familiar with the locomotion technique. After that, the participant enters a room with 10 m  $\times$  10 m and 4 m ceiling height, in which the participant must perform tasks. The instructions were given by the researcher to the participant during the experiment. The first task is to move to the center of the room where a red button is located and to press the button with the controller. When the controller approaches the red button, a sound is triggered and two screens with instructions for the next tasks appear on one of the walls in the room. The participant then must move close to the screens and read the instructions for the next tasks. The second task is to find the cube with the letter “A” in the room, grab the cube with the controller and move it next to the cube with the letter “B” (on the other side of the room). After completing this task, the participant should approach and press the blue button in the wall of the room, next to a door. Pressing the blue button with the controller triggers an animation that opens the door in front of the participant and gives access to a new sequence of corridors, where a male character (autonomous agent) appears running. The participant should try to follow the autonomous agent as close as he can until he reaches the end of the corridor, where the autonomous agent will stand still. This last sequence of corridors is composed by 3 corridors with 2 m wide and 10 m long. The virtual environment was designed as simplified as possible, albeit with a realistic appearance, to provide a greater immersion of the participant.





**Fig. 4.** Participant using the equipment during the experiment.

## 2.5 Questionnaires

To analyze the degree of immersion, presence and usability of the two techniques, a questionnaire model [11] was used with 5 categories relevant to the study: 1 - Degree of Immersion (DI); 2-Control Factors (CF); 3-Sensory Factors (SF); 4-Distracton Factors (DF); 5-Degree of Realism (DR). Participants answered the questions using a seven-point rating scale: (DI) 1 - never; 7 - always; (CF) 1 - hardly; 7 - easily; (SF, DF, DR) 1 - very low; 7 - very high.

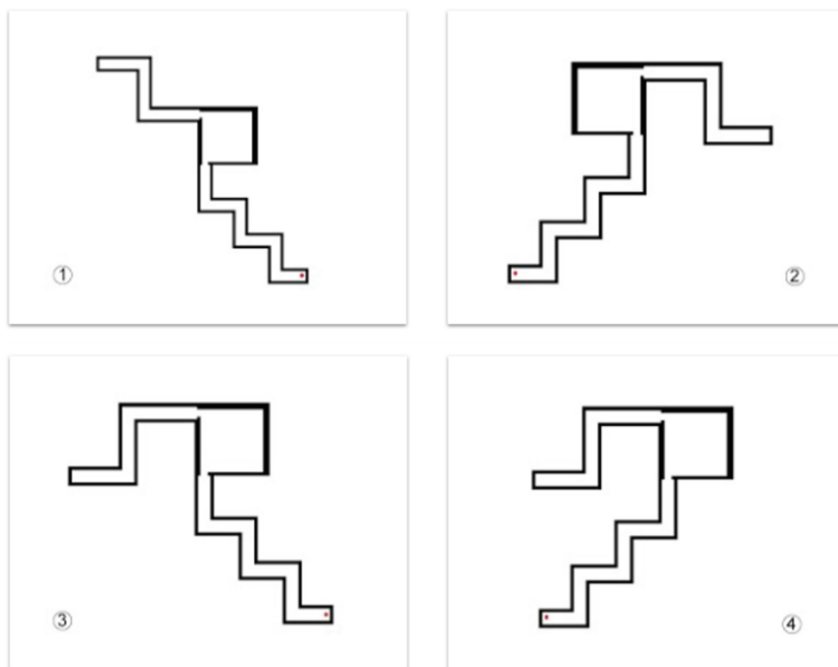
A question from the category “Distraction Factors” (“How much were you aware of the presence of the control device during the simulation?”) is presented separately in the results table with the code DF1, since participants answered to this question with high values, resulting from two factors: participants were holding the controller and they could feel it, and the controller was also rendered in the virtual environment so participants could see it.

## 3 Results and Discussion

### 3.1 Cognitive Maps

As mentioned before, after the participants completed the first locomotion technique experiment they were asked to choose the correct map between the following four options (Fig. 5):

This question was introduced to study if participants created a cognitive map of the virtual environment and if there was a relationship between the locomotion technique used in the experiment and a better space knowledge. The results are presented in the (Table 1):



**Fig. 5.** Maps presented to the participants, which had to choose the correct one used in the virtual environment. The correct map is number 3 (*lower left corner*).

**Table 1.** Cognitive maps overall results.

Map nr.	Overall answers	Participants that tried the locomotion-in-place in first place	Participants that tried the teleport in first place
Map 1	7	4	3
Map 2	2	0	2
Map 3 (correct)	<b>11</b>	<b>6</b>	<b>5</b>
Map 4	7	4	3

Regarding the cognitive maps results, although the correct answer had the highest score, it represents only 40.7% of the number of participants. There was no significant difference between the answers given by participants that tried the Locomotion-in-place technique first and the participants that tried the Teleport technique first.

There is a slight tendency towards the correct map, but due to the small sample no conclusions can be drawn at this point.

### 3.2 Collisions

Collisions occurred whenever a participant collided with a wall or with the red button in the center of the room of the virtual environment. The data was collected in the background. The results of the collisions with the two techniques are detailed in the following (Table 2):

**Table 2.** Number of collisions during the experiment.

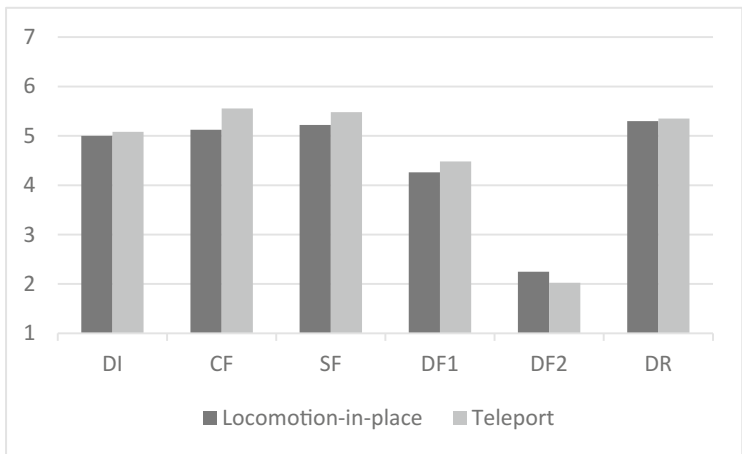
Technique	Nr. of participants	Collisions	M	Median	SD
Locomotion-in-place	27	15	0.56	0	0.97
Teleport	27	142	5.26	5	2.54

Regarding the number of collisions, the Locomotion-in-place technique had a total number of 15 collisions ( $x = 0.56$ ,  $Med = 0$ ,  $SD = 0.97$ ) and the Teleport technique a total of 142 collisions ( $x = 5.26$  ( $P = 0.001$ )), with a statistically significant difference between the number of collisions of the two techniques ( $z = -4.83$ ,  $p < 0.001$ ).

It was expected that the performance with our technique would be better, we verified that it was confirmed and that the difference is very high.

### 3.3 Survey Results on Presence and Usability

Regarding the Presence and Usability questionnaire results, there is no statistically significant difference between the two techniques, as presented on the table above. Participants declared that the degree of immersion in the experience was high, both in the Locomotion-in-place technique ( $x = 5$ ,  $SD = 9.06$ ) and in the Teleport technique ( $x = 5.08$ ,  $SD = 11.64$ ). The results reveal that participants easily moved and interacted with the virtual environment both in the Locomotion-in-place technique ( $x = 5.12$ ,  $SD = 9.99$ ) as well as in the Teleport technique ( $x = 5.56$ ,  $SD = 13.11$ ), and the feeling of movement within the virtual environment was very convincing in both techniques ( $x = 5.22$  in Locomotion-in-place;  $x = 5.48$  in Teleport). Participants answered that they were aware of the controller's presence in both techniques ( $x = 4.26$  in Locomotion-in-place;  $x = 4.48$  in Teleport), but that the controller did not distract or interfere with the tasks requested in the Locomotion-in-place technique ( $x = 2.25$ ,  $SD = 3.79$ ) nor in the Teleport technique ( $x = 2.02$ ,  $SD = 3.21$ ). Regarding the degree of realism of the experiment the participants considered both experiences to be quite realistic ( $x = 5.30$ ,  $SD = 21.86$  in Locomotion-in-place;  $x = 5.35$ ,  $SD = 23.59$  in Teleport).



**Fig. 6.** Presence and Usability results – X axis: Degree of Immersion (DI); Control Factors (CF); Sensory Factors (SF); Distraction Factors 1 (DF1); Distraction Factors 2 (DF2); Degree of Realism (DR). Y axis – 1: not affirmative; 7: highly affirmative.

## 4 Conclusions and Future Work

This study was aimed to verifying which of the two techniques of locomotion presented is more natural for the study of human behavior. The study hypothesis “the “Locomotion-in-place” technique will be more natural for the participants than the Teleport technique” was verified, the participants had more control with the locomotion-in-place than with the Teleport, regarding the number of collisions during the experiment.

The results showed that Locomotion-in-place is a technique where it’s easier to control the avatar, measured in this study by the number of times the avatar collides with walls and objects in the virtual environment. The degree of presence was very high for both techniques. There was a high degree of immersion, control and realism and a low degree of distraction on both techniques. Regarding the creation of cognitive maps, we didn’t verify differences between the two techniques, thus, we cannot draw any conclusions.

The locomotion-in-place is a promising technique for the study of human behavior, particularly if a strict control of the avatar is required to place it on a pre-defined path, without colliding with elements of the virtual environment. This aspect is very important in studies of human behavior, where it’s necessary to follow virtual autonomous agents or verify the decision of participants in a T-corridor.

The limitations of this study were the small sample of participants and the small differences between the options of maps presented, which limited the possibilities of investigation regarding cognitive maps.

Future work may consist of evaluating the Locomotion-in-place technique in more complex and challenging virtual environments, especially regarding cognitive maps. The sample must be larger in the future, to draw conclusions in the evaluation of

cognitive maps, and the options of maps presented should contain greater differences to eliminate possible random answers. Also, in the future, cybersickness should be measured for this technique, although there were no complaints from participants.

**Acknowledgments.** This research is supported by FCT project “UID/EAT/04008/2019”.

## References

1. Almeida, A.L.M.: Avaliação da eficácia de avisos de segurança em diferentes níveis de carga cognitiva num simulador em realidade virtual. Ph.D. thesis. FMH-University of Lisbon (2018)
2. Vilar, E., Teixeira, L., Rebelo, F., Noriega, P., Teles, J.: Using environmental affordances to direct people natural movement indoors. *Work A J. Prev. Assess. Rehabil.* **41**, 1149–1156 (2012)
3. McMahan, A.: Immersion, engagement, and presence: a method for analyzing 3-D video games. In: *The Video Game Theory Reader*, pp. 67–86 (2003)
4. Vilar, E., Rebelo, F.: *Virtual Reality in Wayfinding Studies* (2010)
5. Silva, C., Rebelo, F., Vilar, E., Noriega, P.: Preliminary study about social influence over wayfinding decisions. *Procedia Manufact.* **3**, 5920–5926 (2015)
6. Boletsis, C.: The new era of virtual reality locomotion: a systematic literature review of techniques and a proposed typology. *Multimodal Technol. Interact.* **1**, 24 (2017)
7. Bozgeyikli, E., Raij, A., Katkooi, S., Dubey, R.: Locomotion in virtual reality for room scale tracked areas. *Int. J. Hum. Comput. Stud.* **122**, 38–49 (2018)
8. Nabiyouni, M., Saktheeswaran, A., Bowman, D.A., Karanth, A.: Comparing the performance of natural, semi-natural, and non-natural locomotion techniques in virtual reality. In: *2015 IEEE Symposium on 3D User Interfaces (3DUI)*, Arles, pp. 3–10 (2015)
9. Darken, R., Cockayne, W., Carmein, D.: The omni-directional treadmill: a locomotion device for virtual worlds. In: *Proceedings of the ACM Symposium on UIST (User Interface Software and Technology)*, pp. 213–221 (1997)
10. Bozgeyikli, E., Raij, A., Katkooi, S., Dubey, R.: Point & teleport locomotion technique for virtual reality. In: *CHI PLAY 2016, Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play*, pp. 205–216 (2016)
11. Witmer, B.G., Singer, M.J.: Measuring presence in virtual environments: a presence questionnaire. *Presence: Teleoper. Virtual Environ.* **7**(3), 225–240 (1998)



# Openness Feeling on Height Direction in High Ceiling Room and Bending Pattern of Leading Passage

Takuya Sugiyama<sup>1(✉)</sup> and Yohsuke Yoshioka<sup>2</sup>

<sup>1</sup> Department of Architecture, Division of Creative Engineering,  
Graduate School of Science and Engineering, Chiba University,  
1-33, Yayoi-cho, Inage, Chiba, Japan  
staktax@chiba-u.jp

<sup>2</sup> Graduate School of Engineering, Chiba University,  
1-33, Yayoi-cho, Inage, Chiba, Japan  
yoshioka.yohsuke@faculty.chiba-u.jp

**Abstract.** This paper investigates a psychological experiment was conducted for examine whether the openness feeling on height direction arising when entering a high ceiling room could be control by the bending pattern of leading passage. 32 college students as the participants walked around the virtual environment including the high ceiling rooms with the narrow passages. Seven experimental conditions are created by connecting six different shaped “narrow-passages” to one side of the “high ceiling room” or not connecting any approach. The result is that the ceiling height in the “high-ceiling-room” tends to adjust lower when connecting the “narrow-passage” of the upward slope than when connecting the straight “narrow-passage”. It is suggested that by adding a physical movement “climbing up an oblique road” could suppress openness feeling in the high ceiling room.

**Keywords:** Virtual reality system · High ceiling room · Physical exercise · Openness feeling · Psychological experiment

## 1 Introduction

When entering a space with a high ceiling, there is a sense that the overhead space is open. The strength of this feeling of openness is primarily caused and regulated by the change in the ceiling height before and after entering the high-ceiling room. However, it can also be controlled by the setting of the approach space leading to the high-ceiling room [1–3].

Several studies have examined spatial experiences pertaining to moving in and out of a space. However, these studies only focused on the influence of visual information on spatial evaluation [4–6]. In the present study, we examined the relationship between body movement in the approach space and openness feeling in the high-ceiling room. The present findings are expected to enable us to propose a dynamic space design method that directs the high-ceiling room effectively, by examining the influence of physical exercise on the perception of the ceiling height in the high-ceiling room.



Thus, the present study aimed to clarify the effect of the relationship between physical exercise and spatial cognition.

## 2 Methods

We conducted experiments using VR technology. The advantages of using the VR technology include the ability to evaluate a space on a 1/1 scale, to be able to experience multiple spatial conditions in a short time, and to enable participants to perform space manipulation interactively. Participants were 32 college students (16 males and 16 females). They experienced the virtual environment (virtual environment construction software: Vizard 5.0 and HMD: HTC Vive), including a “high-ceiling-room” and “narrow-passages” (Fig. 1).



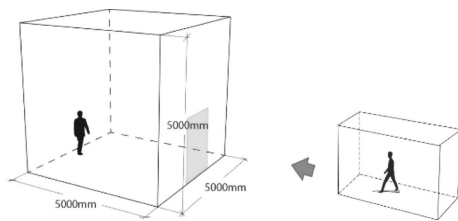
**Fig. 1.** A participant walking along a slope linked to the virtual space

### 2.1 Experimental Condition

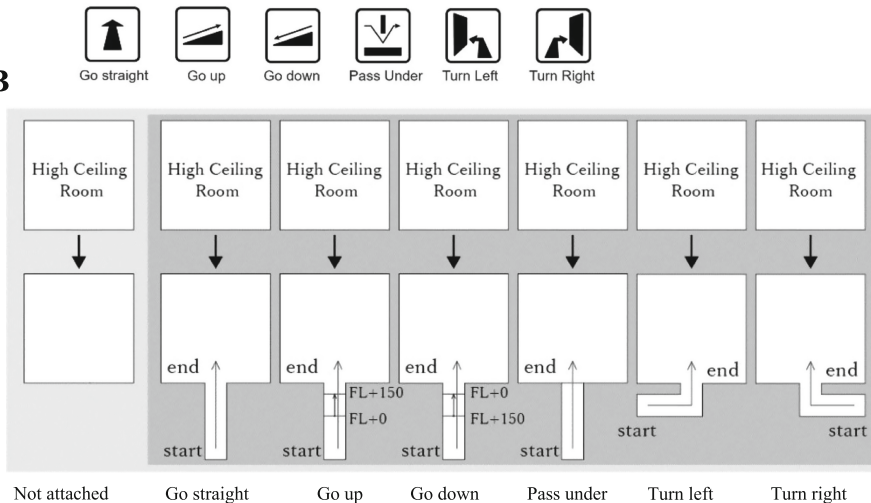
The width of the “high-ceiling room” was  $5000 \times 5000$  mm, and the standard ceiling height was set at 5000 mm. Seven experimental conditions were created by connecting six “narrow passages” of different shapes, to one side of the “high-ceiling room” or by not connecting any approach passage.

The “narrow passages” were corridors, and depending on their bending pattern, participants were instructed to use the following six different physical movements: “go straight”, “go up”, “go down”, “pass under”, “turn left”, and “turn right”. The condition in which the “high-ceiling room” was not attached to an “approach space” was set as the reference condition (Fig. 2).

A



B



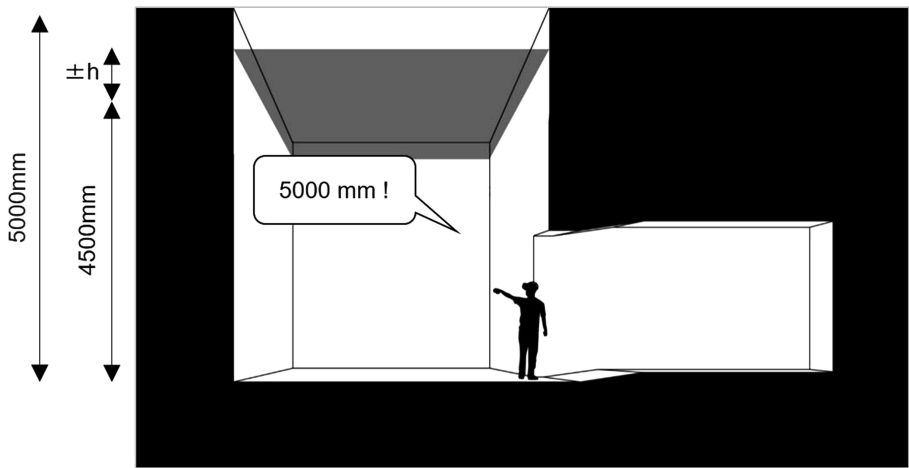
**Fig. 2.** (A) The high-ceiling room and six kinds of approach spaces (B) Seven experimental conditions

## 2.2 Experimental Procedure

First, we allowed the participants experience the space of the reference condition and memorize the ceiling height (5000 mm) in a short time.

Next, the participants moved instantaneously according to one of the seven experimental conditions and walked to the “high-ceiling room” through the connected “narrow passage”. The participants could adjust the height of the ceiling of the “high-ceiling room” using a hand-held controller. Thus, they adjusted the ceiling height so that it coincided with the ceiling height of the reference space memorized earlier. The ceiling height before adjustment was set at 2 patterns of 4500 mm and 5500 mm, which were 500 mm lower and higher than the standard, respectively.

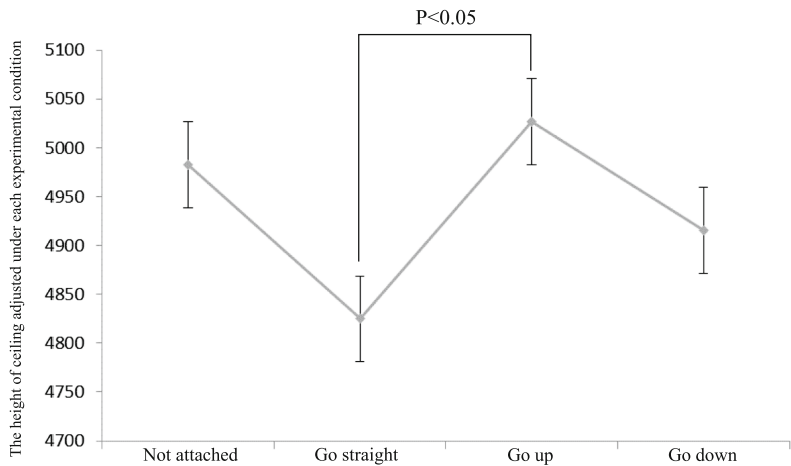
Figure 3 shows an example of the pattern of 4500 mm, which was 500 mm lower than the standard. When the height of the ceiling adjusted by the participants was lower than the standard ceiling height of 5000 mm, he/she evaluated that the ceiling height was equivalent to 5000 mm, indicating that the ceiling height was correspondingly high.



**Fig. 3.** Example of the pattern of 4500 mm, which was 500 mm lower than the standard. Example: 5000 mm > (4500 ± h) mm

### 3 Results

A one-way ANOVA was performed on the ceiling heights adjusted by the participants in each experimental condition, with the shape of the “narrow passage” as a factor. Since the null hypothesis for the main factor was rejected, a multiple comparison test was conducted for each condition, using the Bonferroni method. Findings revealed no significant differences between the experimental conditions “not attached”, “go straight”, “go up”, “go down”, “pass under”, “turn left”, and “turn right”. Only the experimental conditions “go straight” and “go up” exhibited significant differences with the experimental conditions “not attached”, “go straight”, “go up”, and “go down” (Fig. 4).



**Fig. 4.** Comparison among ceiling heights adjusted under each experimental condition

## 4 Discussion

The relationship between the characteristics of physical exercise promoted by the shape of a connected “narrow passage” and the feeling of overhead openness in a “high-ceiling room” was quantitated and analyzed based on the change in the height of the ceiling adjusted by participants in seven experimental conditions. It was confirmed that the ceiling height in the “atrium space” entered immediately after a passage tended to be perceived lower when the connecting “narrow passage” was an upward slope than when it was straight. These findings suggested that by adding a physical movement such as “walk along an oblique passage”, it is possible to manipulate the overhead feeling of openness in a “high-ceiling room”. There was no significant difference among the other passage conditions, but a similar trend was observed for the descent gradient.

These findings may be explained by the fact that the control of sight movement and the difference between a space image and the real space image caused by the movement “go up” and “go down” influence the psychological evaluation of the ceiling height in a “high-ceiling room.” The ceiling height may have been perceived as low after walking along the oblique passage because the participants may have “imagined approaching the ceiling by walking along the oblique passage.” Accordingly, entering the high-ceiling room immediately after passing such a space would have created a feeling of pressure in the direction of the ceiling. Additionally, as the shape of the “narrow passage” inclined in the upward direction increases the line of sight of the participant, and because of looking out in the direction of the ceiling of the “high-ceiling room” immediately after passing through the “narrow passage,” the feeling of opening up would have diminished.

## 5 Conclusions

In this study, we analyzed the changes in the feeling of openness that occur after passing through a narrow passage. Findings revealed that the openness feeling associated with a high-ceiling room could change according to the approach space. In addition, when connecting an approach space with an inclination in the upward direction, the ceiling height tended to be perceived as lower in the high-ceiling room, and that the activity of “going up” could manipulate the overhead openness feeling in a high-ceiling room.

**Acknowledgments.** This work was supported by JSPS KAKENHI Grant Number JP17H03359.

## References

1. Ohno, R., Katayama, M., Komatsuzaki, T., Soeda, M.: A study of distance perception using a visual simulator linked with walking motion. *J. Archit. Plann. Environ. Eng. AIJ* **550**, 95–100 (2001)
2. Okabe, A., Aoki, K., Hamamoto, W.: Distance and direction judgment in a large scale natural environment effects of a slope and winding trail. *Environ. Behav.* **18**(6), 755–772 (1986)
3. Hanyu, K., Itsukushima, Y.: Empirical studies on cognitive distance of stairways. *IATSS Rev.* **25**(4), 243–253 (2000)
4. Komiyama, A., Hatsumi, M.: Cognitive structure of ceiling height of interior space. *J. Archit. Plann. Environ. Eng. AIJ* **490**, 111–118 (1996)
5. Komiyama, A., Hashimoto, K., Hatsumi, M., Takahashi, T.: Experimental study on evaluation of volume and spaciousness of interior-space. *J. Archit. Plann. Environ. Eng. AIJ* **496**, 119–124 (1997)
6. Tsumita, H., Tamao, Y., Hua, X.: Study on spatial cognition of width, depth and height in spaces in well-hole style. *J. Archit. Plann. AIJ* **75**(648), 315–320 (2010)



# Exploratory Study to Investigate the Influence of a Third Person on an Individual Emergency Wayfinding Decision

Elisângela Vilar<sup>(✉)</sup>, Paulo Noriega, Francisco Rebelo, Inês Galvão,  
Daniel Semedo, and Nuno Graça

Faculdade de Arquitetura, Universidade de Lisboa, Rua Sá Nogueira,  
Polo Universitário, Alto da Ajuda, 1349-055 Lisbon, Portugal  
elipessoa@gmail.com, pnoriega@campus.ul.pt,  
frebelo@fmh.ulisboa.pt,  
inesgalrao.ciaud@fa.ulisboa.pt,  
daniel.semedo95@gmail.com, nuno.run@hotmail.com

**Abstract.** Disorientation is an usual issue in many situations, namely during emergency into complex buildings. It may cause a lack of crucial time mainly during early evacuation stages, increasing the chance of harming. This exploratory study aims to investigate the influence of others over a personal route-choice decision during wayfinding into a complex building. A Virtual Reality-based methodology was used and a virtual hotel was adapted from Vilar [1] in order to present six T-shape intersections with two opposite corridors. Two conditions were considered, an everyday condition, that represents the occupant interaction in an ordinary situation, and an emergency condition, in which a fire occurs into the building. Virtual character was inserted in order to investigate the influence of others over a directional choice decision. Findings point to a social influence over wayfinding decisions, suggesting that it can be an important aspect to be considered by safety planners, graphical designers, architects, managers and all those related with safety into complex buildings.

**Keywords:** Virtual Reality · Wayfinding · Complex buildings · Ergodesign · Social influence · Emergency

## 1 Introduction

Predicting people's movement within built environment is particularly important when complex buildings (e.g., hospitals, convention centers and university campus) are the focus of intervention by professionals involved in planning these structures.

According to Conroy [2], these professionals are not able to know precisely how people displacement occurs in a built environment and, sometimes, neglecting this information and replacing it by intuition. This gap in the knowledge about people's behavior regarding to their navigation indoors may contribute to increase the wayfinding problems, with which the visitors are often confronted while interacting with complex buildings, mainly during an emergency situation.

Disorientation is an usual issue in stressful situations, namely during emergency into complex buildings. It may cause a lack of crucial time mainly during early

evacuation stages, increasing the chance of harming. Previous study [3] suggest that, during an emergency wayfinding situation into unfamiliar complex building, people tend to be influenced by some architectural features of the environment, such as illumination and corridor width, while choosing between two alternative routes to follow. Studies also point that, in stressful situations, the environmental characteristics can have more influence over emergency wayfinding decisions than the emergency directional signs, mainly during first decision points [4, 5].

The influence of others, or social influence, was also focus of study in emergency situations. In a research carried out by Latané and Darley [6], a group of male undergraduate students were placed in a room to fulfill a questionnaire in three experimental conditions, (i) alone (naïve), (ii) with more two persons who knows that it was a study (passive), and (iii) with two more naïve subjects. While they were filling out the questionnaire, some smoke was introduced in the room through a vent in the wall. In the condition with two passives, the passives were instructed to act as they were naïve, avoiding interaction, and to show indifference when the smoke started. Results shown that 75% of subjects reported the smoke in the alone condition, and only 38% of subjects reported the smoke in the three naïve condition. Only 10% of subjects reported the smoke in the two passives condition. This study is a strong evidence of the social influence in fire emergency. Authors argued that the way of the naïve interpreted the ambiguous situation may have influenced the outcomes. Thus, according to the authors, seeing other people remain passive led the naïve to decide the smoke was not dangerous.

The social influence, was also the focus of study of Nilsson and Johansson [7]. They reported that the social influence is more important when people face some degree of uncertainty, with a limited or ambiguous information, for instance, when a fire alarm is unclear or uninformative. In their study, authors selected 5 from 18 experiments previously performed, according their level of ambiguity, considering the type of alarm used (i.e., alarm bell, more ambiguous, and pre-recorded message, less ambiguous). Participants' behaviors and actions were analyzed through video recording, and the time that the behavior and action occurred, considering pre-movement time, was measured in relation to the time that the alarm was triggered (i.e., the time when the alarm started was set to zero). Three main types of behavior were analyzed considering pre-movement time, (i) look at others beside or behind oneself, (ii) start to prepare, and (iii) rise. Results suggest that people are influenced more by others who are closer than by those who are distant. So, social influence increases with decreasing distance between people.

Also, some models have been studied considering the influence of other individuals over wayfinding decisions, in both situations, during everyday activities and in an emergency. The affiliative model hypothesizes that people tend to move toward familiar places and persons during emergencies. According to the affiliative model [8], the pattern of movement both towards and away from the treat is mediated by the degree of familiarity of the individual with accessible persons or places. The affiliative model also predicts that the influence of the attachment objects (i.e. person and place affiliation) is even more likely to happen in an emergency than under normal circumstances, that is in an emergency people have higher probability to be drawn toward the familiar than in an everyday situation. In this way, Sime [8] states that the direction

of movement will be related not only to the location of the fire but also to the location and degree of familiarity of the individual with the person and places. Some other studies have corroborated with the affiliative model, such as the unannounced evacuation of large retail-stores carried out by Sandberg [9]. This study investigated the emergency evacuation in two large retail-stores and main findings suggest that most of occupants (46%) started the evacuation only after the staff told them what was going on, and 33% started to evacuate by the alarm signal. Also, 100% of people stop the activity they were performing and started the evacuation if the suggestion to leave the building came from companion. Most of people which were unfamiliar with the building had help from the staff to be directed to an exit. In this way, author concludes that the emergency wayfinding might be influenced by familiarity with the building, group behavior and staff intervention. The BRE Digest 388 [10] also concludes that people in an emergency evacuation situation prefer to use familiar routes for escape.

Additionally, reports from investigations of the World Trade Center (WTC) fires [11], usually refer to the influence of others over emergency wayfinding decisions during the evacuation, such as this report from an occupant of the WTC 2: *“heard a noise that prompted me to get up and look out the window. I saw people out of the corner of my eye, grabbing their bags and leaving. I turned and got my bag, with my pocketbook and things to leave my cubicle and follow the people [to the staircase]. I didn’t have to investigate; I just left [because] I saw other people leaving”*.

Considering this context, the present study aims, in an exploratory way, to investigate the influence of others over a personal route-choice decision during an emergency wayfinding into a complex building. For this, a Virtual Reality - based methodology was used to overcome some ethical and methodological constraints. In this sense, as secondary goal, this exploratory study aims to verify issues related to scenario definition (i.e., VE design and development, narrative, equipment setup) to define features of best practices for VR scenario development. Based on literature review, the main hypothesis is that people will be influenced by others during their wayfinding decisions. It can occur in both, daily and emergency situations.

## 2 Method

In order to verify the main hypothesis, this exploratory study was adapted from a previous one [3, 12]. A two forced choice method was used to collect users’ response about directional choices in an everyday situation and in an emergency situation. The route followed by the participants along a virtual environment (VE) was the study’s main focus, with special attention to their decision-taking (i.e., path selection) at the corridors’ intersection points. As such, these concerns have conditioned the architecture of the experimental virtual environment, adapted from Vilar [5] for this study.

### 2.1 Study Design

The main hypothesis (i.e., people will be influenced by others during their wayfinding decisions) was investigated considering two experimental conditions. The study used a within-subjects design (i.e. everyday and emergency conditions). The dependent



variable is the percentage of choices favoring an intended in six corridor intersections. The main difference between everyday and emergency conditions was that when reaching the first floor through the elevator (beginning of the emergency condition), a fire alarm starts and smoke and fire appear near the participant, forcing he/she to escape and find his/her way out. Figure 1 shows the emergency condition, with the fire and smoke.



**Fig. 1.** Screenshot of the emergency condition showing the fire.

## 2.2 Participants

Thirteen volunteers participated in this study. They were aged between 18 and 67 years old (mean age 25.42 years, SD 11.42), being 9 male (mean age 26.54 years, SD 13.48) and 4 female (mean age 23 years, SD 4.82). All participants had normal sight or wore corrective lenses, and no color vision deficiencies were detected through the Ishihara test [13]. They also reported no physical or mental conditions that would prevent them from participating in a VR simulation.

## 2.3 Experimental Settings

Participants used a HTC VIVE™ Virtual Reality System, with a VIVE Headset and VIVE controllers. Harman Kardon™ headphones were also used by participants to listen to instrumental ambient music, the wayfinding task instructions given orally by the virtual character and the sounds of a fire alarm and fire while into the VE. The Steam VR tracking system was installed into a room with  $2\text{ m} \times 3\text{ m}$  of size allowing participants walk around while interacting with the VE. VIVE wireless controllers were used to interact with the VE in order to press buttons and moving around. The displacement method used was based on a teleportation metaphor. In this way, while

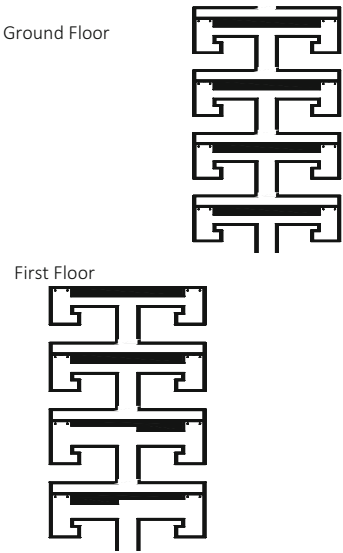
pressing the trigger button on the base of the wireless controller, the avatar moves into the VE from one place to another.

## 2.4 Virtual Environment (VE)

The VE was adapted from a virtual hotel already used by Vilar [5]. In this way, six “T-type” corridor intersections were considered in a two levels building (i.e. ground floor and first floor). These six corridor intersections were mixed and randomly distributed along the floor plan.

A Virtual Human (VH) was inserted in the VE to investigate social influence during every day and emergency condition. The VH was an adult man who run in the direction of a specific corridor in two situations: a neutral, in which the opposite corridors have the same width and brightness, and a contradictory, in which one corridor is wider and brighter than the other one.

The six “T-type” corridor intersections were designed considering: (i) two neutral corridors’ intersections, with two opposite corridors (i.e. left and right) with the same width (i.e. 2 m wide) without any VH; (ii) two corridors’ intersections, with two opposite corridors (i.e. left and right) with the same width (i.e. 2 m wide) with a VH running in a corridor direction (i.e. for one corridor, the VH run to the left side and for the other one the VH run to the right side); and two corridors’ intersections, with two opposite corridors (i.e. left and right) with different width (i.e. 2 m  $\times$  3 m wide, considering left and right corridors) and bright (i.e. the wider corridor was brighter than the narrow one), with a VH running to the direction of the narrower and darker



**Fig. 2.** Floor plan of the ground and the first floor of the virtual hotel with the six “T-type” corridor intersections.

corridor. Figure 2 shows the floor plan for the ground and first floors of the virtual hotel.

The VE was first designed using AtoCAD 3D® and then exported to MAYA® where all geometry was revised and UVmaps were applied onto the surfaces. Everything was exported to Unity where textures, lighting and objects were applied. The lightmap was baked. All VH were created using Adobe Fuse and the package Lip-SyncLite, from UNITY asset store, was used to synchronize the VH lips with the text. The camera was from the SteamVR package for UNITY (i.e. CameraRig) and the prefab was set at the floor (i.e., 0 m). The eye level into VE is the HTC VIVE HMD, so it is adjustable from person to person, depending on the participant eye level.

## 2.5 Experimental Task

**Contradictory Situation.** A situation was considered contradictory when conflicting information is given to participants. In this study, conflicting information was defined as having a VH running to the corridor that is the opposite of the one most chosen by participants in the study of Vilar and colleagues [1, 3]. Thus VH run to the direction of the narrower and darker corridors.

**Scenario and Wayfinding Tasks.** To increase participant involvement, a scenario was created. At the beginning of the experimental session, the following cover story was given to the participants: *“You were invited to give a lecture in an important conference at a hotel and conference center. The conference staff told you that you must talk with the receptionists to complete your registration at the conference and to know the location where the lecture will take place. As the city has a lot of traffic, you are late for your presentation. Please, complete your registration and find your lecture room as soon as possible”.*

Participants were also told that they should behave as they would in a real-life situation. The receptionist (virtual character) would help participants to complete his/her conference registration and to know the location where the presentation will be made. When the participant reaches the second level where the presentation is to occur, he/she is informed that a fire has been detected on the premises.

It was considered a controlled navigation approach because the corridors already passed by the participant were closed by doors during everyday wayfinding and by fire and smoke in the emergency situation. Thus, for each choice point, when participants chose one of the two alternative corridors, the corridor of the path that was not chosen was closed by a door (or fire), forcing them to continue along their initial selected path.

## 2.6 Procedure

Before starting the VR-based components, all participants were asked to sign a consent form and advised that they could stop participation at any time. The VR test was divided into a training session and an experimental session. Participants were told that the experimenter’s objective was to evaluate new software for VR simulation, so they ought to fulfil the tasks as accurately and as quickly as possible. Participants were unaware of the real objective of the experiment.

The VR test began with the training session which had the following main objectives: (1) to familiarize participants with the simulation set-up; (2) to allow them to practice the use of navigation and visualization devices, to bring their virtual movements closer to their realistic/natural actions; (3) to homogenize differences in the participant's performance using joystick; and (4) to make a preliminary check for symptoms of simulator sickness (participants were asked to report whether they felt any discomfort). Participants were encouraged to explore freely and navigate into the VE, as quickly and efficiently as they could, without time restrictions. Participants were further instructed to inform the experimenter when they felt relaxed and comfortable with the equipment. The researcher also monitored participants' control of the navigation device by verifying their accuracy in executing some tasks, such as circumnavigating a pillar placed in the middle of a room without bumping into this element and walking through a zigzag corridor without touching the walls. Only after verifying some of these equipment-related skills did the researcher permit the participant to start the experimental session.

No dialogue between the participant and the researcher was allowed after the simulation started.

The interaction started in the ground floor of a hotel and convention center where participants received a wayfinding task (i.e. find the elevators and go to the first floor) from a virtual character present in the VE. Once they reached the first floor, exited the elevator and walked through a room, an auditory alarm sounded. Thus, participants were faced with finding an emergency egress point by navigating through the second floor to escape from the fire. Smoke and flames always appeared behind the participants in the VE, thereby closing the corridor that they had already passed and preventing retreat in that direction.

If the participants reached a time limit of 20 min inside the simulation, the experimental session was stopped to prevent eye fatigue, or simulation sickness, or both. Simulator sickness was mainly evaluated through participants' verbalizations. However, the researcher also monitored them during the interaction for symptoms such as redness of face, nausea, dizziness and sweating [14, 15].

At the end of the experimental test, a post-task questionnaire was used to collect demographic information such as age, gender, occupation and dominant hand. Participants were also asked to answer, in seven-point scale format, questions related to their perceived hazard and overall involvement during the interaction with the simulation.

### 3 Results and Discussion

In order to verify the main hypothesis (i.e., people will be influenced by others during their wayfinding decisions), the participants' directional choices during their interaction with a VE were registered. Directional choices were left/right alternatives in "T-type" corridor intersection. Results from everyday condition (Table 1) and emergency condition (Table 2) were collected and analyzed.

Results were analyzed only considering when the VH was seen by the participants. Main results suggest that when critical situation was considered in everyday condition,

**Table 1.** Results considering social influence in six “T-type” corridors in everyday condition.

Everyday condition					
<i>Corridor</i>	Environment characteristics	VH direction	% saw the VH	% followed the VH	Most chosen direction
<i>C1</i>	Right corridor - brighter and wider	Left corridor	100 (13)	76,92 (10)	
<i>C2</i>	Left corridor - brighter and wider	Right corridor	100 (13)	76,92 (10)	
<i>C3</i>	Equal brightness and width	Left corridor	92,30 (12)	50 (6)	
<i>C4</i>	Equal brightness and width	No VH	n/a	n/a	Left (7)
<i>C5</i>	Equal brightness and width	No VH	n/a	n/a	Right (9)
<i>C6</i>	Equal brightness and width	Right corridor	92,30 (12)	100 (12)	

**Table 2.** Results considering social influence in six “T-type” corridors in emergency condition.

Emergency condition					
<i>Corridor</i>	Environment characteristics	VH direction	% saw the VH	% followed the VH	Most chosen direction
<i>C1</i>	Equal brightness and width	Right corridor	53,84 (7)	85,71 (6)	
<i>C2</i>	Equal brightness and width	No VH	n/a	n/a	Right (7)
<i>C3</i>	Equal brightness and width	No VH	n/a	n/a	Left (8)
<i>C4</i>	Equal brightness and width	Left corridor	100 (13)	92,30 (12)	
<i>C5</i>	Left corridor - brighter and wider	Right corridor	76,92 (10)	50 (5)	
<i>C6</i>	Right corridor - brighter and wider	Left corridor	92,30 (12)	75 (9)	

participants’ relied more on the VH directional choice. Thus the majority of the participants (approximately 77%) preferred to follow the VH.

The same was not verified for neutral corridors’ intersections. For these cases results were inconclusive.

Considering the total number of times that the VH was seen by the participants’ (i.e., VH was seen 50 times, considering both critical and neutral situation), 76% of directional choices taken by the participants favored the same direction followed by the VH, in other words, 76% of the time participants preferred to follow the VH.

For the emergency condition, the environmental characteristics (i.e., wider and brighter corridors) seems to have higher impact over participants decision, decreasing the percentage of participants who followed the same direction followed by the VH.

Additionally, the VH seems to have be less seen by participants in the emergency condition than for the everyday condition (i.e., VH was seen 42 times in both, critical and neutral situations). Despite this, also about 76% of the participants preferred to follow by the same corridor followed by the VH.

Regardless of the order of appearance of corridor intersections, when the first time that the participant saw the VH was considered, 75,96% followed by the same direction as the one followed by the VH in everyday condition and 75% followed the VH in emergency condition.

## 4 Conclusion

The main motivation for this exploratory study is the influence that a third person seems to have over a personal wayfinding decision. Some studies already point to this direction and were carried out considering the influence of others [e.g. 6, 7]. However, the problem of social influence over emergency wayfinding decisions into complex buildings is still a matter to consider, namely for those responsible for planning and design.

Main results from this exploratory research point that, even in a VR setup and interacting with a VH, people seems to be influenced by the VH directional decisions, confirming the main hypothesis.

Additionally, when using VR as interaction environment, some features of the scenario (i.e., narrative, VE, equipment setup) have to be tested and validated to minimize the constraint that this type of approach may have over participants behavior. In this sense, this exploratory study aimed to test the designed scenario to be used for further studies. Thus, some features were identified as needing more attention, namely the number and order of corridor intersections should be revised. Considering previous studies [i.e., 3, 5], six “T-type” corridors’ intersection in line may have been an over stimuli on the participant, and even the six corridors’ intersections had been placed in a random sequence, corridors situations appeared grouped (first the two neutral, followed by the two critical situations). These facts may be influenced the results, as they could favoring random choice behavior. In this way, sample number need to be increased and VE design should be revised to avoid random choice behavior. Other point to consider was the length of the corridors. As the VH was an amination that appeared when triggered by the participant in a previous pre-defined point of the VE (i.e., on the corner of the main corridor that leads to the “T-type” corridor intersection), if the participant, for some personal reason, decided to stop, to go back, or to move slowly, he/she could not be able to see the VH wayfinding decision. This problem occurred because the main corridor was very short, so revising its length should solve it.

The number of participants need to be increased in order to have more reliable results, and it can be pointed as a limitation of this study.

For this exploratory study, the VH was a male young adult, wearing shorts and t-shirt in order to present some familiarity with the sample. For future, studies should consider other VH’s status, such us fireman, boss, woman, among others, to investigate

this effect over social influence in emergency wayfinding situation. Also, it would be important to explore the group effect, increasing the number of VH into the VE. Considering main results, social influence during wayfinding, mainly in emergency situation need to be more investigated. Even for a exploratory study, it is clear the influence of other over wayfinding decisions and it can highly impact buildings' use. In this way, studies considering the influence of others should be reinforced in order to define guidelines to help in the designing of complex buildings, in the definition of management strategies, and in the designing of emergency protocols and systems.

**Acknowledgments.** This research is supported by FCT grant n. SFRH/BPD/93993/2013.

## References

1. Vilar, E.: Using Virtual Reality to Study the Influence of Environmental Variables to Enhance Wayfinding within Complex Buildings (2012)
2. Conroy, R.: Spatial Navigation in Immersive Virtual Environments. University of London, London (2001)
3. Vilar, E., Rebelo, F., Noriega, P., Teles, J., Mayhorn, C.: The influence of environmental features on route selection in an emergency situation. *Appl. Ergon.* **44**, 618–627 (2013)
4. Vilar, E., Rebelo, F., Noriega, P., Teles, J., Mayhorn, C.: Signage versus environmental affordances: is the explicit information strong enough to guide human behavior during a wayfinding task? *Hum. Factors Ergon. Manuf.* **25**, 439–452 (2015)
5. Vilar, E., Rebelo, F., Noriega, P., Duarte, E., Mayhorn, C.B.: Effects of competing environmental variables and signage on route-choices in simulated everyday and emergency wayfinding situations. *Ergonomics* **57**, 511–524 (2014)
6. Latané, B., Darley, J.M.: Group inhibition of bystander intervention in emergencies. *J. Pers. Soc. Psychol.* **10**, 215–221 (1968)
7. Nilsson, D., Johansson, A.: Social influence during the initial phase of a fire evacuation—analysis of evacuation experiments in a cinema theatre. *Fire Saf. J.* **44**, 71–79 (2009)
8. Sime, J.D.: Movement toward the familiar: person and place affiliation in a fire entrapment setting. *Environ. Behav.* **17**, 697–724 (1985)
9. Sandberg, A.: Unannounced evacuation of large retail-stores: an evaluation of human behaviour and the computer model Simulex (1997)
10. Digest 388: Human Behaviour in Fire. Building Research Establishment (1993)
11. Zmud, J.: NIST NCSTAR 1-7B Federal Building and Fire Safety Investigation of the World Trade Center Disaster Technical Documentation for Survey Administration: Questionnaires, Interviews, and Focus Groups (2005)
12. Vilar, E., Duarte, E., Rebelo, F., Noriega, P., Filgueiras, E.: A pilot study using virtual reality to investigate the effects of emergency egress signs competing with environmental variables on route choices. In: Marcus, A. (ed.) *Design, User Experience, and Usability. User Experience Design for Everyday Life Applications and Services. DUXU 2014. Lecture Notes in Computer Science*, pp. 369–377. Springer, Cham (2014)
13. Ishihara, S.: Test for Colour-Blindness. Kanehara & Co., Ltd., Tokyo (1988)
14. Kennedy, R.S., Hettinger, L.J., Lilienthal, M.G.: Simulator sickness. In: Crampton, G.H. (ed.) *Motion and Space Sickness*, pp. 317–342. CRC Press, Boca Raton (1990)
15. Keshavarz, B., Hecht, H.: Validating an efficient method to quantify motion sickness. *Hum. Factors J. Hum. Factors Ergon. Soc.* **53**, 415–426 (2011)



# How Deep Is a Virtual Reality Experience? Virtual Environments, Emotions and Physiological Measures

Tiago Oliveira<sup>1,2,3</sup>, Paulo Noriega<sup>2,3</sup>, José Carvalhais<sup>2,3</sup> (✉),  
Francisco Rebelo<sup>2,3</sup>, and Vanessa Lameira<sup>2</sup>

<sup>1</sup> Faculdade de Arquitetura, Universidade de Lisboa, Rua Sá Nogueira,  
Pólo Universitário, Alto da Ajuda, 1349-055 Lisbon, Portugal

<sup>2</sup> FMH, Ergonomics Laboratory, Universidade de Lisboa, Estrada da Costa,  
1499-002 Cruz Quebrada, Portugal  
jcarvalhais@fmh.ulisboa.pt

<sup>3</sup> CIAUD, Universidade de Lisboa, Rua Sá Nogueira, Pólo Universitário,  
Alto da Ajuda, 1349-055 Lisbon, Portugal

**Abstract.** Previous studies have shown a relationship between virtual environments and subjectively evaluated emotions. The present study intends to understand if an emotion evaluated subjectively is related to an objective measurement like heart rate. In the study, a design between subjects with two virtual environments was used. A sample of 58 participants participated in this study, in two immersive virtual environments: Helix<sup>®</sup> (a roller coaster experience,  $n = 36$ ); and Yana<sup>®</sup> (experience of sunset/sunrise,  $n = 22$ ). Subjective and objective measures (heart rate) were measured. The results are consistent with previous studies and our hypotheses. As for the subjective measures it is concluded that these measures were related to physiological measures, so the emotional response to an event in virtual reality is not only an interpretation of the situation but also a physiological phenomenon.

**Keywords:** Virtual reality (VR) · Immersive virtual environments (IVEs) · Emotions · Heart rate · User experience (UX) · Physiological measures

## 1 Introduction

The results of our previous study [1] demonstrated that the Self-Assessment Manikin (SAM) was adequate to discriminate the emotional dimensions (Valence, Arousal and Dominance) and that the used questionnaire was sufficiently refined so that in its results we can observe the expected relationships between the subjective measures collected and the different Immersive Virtual Environments (IVEs) analyzed. However, some doubts have arisen: will those subjective measures be a mere response to a situation, or they have also a physiological answer?

Most of the studies evaluate the emotional reactions from questionnaires that are carried out after the exposure to the stimulus of the IVEs [1–8]. But with the application of the questionnaire only after the experience, it is not possible to access an evaluation while the participant is immersed in the virtual environment.



It is also possible for the researcher to ask questions to the participant while he/she is using a Head-Mounted Display (HMD), as described by Men [8], however if the researcher poses any question, he will break the sense of virtual presence of the participant [7]. Ideally, there should be no interaction between the participant and the researcher during RV interaction.

Some studies integrate subjective experience questionnaires directly in virtual reality environments [9] thinking that in this way they minimize the break in sense of presence. However, physiological measures such as Heart Rate (HR) can be measured during exposure to the stimulus, without intrusiveness, since the cardio-frequency meter is a band that is placed on the wrist, similar to a watch.

Some studies have sought to correlate the presence with electrophysiological measures such as HR, respiration rate, skin resistance and peripheral skin temperature. Despite the results of HR and skin temperature did not prove to be good measures of presence and results of their correlation with presence were inconclusive [10].

The literature states that the Arousal is a particularly strong indicator of emotional involvement. Arousing emotions should lead to higher presence ratings and correlate more closely with presence ratings, than calm or serene emotional states [1–3]; for a review see Diemer [11].

Other studies reveal that higher HR and Electrodermal Activity (EDA) are correlated with physiological arousal and as such with some of the influencing factors associated with user Quality of Experience (QoE) [12].

This study was proposed to evaluate the subjective emotional (valence, arousal and dominance) and heart rate responses, when the participants interact with two immersive Virtual Reality (VR) environments. A between subject design was used with two virtual environments.

In this study, we chose the IVEs Yana® and Helix® because in the previous study [1] they were shown to be opposites in the Arousal and Dominance dimensions. In the Yana® participants generally reported having relaxed during the experience, and in the end said to feel calmer.

We intended to prove if there are significant differences in HR between control state (rest) and experience IVE (Yana®/Helix®), and if this is related to subjective measures analyzed. These results intend to bring robustness to the use of HR measures as an indicator in deeper assess of User Experience (UX) in IVEs.

## 2 Methodology

### 2.1 Sample

In Lisbon during a public event named Futuralia 2017, we have recruited our convenience sample. Futuralia is the largest education and training fair in Portugal. For three days in Futuralia we recruited 58 participants of which 30 women and 28 males. The average of age was 20.91 years, with 8.78 years of std. deviation. The minimum age was 14 years and the maximum of 58 years.

We randomly divided participants into 2 groups.

In the first group 22 participants (55% Female, 45% Male) experienced the YANA® IVE. This group showed an average age of 18.86 and std. deviation of 3,67 years;

In the second group 36 participants (49% Female, 51% Male) experienced Helix® IVE (Virtual Roller Coaster). This group showed an average of 22.17 years and 10.65 years of standard deviation.

Participants were asked about the existence of any antecedent in relation to epileptic manifestations, or eventual cardiac pathologies. All participants denied.

Women were asked about the existence of pregnancy. When the answer was positive, for safety reasons, we did not grant the Virtual Reality experience.

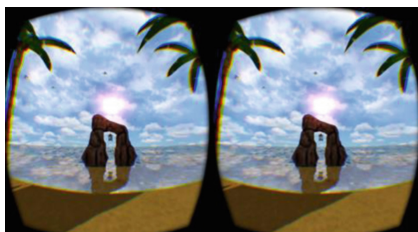
Thus, all pregnant women or persons with episodes of epilepsy, or with cardiac pathologies were excluded from participating in this study.

## 2.2 Immersive Virtual Environments

The two IVEs that were most opposed in the results of our first study [1] were chosen. The first IVE was Yana® Virtual Relaxation, a paradisiac beach developed by The Campfire Union Inc:

**Description:** In the IVE YANA, the user enjoys a sunset and sunrise on a paradisiacal beach. The user is in the center of the beach and glimpses in the middle of the sea a rock formation that is reflected in the calm waters of the sea (Fig. 1). After the sun goes down, it takes place at night time (Fig. 2). During the night time the sky fills with stars forming constellations. Falling stars paint the sky.

On the horizon line a boat appears sailing parallel to the beach. The sound environment is made up of sounds of seagulls, birds, Tibetan bowls, bells and sea waves.



**Fig. 1.** Detail: begin IVE YANA®



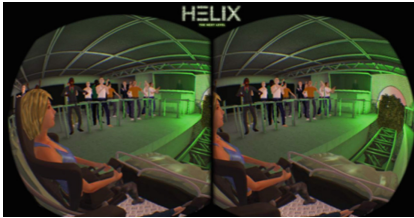
**Fig. 2.** Detail: begin of the night IVE YANA®

This environment was chosen because in the results of our previous study [1] it was shown that it had the lowest values of Arousal.

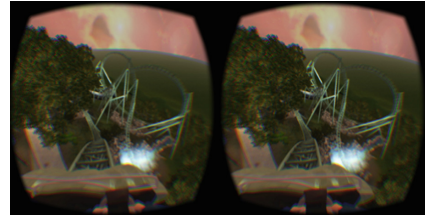
The second IVE Helix® is a virtual roller coaster experience: Helix® Roller Coaster VR, was developed by Archivision®.

**Description:** When the Ive Helix starts, the user is sitting in a roller coaster chair. The other chairs beside him (Fig. 3) and behind him are occupied with virtual avatars. The

electronic music and the enthusiastic cries of the avatars create the sound environment. The ride begins (Fig. 4), during the roller coaster ride the user experiences, climbs, descents and loopings.



**Fig. 3.** Begin of IVE Helix®



**Fig. 4.** Detail: begin of the slope, IVE Helix®

This IVE was chosen because in the results of our first study [1] it was shown to have the highest Arousal values.

### 2.3 Measures and Analysis

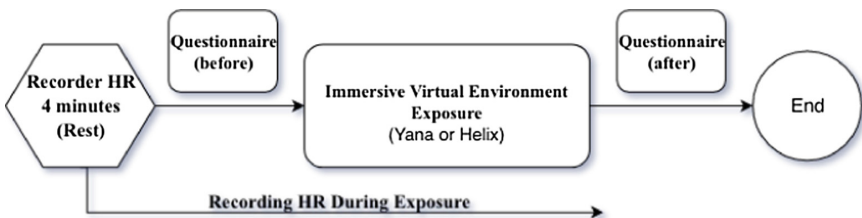
Independent samples were used, and the manipulated variable was IVE (Yana® and Helix®). The subjective dependent variables were emotional dimensions, arousal, valence, domain. The objective dependent variable was HR.

It is common to investigate the presence and the emotional experience from the correlation between these measures [1, 4, 6] mainly in the literature on the exposure to VR [13–18].

The participants sat down in a chair, the heart rate monitor was placed on his wrist. The heart rate was measured for 4 min (it will serve as control when compared to heart rate measurements during IVE exposure).

The exposure to the IVE Yana was approximately 8 min, and the exposure to IVE Helix was approximately 4 min.

Before experiencing IVE, all participants answered the first part of the questionnaire. At the end of the IVE, the participants answered the second part of the questionnaire (Fig. 5).



**Fig. 5.** Research moments diagram

## 2.4 Objectives

The main objective was to verify if the physiological indicator heart rate is related to the arousal levels of the participants in a virtual reality experience.

The specific objectives were to recognize associations between different virtual environments and: Emotional dimensions: Valence, Arousal, Dominance; Heart Rate; To identify whether an exciting experience such a virtual roller coaster (helix) experience induces an increase in Heart Rate mode; To identify if a relaxing experience like watching the sunset on a virtual beach induces a decrease in Heart Rate mode.

## 2.5 Procedures

Volunteers of the degree in Ergonomics of the Faculty of Human Kinetics of Universidade de Lisboa helped us during the experimental periods. They organized the participants and registered the values of subjective measures reported by them.

All participants, after reading the informed consent form and clarifying some doubts, agreed to participate in the study in exchange for experiencing IVE with a head mounted display (HMD).

The content of the IVE was unknown to all participants; they just knew that it was VR. In this way we assume that the interest in participating was based on the curiosity to use the RV.

IVE was randomly selected and participants only experienced one IVE without previous knowledge of the content.

After reading and accepting the consent form, the participants would move to an ordinary chair, and were asked to place a heart rate monitor on the wrist. From that moment we asked the participant to remain serene sitting in the chair for a period of 4 min in order to record (2 Hz) his heart rate as control measure. During this time, we asked the participants to speak as little as possible.

After recording HR as a control, participants were advised that there were no right or wrong answers to the questionnaire that was to be shown to them. The answers to the questionnaire should be the individual perceptions regarding the issues. All participants were advised that they could leave the experience at any time for any reason that was relevant. The questionnaire was then introduced to the participants. First some sociodemographic questions and then questions about what they expect to feel with the use of VR.

After questionnaire being answered, the researcher assists the participant in comfortably placing the Head-Mounted-Display (HMD). After all, properly adjusted and the sound set by the participant, the participant tells when to start the VR experience.

At this moment the hour, minutes and seconds were recorded, to start recording the HR during the IVE exposure.

At the end of IVE the HR record was interrupted. The researcher helped remove the headphones and then the HMD. The researcher asks if everything is okay. Given the affirmative answer the researcher introduced the second part of the questionnaire, now the participant responds according to the emotional response generated by the IVE.

## 2.6 Evaluation Questionnaire

We used the questionnaire from our first study [1]. In order to make an evaluation compatible with the objectives of the study and the temporal constraints of this type of events (public event Futuralia 2017), The first part of the questionnaire was applied before the participant used the RV. At this stage it was important to collect some sociodemographic questions that allowed us to later relate the data collected according to gender, age, level of schooling, nationality. Then it was important to gauge the participant's typology and expectation regarding VR. For this there were two questions about prior use, or knowledge of the existence of VR as technology. Two issues concerning the habit of playing FPS (first player shooter). Next, in relation to the expected use of VR, the participants were questioned about the experience they were about to have about valence arousal and dominance with the use of SAM (self-evaluation-manikin); The presence was measured between semantic anchors with 9 degrees of freedom. In the questionnaire, after the VR experience, were applied the same previous measurements.

So, participants were questioned about the sense of Presence, Valence, Arousal and Dominance before and after the IVE. After the IVE we also asked questions relating to the sense of Concentration, Relaxation and Activation during and after the IVE. All the answers were measured with 9 degrees of freedom.

## 2.7 Hardware

The hardware was constituted by the PC, the display and the Cardio-frequency meter.

**Display:** As HMD, an Oculus® Rift DK2 was used. The specifications of this HMD are: Display 5.7 in. OLED (PenTile); Resolution  $1920 \times 1080$ ,  $960 \times 1080$  per eye; Refresh Rate 75 Hz, 72 Hz, 60 Hz; Persistence 2 ms, 3 ms, full; field of view  $100^\circ$  (nominal); Update Rate 1000 Hz, Positional 60 Hz; Weight 0.97 lbs (440 g);

**PC:** Alienware® M17x R3 17.3" Intel i7-2670QM 2.20 GHz, 16 GB RAM, 512 GB + 256 GB ssd. NVIDIA GeForce GTX 560 M graphics card;

**Cardio-Frequency Meter:** Mio® Alpha I, 2 Hz, Max Readable Heart Rate: 220 BPM, Min Readable Heart Rate: 30 BPM;

## 3 Results

Of the 58 participants, 31% said they had already experienced virtual reality at least once. All the participants affirmed at the end of the IVE use that it was the first time that they had been in that IVE.

Table 1 shows the values of the mean and standard deviation of the subjective measures (Arousal, Valence, Dominance; Presence) before experiencing IVE, and after experiencing IVE.

For a greater control we can also observe the mean and standard deviation of the subjective measures: Concentration (during IVE); Relaxation (during IVE); Relaxation (after IVE); Activation (after IVE).

Still in Table 1, we can observe the objective measure HR with the respective values: mode; median; 10th percentile. For HR analysis we can observe the mean frequency through the mode. With the median, we observed the maximum frequency. Through the 10th percentile, we observe the minimum frequency.

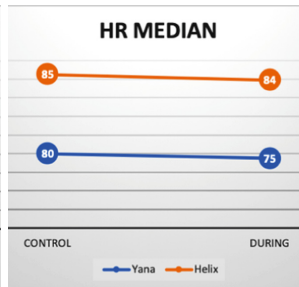
**Table 1.** Summary of results (subjective and objective measures) obtained in the studied environments.

Variables	Statistics	Yana®		Helix®	
		Before	After	Before	After
Arousal	Average	5.32	2.64	6.28	6.42
	Std. deviation	2.12	2.32	1.81	2.22
Valence	Average	7.14	7.59	6.89	7.78
	Std. deviation	1.28	1.29	1.65	1.33
Dominance	Average	5.41	5.09	4.97	4.69
	Std. deviation	2.42	2.24	2.03	2.60
Presence	Average	7.64	7.18	7.22	7.31
	Std. Deviation	1.33	1.76	1.48	1.79
Concentration (during)	Average		7.64		7.39
	Std. deviation		1.21		1.48
Relaxation (during)	Average		7.86		5.22
	Std. deviation		1.21		2.22
Relaxation (after)	Average		7.41		5.86
	Std. deviation		1.62		2.01
Activation (after)	Average		3.82		6.17
	Std. deviation		1.82		2.02
Heart Rate (control)	Mode	80		83	
	Median	80		84	
	Percentile 10 <sup>th</sup>	67		73	
Heart Rate (during)	Mode		68		83
	Median		75		84
	Percentile 10 <sup>th</sup>		66		71

ANOVA between groups was made. For the Arousal, with a test statistic  $F = 38,231$  corresponds a null p-value, thus it is rejected  $H_0$ , being able to affirm that there are significant Arousal differences between the two IVEs (Yana/Helix). We also observed significant differences between the two IVEs in the control measures of

Relaxation (during), Relaxation (after) and Activation (after), with the respective test statistics  $F = 26,306$ ,  $F = 8,121$  and  $F = 19,869$ , corresponding all to null p-values. For the other subjective measures, there were no significant differences between the two environments (Yana/Helix).

To better illustrate the results obtained with HR measurement by IVE, between control and during exposure to IVEs, see graphs: HR Mode (Fig. 6), HR Median (Fig. 7), HR 10th Percentile (Fig. 8).



**Fig. 6.** HR mode: Yana/Helix (control/during) **Fig. 7.** HR median: Yana/Helix (control/during) **Fig. 8.** HR 10<sup>th</sup> Percentile: Yana/Helix (control/during)

As expected, compared with Yana the values of HR with Helix are always higher.

## 4 Conclusion

The results obtained were in agreement with our initial hypotheses. Arousal has been shown to have a strong correlation with heart rate. The sample used is a convenience sample recruited at an event called Futuralia. This event is intended for high school finalists, so the participants of our study were essentially secondary school students. Participants before experiencing IVE were mostly very enthusiastic because they were going to experience Virtual Reality. These facts can also be verified by the high Arousal states prior to the IVE trial. This may have influenced the results of no significant differences between the control measurement and the Heart Rate measurement during the roller coaster IVE (Helix).

We also verified significant differences in Activation after the experimentation evoked in YANA and Helix, with helix reported as the highest, accompanied with an average frequency (mode), minimum frequency (10th percentile), and maximum frequency (median) of HR also higher.

In the sunset at the beach (YANA) we find that it induces a state of calm in the participants which is accompanied by a decrease in Heart Rate. This fact reveals once more the relationship of proximity between the Arousal values evoked after the trial of this IVE. It should be noted that the Presence values were lower than in the Helix

environment, however we think that these values are due to the weak perceived realness of the Yana environment when compared to the Helix environment.

These results empirically demonstrate the power of using virtual reality as a modulating instrument for calming and relaxation stages, accompanied by the physiological response of a lower HR. Our results strengthen the development and design of IVEs for stress management and relaxation.

For UX evaluations the HR is a very interesting measure to describe the levels of Arousal during the use of VR products. Further research is needed on this topic.

## References

1. Oliveira, T., Noriega, P., Rebelo, F., Heidrich, R.: Evaluation of the relationship between virtual environments and emotions. In: Rebelo, F., Soares, M. (eds) *Advances in Ergonomics in Design. AHFE 2017. Advances in Intelligent Systems and Computing*, vol. 588 (2018)
2. Trindade, Y., Rebelo, F., Noriega, P.: Tourism and virtual reality: user experience evaluation of a virtual environment prototype. In: Marcus, A., Wang, W. (eds) *Design, User Experience, and Usability: Users, Contexts and Case Studies. DUXU 2018. Lecture Notes in Computer Science*, vol. 10920 (2018)
3. Estupiñan, S., Rebelo, F., Noriega, P., Duarte, E.: Can virtual reality increase emotional responses (Arousal and Valence)? A pilot study. In: *Design, User Experience, and Usability: User Experience Design for Diverse Interaction Platforms and Environments*, pp. 541–549 (2014)
4. Ma, X., Cackett, M., Park, L., Chien, E., Naaman, M.: Web-based VR experiments powered by the crowd. In: *World Wide Web Conference*, pp. 33–43 (2018)
5. Livatino, S., Koffel, C.: Handbook for evaluation studies in virtual reality. In: *Proceedings of the 2007 IEEE International Conference on Virtual Environments, Human-Computer Interfaces, and Measurement Systems*, pp. 1–6 (2007)
6. Schatz, R., Sackl, A., Timmerer, C., Gardlo, B.: Towards subjective quality of experience assessment for omnidirectional video streaming. In: *9th International Conference on Quality of Multimedia Experience*, pp. 1–6 (2017)
7. Bowman, A., Gabbard, J., Hix, D.: A survey of usability evaluation in virtual environments: classification and comparison of methods. *Presence: Teleoperators Virtual Environ.* **11**(4), 404–424 (2002)
8. Men, L., Bryan-Kinns, N., Hassard, A., Ma, Z.: The impact of transitions on user experience in virtual reality. In: *Virtual Reality (VR)*, pp. 285–286 (2017)
9. Schatz, R., Regal, G., Schwarz, S., Suett, S., Kempf, M.: Assessing the QoE impact of 3D rendering style in the context of VR-based training. In: *Quality of Multimedia Experience (QoMEX) 2018 Tenth International Conference*, pp. 1–6 (2018)
10. Riva, G., Eds, G., Wiederhold, K., Jang, P., Kaneda, M., Lurie, Y., Kim, I.: An Investigation into physiological responses in virtual environments: an objective measurement of presence, pp. 175–184 (2003)
11. Diemer, J., Alpers, W., Peperkorn, M., Shibani, Y., Mühlberger, A., Oathes, J.: The impact of perception and presence on emotional reactions: a review of research in virtual reality, pp. 1–9 (2015)
12. Egan, D., Brennan, S., Barrett, J., Qiao, Y., Timmerer, C., Murray, N.: An evaluation of Heart Rate and ElectroDermal Activity as an objective QoE evaluation method for immersive virtual reality environments, pp. 3–8 (2016)



13. Robillard, G., Bouchard, S., Fournier, T., Renaud, P.: Anxiety and presence during VR immersion: a comparative study of the reactions of phobic and non-phobic participants in therapeutic virtual environments derived from computer games. *Cyberpsychology Behav.* **6**, 467–476 (2003)
14. Alsina-Jurnet, I., Gutiérrez-Maldonado, J., Rangel-Gómez, M.: The role of presence in the level of anxiety experienced in clinical virtual environments. *Comput. Hum. Behav.* **27**, 504–512 (2011)
15. Price, M., Mehta, N., Tone, B., Anderson, L.: Does engagement with exposure yield better outcomes? Components of presence as a predictor of treatment response for virtual reality exposure therapy for social phobia. *J. Anxiety Disord.* **25**, 763–770 (2011)
16. Riva, G., Mantovani, F., Capideville, S., Preziosa, A., Morganti, F., Villani, D., et al.: Affective interactions using virtual reality: the link between presence and emotions. *Cyberpsychology Behav.* **10**, 45–56 (2007)
17. Bouchard, S., St-Jacques, J., Robillard, G., Renaud, P.: Anxiety increases the feeling of presence in virtual reality. *Presence* **17**, 376–391 (2008)
18. Price, M., Anderson, P.: The role of presence in virtual reality exposure therapy. *J. Anxiety Disord.* **21**, 742–751 (2007)



# Emotion Through Narrative: Validation for User Engagement in Game Context

Yanick Trindade<sup>(✉)</sup>, Francisco Rebelo, and Paulo Noriega

CIAUD, Lisbon School of Architecture,  
Universidade de Lisboa, Rua Sá Nogueira, Pólo Universitário,  
Alto da Ajuda, 1349-063 Lisbon, Portugal  
lamberttrindade@hotmail.com

**Abstract.** In the development of a gaming experience guided by the perennial search for user engagement, one of the relevant conditions to ensure and validate, it's its narrative and context. If we associate this the dissemination of cultural aspects, the development of proposals able to give an engaging experience capable to attracting future visitors, is a relevant aspect to make known not only the place but also its culture. And so, the development of game narrative proposals can have a relevant function in involving potential tourists. Our goal in this study is to evaluate narratives in order to validate the one that will be able to give an engaging experience, for later adaptation through a Virtual Reality game experience. The evaluation was performed using the Self-Assessment-Mannequin (SAM), Emotional Engagement Scale (EES) and Cognitive Engagement Scale (CES). After the analysis of the results of these two groups, it was verified that the long narrative was able to arouse great interest on these two groups. To achieve the goal, we have developed two narratives, (i) Neutral Narrative, (ii) Emotional Narrative. We started the analysis of the results for the participants of São Tomé island and it was verified that the results reveal that the longer narrative was able to arouse more interest of them. Considering the adaptation of this narrative in a virtual reality experience in a stand, we developed a second comparative study with an adult population of another country, in this case, the Portuguese. It should be noted that in this second sample we only use the narrative that aroused the greatest interest, the Emotional Narrative. The genesis of the comparison is due to the fact that the experience in a stand is open to a large and varied public, both by age and country of visitors.

**Keywords:** Narrative · Emotional design · Culture · Engagement

## 1 Introduction

Awakening interest in cultural aspects, by sharing objects, ways of being, thinking, communicating and diffusing, praises the relevance of sharing the intrinsic collective memories of a community. The historical heritage of the São Tomé culture is found in the reciprocal acculturation between Africans from southern Sahara and Europeans from Portugal [1]. And so, the aggregation of value through the connection of concepts such as game, digital, culture and tradition as well the interaction that enhances emotion, fosters mutual exchange between people from different origins. Since the

1950s tourism appears as a relevant economic sector and cause of social and environmental change [2]. As for the characteristics, they should be defined as: Intangible - for not being a product but a service; heterogeneous - each user behaves and lives the experience and service in their own way; Inseparable - is enjoyed at the destination; ephemeral - can't be resold after loss of opportunity at a given moment; lack of ownership - can't be owned, just a service [3]. Tourists are conquered by the place beauty and charm of the landscapes belonging to a certain destination; some of which come from the desire to feel and experience sensations from distant places [4] and others from the desire to discover something deeper than superficial, which derive from the knowledge of the social and cultural aspects of the place [5]. Narrative can enhance the quality of content that we want to share and provide. Narrative derive from the Latin word *gnarus*, which means "knowing", a telling story [6]. About "What is a narrative?" The common answer is "a story" whereas for the "narrative in general" it's "storytelling" [7]. But the definition can be deeper. History is essential for the narrative, having the central properties of an event/events, following chronologically in time and transmitted through a medium [7]. Narrative is a vital human activity. Through narrative we present ourselves as heroes or victims and find ourselves in the process of presenting ourselves and our experiences [6]. We warn others of lessons we have learned from our own experience or the experience of others. Through narrative, we remember personal experience, we translate knowing in telling. Because of their human importance, narrative have been in interest to scholars almost from the beginning of scholarship [6]. About narrative structure, there are scholar's who articulate a structure of narrative that they believe to be universal. All narrative from all culture could be characterized in terms of structural opposition of nature and culture. Other scholars have documented ways in which each group tell narratives with structure rather different. Depside divergence, both fell that narrative structures are structures of minds or memories, whether inherited or encultured [6].

Engagement of user is a key issue to analyze and measure the experience we want to provide. Emotions are reactions to events, objects, and even memories, which invoke psychosomatic responses [8]. Emotions interact with the excitation mechanism, that can be classified as a dimension that goes from calm to excite [9]. Emotion and arousal combined are our feelings, remaining as a mood for minutes, hours or days, affecting our opinion about something. Good usability and aesthetics tend to trigger good emotions, like joy and pleasure, creating good memories [10].

## 1.1 Goals

This exploratory study belongs to a larger research work designed with the intention to promote cultural tourism in São Tomé through Virtual Reality experience. In this study, we focus only on the analysis of the emotional reaction through narratives. through Virtual Reality experience. In this study, we focus only on the analysis of the emotional reaction through narratives. We begin by analyzing two narratives and see which one was able to provide a more engaging experience with a participant group from the place where we want to promote their culture (São Tomé). After analyzing the results, we extended the study to the Portuguese adult participant group for a broader analysis and to have the vision of potential tourists. The reason why we do this study also on the São

Tomé island is to have an inside view of the content we want to offer to the tourists. Do the autochthonous like what we want to show? The data collected in this study will help us to define strategies for our main research work.

## 2 Methodology

### 2.1 Participants

This study was attended by 59 participants, divide in two groups. The first group is from São Tomé island, and the second group is from Portugal. Of these, 31 were male and 28 were female. Two types of narrative were created, the first was a neutral narrative and the second an emotional narrative. For the São Tomé group, we chose the between-subject to compare the differences between the two narratives through two subgroups of 23 participants for the neutral narrative and 21 for the emotional narrative, the age range was between 11 and 13 years old. In the group from Portugal, we only use the emotional narrative with 15 participants and the age range was between 23 and 35 years old.

### 2.2 The Visual Narrative

Participants visualized a mini-story called “SOIA-The Dream Island”, which was created using INKSCAPE® (Fig. 1).



**Fig. 1.** Narrative name and the main character (Soia).

There are two similar narrative whose main character, location, and purpose are the same. The first narrative is neutral, where the objective defined is “find the center of the world”. The second narrative despite having the same goal of the first, has a set of scenic elements of the geography and São Tomé culture, with the aim of provoking emotional reactions. The main character is Soia. The word Soia, comes from the dialect that is spoken on the São Tomé island and means history. She appears dressed in São Tomé traditional women clothing. The visual content was drawn in INKSCAPE®, and later attached to the Microsoft PowerPoint®.

#### – The Neutral Narrative

In the first narrative, we have a sequence with 6 slides: A screen with the story name is shown, and then the main character (Soia) appear and give the welcome and say her name, location and also give a challenge to the viewer, found the center of the world and the demand that he will live, the surrounding environment as well as the aspects of the São Tomé island culture that they will find in his journey to found the center of the world, located on the “islet of Rolas”. Before ending, Soia extends her hand and tells the viewer to repeat with her the magic words that will take him to the imaginary world of the tales (these words are written in dialect that is spoken in the São Tomé island) (Fig. 2).

#### – The Emotional Narrative

The second narrative was created with 18 slides. At the beginning also appears the name of the story and the main character (Soia) who introduces himself and welcomes. After this intro, the narrative is already different from the first. Soia presents her grandmother and invites us to know the island of São Tomé through a challenge that is, to find the center of the world, showing the map of the challenge designed by her, saying that to get there, they need to believe in the power of imagination. Soon thereafter appears an animation of an imaginary place inspired by the landscapes of São Tomé island and then, she gives an encouraging message that we need to believe in the power of imagination. The next moment, the image of a place known by all inhabitants of São Tomé, the “Big Dog” peak, located in the natural reserve of São Tomé Island (natural park Óbo) is shown. And suddenly the image of a giant appears too. Soia says that the giant is the guardian of magic water, this water has the power to cure any problem you have in your eyes (inspired by one of the traditional tales of São Tomé Island). Soon after, she says that she needs the viewer to bring the magic water that is in the imaginary world of the traditional tales of São Tomé, because she has a problem in her eyes. During the journey in the imaginary world of tales, the viewer will encounter objects, sounds and other particularities of São Tomé, passing through music, stories, painting, the green of the flora that surrounds us and the blue of the sky that is reflected in the beaches that nature offers us and that consequently will allow us to see the landscape and the intrinsic cultural aspects of this island. But she also warns the viewer that he will encounter some obstacles that he will have to overcome (like a game). Towards the end, she presents her doll with the name Luga. Luga in the imaginary world of tales comes to life and ceases to be a simple doll, but she tells the viewer that he needs to believe. Before ending, Soia extends her hand and tells the viewer to repeat with her the magic words that will take him to the imaginary world of the tales (same as the end of the shorter narrative).



Fig. 2. Some images of the narrative.

### 2.3 Measures

As evaluation tools we use: Self-Assessment Manikin (SAM): Evaluation technique through a non-verbal pictorial for measurement of arousal and pleasure, related with the affective reaction of the participant to various stimuli. For this, two scales were used: The Affective Valence Scale (Unpleasure/Pleasure) and the Arousal Scale (Calm/Excited) [11]. Emotional Engagement Scale (EES) with 4 questions related to: If they liked the content; If was interested in the content; If wished to see anything else; and the mood when viewing the content [12] and the Cognitive Engagement Scale (CES) with two questions related to: The concentration and the mood when viewing the content [12]. These three methods were used for more accuracy in the results.

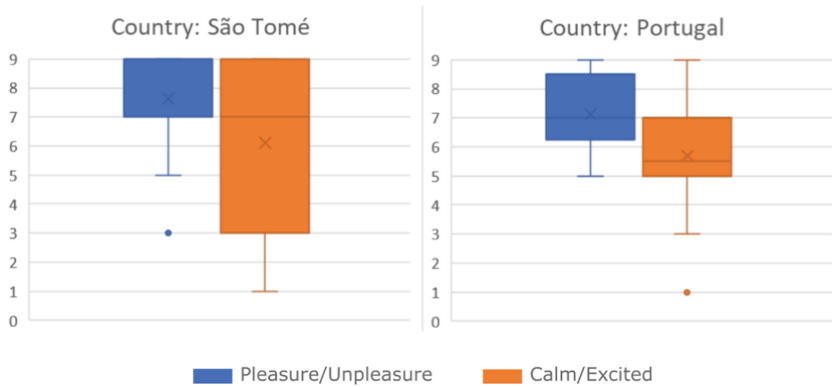
### 2.4 Procedures

Participants provided the written consent form and the experience was performed under the same conditions. The experience was displayed with a notebook computer. The between-subject design was applied for the participant from São Tomé, divided into two groups that visualize the Neutral and Emotional narrative. Each group perform a pre-test using SAM to measure the emotional reaction, through generic examples to familiarize himself with the methods that will be applied few moments after they see the visual narrative. For more accuracy in the results, we also apply the Emotional Engagement Scale and Cognitive Engagement Scale. After seeing the visual narrative, the participant will respond the SAM questionnaire. After we apply also the Emotional Engagement Scale (EES) and Cognitive Engagement Scale (CES). In a second moment, we extended the study to the Portuguese adult population. It should be noted that in this second sample we only use the narrative that had the greatest interest in the previous sample.

### 2.5 Results and Discussion

Will present and discuss the reach results in order to give answers to our main goal. In particular, we want to know what kind of narrative is capable of engage the autochthonous participants from São Tomé island and potential tourist from another country. In addition, we want to know engagement differences between different age groups, due to the fact that we want to provide an experience in a stand that is open to a large and varied public. With the purpose of assessing and comparing the results obtained, we used three data collection tools, SAM, EES and CES. We started the analysis of the results for the participants of São Tomé island and it was verified that the results reveal that the Emotional Narrative was able to arouse more interest of them. With the aim to compare results from participant from different origin, we developed a second comparative study with an adult population of another country, in this case, the Portuguese. It should be noted that in this second sample we only use the narrative that aroused the greatest interest in São Tomé participants, the Emotional Narrative. Figure 3 present the results for Pleasure (unpleasure/Pleasure) and arousal (calm excited). It was found that for pleasure, both participant groups showed great pleasure

value (Portugal = 7,1 and São Tomé = 7,6). For arousal, the results for both groups are slightly above average (Portugal = 5.5 and São Tomé = 6), but there is a great dispersion of results for the participants from São Tomé (values between 3 and 9).



**Fig. 3.** SAM: Comparison of the results obtained between the participants from STP and PT.

The results demonstrate that the Emotional Narrative is responsible for very good levels of pleasure, however, it is not intense enough to trigger high levels of arousal, which is important for us to increase levels of engagement. Therefore, the results show the need to develop new approaches to increase participants' engagement levels, that is an important condition for an exciting and pleasurable experience. One of the approaches can be through development of this experience in an immersive environment through Virtual Reality (VR).

Concerning questions related to the Emotional Engagement Scale (EES), Figs. 4, 5 and 6 presents the results for the questions related to "Did you enjoy this history?;" "Was this history interesting?;" "Did you want to see anything else?;" and "Describe your mood during this activity". Regarding the first question "did you like the story?" (see Fig. 4), it was found that both samples (pink color = Portugal and green color = São Tomé) liked the story a lot. It was verified, however, that there is a greater dispersion in the participants of São Tomé. Also, we can see that the same story can be used for both groups, (São Tomé children and adults from Portugal). Regarding the next two questions, "Was this history interesting?" and "Did you want to see anything else?" both groups express their desire to continue to interact and to know more about the narrative (see Fig. 5). For the question related with mood "Describe your mood during this activity" there is a neutral tendency between "excited" and "bored" variables (see Fig. 6).

In short, the emotional involvement in the story for the first three questions was very good. For both groups, the story is adequate but the mood is neutral, justifying the need to give something more to the experience, such as transposing the story to a virtual reality experience with the intention of increasing the levels of "engagement " as previously referenced.





Fig. 4. EES: Did you enjoy this history?

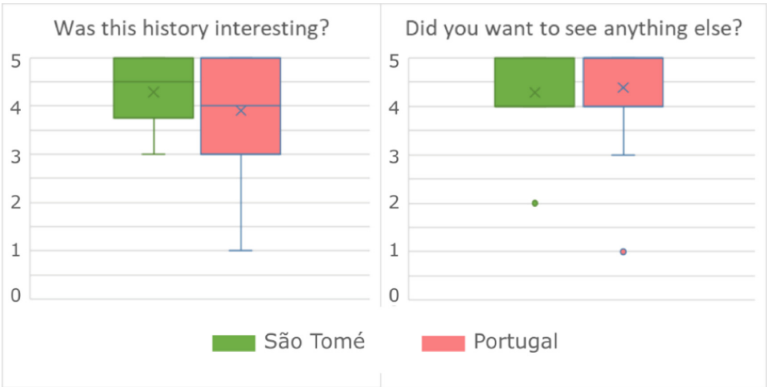


Fig. 5. EES: “Was this history interesting?” and “Did you want to see anything else?”

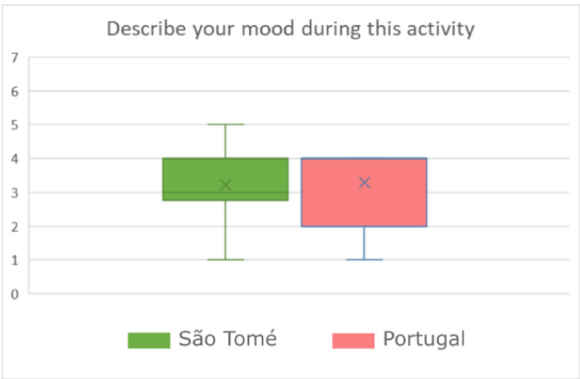
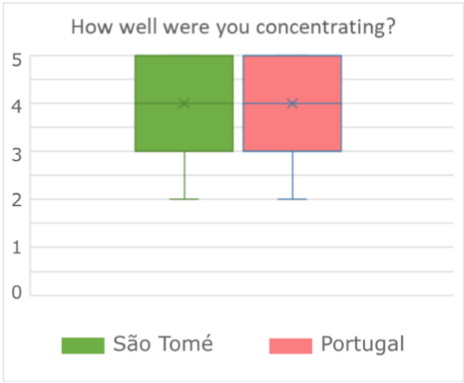


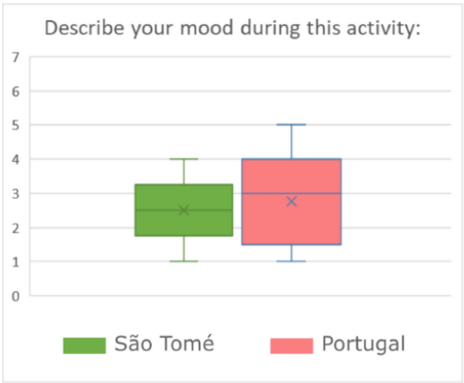
Fig. 6. EES: Describe your mood during this activity

Regarding the Cognitive Engagement Scale (CES), Figs. 7 and 8, respectively, present the results for the “How well were you concentrating?” And “Describe your mood during this activity:”. Regarding the concentration (Not at all - Very Much), the results obtained were very positive with values between 3 and 5.



**Fig. 7.** CES: How well were you concentrating?

The same does not happen for the question of mood (Focused - distracted) where the values were closer to a neutral tendency.



**Fig. 8.** CES: How well were you concentrating?

These results are in agreement with the previous one where it was verified once again that the mood of the participants must be increased.

### 3 Conclusion

This exploratory study belongs to the main research work and fits as a piece of the constructive process that will guide the creation of a virtual reality experience with the aim to seduce potential tourists to discover São Tomé e Príncipe culture.

In the first part of the study with São Tomé participant, the results show that a richer narrative in terms of visual content and sequence of events provides a more pleasurable experience compared to one with less content. After analyzing the results with the first participant group from São Tomé, we extended this study to the Portuguese adult population, having as an only comparative element the longest narrative, which was the one with the highest values in terms of engagement. We verified that the same story serves both age groups and local where they come from. However, there was a need to increase the mood for both groups. With the purpose of adapting the narrative to an immersive experience in the virtual reality environment in a stand, these results will help us in elaborating an experience for a diverse public. This indicator can be very relevant for the construction of a VR game narrative. Rather than constructing an extensive and rich narrative “at once”, we can “break it into small pieces”, i.e., incorporate small stories, to construct the whole, allowing the user to have periods of rest.

In the next stages, extending this study to the adult age group from São Tomé and young people from Portugal will help us to have all compare scope between an internal view of the inhabitants of the place that we want to promote and an external view of potential tourists who wish to visit and get to know the culture of another place.

**Acknowledgements.** CIAUD - Research Center in Architecture, Urbanism and Design.

A Ph.D. scholarship (SFRH/BD/129105/2017) granted to Yanick Trindade, from FCT: Fundação para a Ciência e Tecnologia (the Portuguese Science Foundation), supported this study.

### References

1. Seibert, G.: *Camaradas, Clientes e Compadres: Colonialismo, Socialismo e Democratização em São Tomé e Príncipe*, 2nd edn. Vega Editora, Lisboa (2002)
2. Robinson, P., Lück, M., Smith, S.: *Tourism*, 1st edn. CABI, Wallingford, Oxfordshire (2013)
3. Benea, I.: *Influences of Social Media on the Tourism and Hospitality Industry*. Modul Vienna University, Vienna (2014)
4. Steenjacobsen, J.: Nomadic tourism and fleeting place encounters: exploring different aspects of sightseeing. *Scand. J. Hosp. Tour.* **1**(2), 99–112 (2001)
5. Gibson, A., O’Rawe, M.: Virtual reality as a travel promotional tool: insights a consumer travel fair. In: Jung, T., Dieck, M. (eds.) *Augmented Reality and Virtual Reality*. Progress in IS. Springer, Cham (2018)
6. McCabe, A., Peterson, C.: *Developing Narrative Structure*. Lawrence Erlbaum Associates, Hillsdale (1991)
7. Abbott, H.: Narrative. In: Logan, P.M. (ed.) *The Encyclopedia of the Novel* (2010)

8. Ortony, A., Clore, G.L., Collins, A.: The Cognitive Structure of Emotions. Cambridge University Press, Cambridge (1988)
9. Berlyne, E.: Conflict, Arousal, and Curiosity. McGraw-Hill, New York (1960)
10. Sutcliffe, A.: Designing for User Engagement: Aesthetic and Attractive User Interfaces. Morgan & Claypool (2009)
11. Bradley, M., Lang, P.: Measuring emotion: the self-assessment manikin and the semantic differential. *J. Behav. Ther. Exp. Psychiat.* **25**, 49–59 (1994)
12. Henrie, R.: Measuring Student Engagement in Technology-Mediated Learning Environments (2016)

# **Product and System Design**



# The Importance of Ergonomics in the Development of Sustainable Materials Applied to Footwear Design

Ana Margarida Fernandes<sup>1,2(✉)</sup>

<sup>1</sup> CIAUD, Lisbon School of Architecture, Universidade de Lisboa,  
Rua Sá Nogueira, 1349-063 Lisbon, Portugal  
ana.design.fernandes@gmail.com

<sup>2</sup> ESART-IPCB, Castelo Branco, Portugal

**Abstract.** The central objective of this research is the development of a footwear line, combining ergonomics and design, and subsequently resulting in its application to new proposals for recyclable and sustainable materials in the footwear sector. An objective analysis applying a mixed methodology focused on two areas, the non-interventionist when we study and analyse the starting point and what exists in the market, and the interventionist methodology exploring and developing materials with ergonomic studies. Thus, the intention is to stimulate and innovate with ergonomic and functional shapes, later being tested by a focus group. With the application of the design methodology the following hypothesis was formulated: Will it be possible to apply and test recyclable and existing raw materials in the footwear sector, creating an innovative and ergonomic product? In order to test the hypothesis, we resorted to an action-research methodology that allows us to answer the initial question.

**Keywords:** Ergonomics · Design · Textiles · Footwear

## 1 Introduction

Footwear represents a channel of direct diffusion of the image of the woman who increasingly seeks comfort and sensuality in the way she presents her daily looks. Combining the need to promote their image to the need for protection and safety of their feet the choice of footwear with ergonomic and sustainable studies is increasingly present in the decision to choose predominantly comfortable and functional shoes. The bet on Design implies a series of factors, many of them with strong scientific and technological components for the choice of a certain type of footwear. Increasingly the design should be thought of in terms of its suitability, not forgetting the basic premises of ergonomic and sustainable choice.

In order to help and achieve the general research objective, it was based on the question of departure formulated. “Will it be possible to apply and test recyclable and existing raw materials in the footwear sector to create an innovative and ergonomic product?”.

In order to answer this question, it was decided that specific objectives, which respect the ergonomic qualities of footwear, crossed some lines of thinking about what can ultimately be understood by ergonomics in footwear. They can be described as a compound between sciences and technologies where the constant aim is to adapt, in the development of projected products, with the constant philosophy of comfort as a prerequisite for the development of new products.

This assumption takes on consistency when the author Couto [9] defines that “ergonomics is a set of sciences and technologies that look for the comfortable and productive adaptation between the human being and their work”. In this line of thinking the attempt to create new products and differentiators could meet the needs of a market with constant consumption requirements.

In the area of footwear design, the importance of ergonomics lies essentially in the technical quality of the molds (shoe shapes) and in the suitability of the most appropriate materials for the execution of each developed model.

Drummond [2] in his paper on Design Intervention for Materials and Ergonomics states that “in the meantime, by mastering the processing of composites, the combination of materials into a single one allows for a number of characteristics that can occur simultaneously. This contributes to maximizing ergonomics”.

Gonçalves and Lopes at a congress of Ergonomics report that besides ergonomics we have to approach the comfort issues because they could cross each other. “The dimension of comfort, when treated as an ergonomic principle is difficult to conceptualize. Comfort in ergonomics for products is geared more towards the physical aspects like: temperature, thermal sensations, measures and suitable forms that facilitate the use, information and security” [7]. It then poses another pertinent question besides ergonomics, comfort, the selection of raw materials. According to the author Araujo, “the selection of materials according to the criteria of the designer or the person responsible for the collection is thus a truly important phase of creation. At the conception stage it is necessary to specify the characteristics of the different components of the product so that, during use, it can meet the requirements of the users” [1].

Doordan states that, “material selection significantly influences the form and function and perception of a new product” [3].

After this reflection it is pertinent to analyze the materials presented to a focus group which aims to observe and analyze the importance of the use of materials to develop a collection of women’s footwear, where the ergonomic study of footwear influences the choice of certain materials.

## 2 Methodology

Given the research question and in order to test the answer to the stated problem, it was pertinent to resort to a methodology of mixed, interventionist and noninterventionist research, which tested the question qualitatively.

In the methodology of noninterventionist research, the work was done on the subject to be investigated, using literary information that had analyzed and confronted projects of this nature.

In relation to the interventionist methodology, a mixed action research technique was used, in which a study plan for data collection was elaborated which included the following steps:

- Identification of focus group recipients profile
- Development of the survey
- Pre-test test and related adjustments
- Inquiry Application
- Analysis of the survey
- Data introduction
- Analysis of the data and conclusions.

This questionnaire was applied to a focus group composed of 6 women with the following profile: Age Group - From 20 to 40 years old, Literary qualifications, Graduate students, Occupation: 1 Teacher, 1 Computer Engineer, 2 administrative assistants, 2 students.

The choice of this methodology seemed to fit the best, given that it meets the main objectives; “Will it be possible to apply and test recyclable and existing raw materials in the footwear sector making possible the creation of an innovative and ergonomic product?”.

Starting from the initial question, an inquiry was formulated to a predefined group, focus group. The question is a proposition to the initial question. Whether or not it will be accepted will depend on the results of the analysis and testing, through the techniques and results that will lead to its validation or not<sup>1</sup>.

In a second phase, the intention is to return to direct observation of the interaction between the shoe and the wearer in order to confirm the problem and draw conclusions to later produce the ergonomic footwear and subsequently for it to be released on the market. The results will always be open conclusions, serving in the future to drive new challenges in the area of research. The main limitation of this methodological procedure lies in the dependence of the availability of each of the elements chosen for the final contribution.

## 2.1 Focus Group Analysis

The first phase of observation and analysis in the focus group presented, aims to collect data for the development of research.

This observation is direct and is a qualitative research technique suitable to the researcher who intends in the first phase to understand if sustainability is important in the materials applied as well as comfort in shoes. In order to note the relevant assessments, a qualitative analysis was carried out, where a direct observation table was created with the choice of the 4 most direct questions. In obtaining the research responses, the deontological aspects of the research were taken into account in the way

---

<sup>1</sup> Ketele, J.-M.D., & Xavier-Roegiers (1999). Metodologia de recolha de Dados-Fundamentos dos Métodos de Observação, de Questionários, de entrevistas e de Estudo de Documentos. Lisboa: Instituto Piaget.



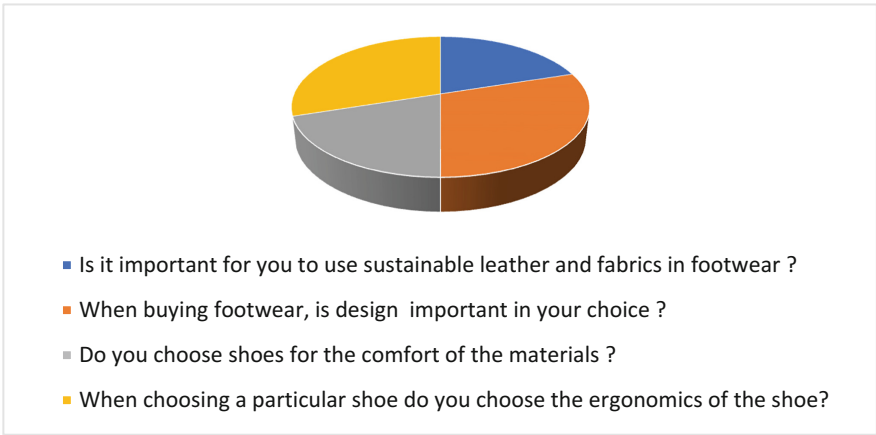
the questions were presented, with the following norms: not forcing respondents to respond, informing on the nature of the study, respecting anonymity and confidentiality of the response.

**Table 1.** Questions and responses to the questionnaire

Question	Indicators					
	Yes	Yes	Indifferent		Yes	Yes
Is it important for you to use sustainable leather and fabrics in footwear?	Yes	Yes	Indifferent	No	Yes	Yes
When buying footwear, is design important in your choice?	Yes	Yes	Yes	Yes	Yes	Yes
Do you choose shoes for the comfort of the materials?	Yes	Yes	Indifferent	Yes	No	Yes
When choosing a particular shoe do you choose the ergonomics of the shoe?	Yes	Yes	Yes	Yes	Yes	Yes

**Results.** As Table 1 shows for the first question that asked whether the use of sustainable leather and fabrics was important we obtained four *yes* responses, one *no* and one answer was *indifferent*. The next responses related to the question of the purchase and the importance of the design. and all six response were *yes*. As for the question about the comfort of the materials we obtained four *yes* responses, one *indifferent* and one *no*. Finally the responses to the question of ergonomics, all six answers were *yes*.

Based on these 4 parameters evaluated with closed questions, it was concluded that the positive issues refer to Design and Ergonomics, as can be seen when the question about design and ergonomics is asked, a *yes* was given by all respondents (Fig. 1).



**Fig. 1.** Chart illustrates the results of the responses to the questions

## 2.2 Design-Development of the Project

In order to achieve the proposed goal of action research based on the innovative development of a line of women's shoes, one starts with the projection of ideas at the level of the design project according to a methodology to find results in an effective way.

Martins and Couto [9] state that. "Design is a process with knowledge, innovation and awareness. The practice of their professional functions should be carried out in an interface with social functions in a reflexive way and based on a critical and rigorous awareness of values". Design being interconnected in a theoretical context, when it questions and analyzes the problems, and the types of solutions, directing all this study to operational and practical contexts, that refers us to several methodological areas, where the identification and analysis of certain requirements, lead the designer to find different types of paths in order to find the best solution for the success of the proposed product.

Munari states that "Design can be considered as a project activity whose problem results from a need" [6].

The development of the design project was centered on the adaptation of Bruno Munari's methodology, which includes several steps in solving the problem and later on to finding the most appropriate solution (Fig. 2).

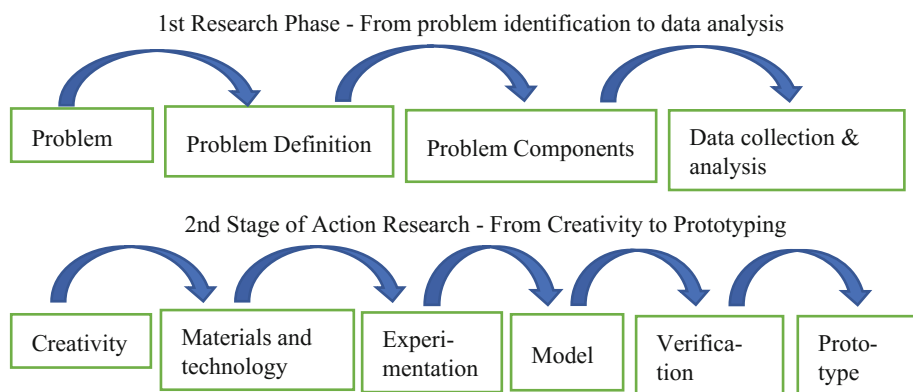


Fig. 2. Stages of the design methodology (Munari adaptation)

## 2.3 Dynamics of Applied Methodology

The first phase of the research was begun with the Problem "Creating a collection of ergonomic women's shoes, with recyclable materials" began. In the definition of the problem, the hypothesis was put forward: "Will it be possible to apply and test recyclable and existing raw materials in the footwear sector, creating an innovative and ergonomic product?" The components of the problem were the "Identification of women with different characteristics to create a focus group".

Further on, the collection and analysis of the data was done along with "cross-referencing of the results obtained when the focus group was gathered".

Once the second phase with the analysis of the data and answering the questions posed, was done we started effectively towards the stage of creativity and development of the product, initially proposed; A Collection of ergonomic women's shoes and recyclable materials.

According to Cardoso and Picoli, "Creativity consists in coordinating the data collected and analyzed in a conspicuous way. Coordination of data in a creative way leads to the solution of the problem".

For the creative development, a survey of raw materials in the footwear sector began, in which a footwear company from the central region of Portugal was selected, and we sought to know what type of materials were used in footwear as shown in Fig. 3.



**Fig. 3.** Different materials used in footwear production

Some waste of raw material was identified, (Fig. 4) which raised the question about the transformation of the remains of materials. The answer obtained on this issue of the leather remains was of interest in an innovative design where the design marks the difference in a specific product, to put in a certain segment of the market.

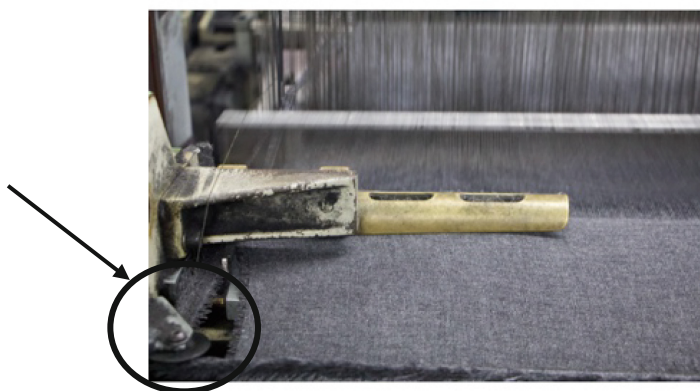


**Fig. 4.** Waste and remains of the materials

In the observation of the different components of production of a shoe the insoles were highlighted as having the possibility of using textiles. A proposal is made for the use of recycled textile fabrics from another company in the area of weaving.

For the development of the collection, new challenges were identified to reach the initial starting point; Reuse of materials used in the industry to which comfort was the point of arrival.

In Textile production, the sides of fabrics were found to be wasteful when they were produced, so it was possible to recycle and reuse these to provide comfort in the footwear and use leftovers of the fabrics called the selvages as shown in Fig. 5.



**Fig. 5.** Selvages as a waste product

Ergonomic insoles with textile waste were studied (Fig. 6) to obtain the first analysis on the possibility of developing the collection in a sustainable and ergonomic way for the chosen public.



**Fig. 6.** Ergonomic insoles

### 3 Conclusions

Throughout this research we sought to understand the association between sustainability and ergonomics through a design methodology in order to obtain guidelines for the development of a collection of women's shoes. The initial objective of finding a focus group to analyze the importance of sustainable raw materials to give comfort to the shoes to be developed was reached after a previously organized session, tested with objective and closed questions, in order to find the challenge.

In the analysis of the filming and questions posed, the importance of recycled raw materials allied to the comfort of the shoe was evident, but not neglecting the whole design of the shoes. Solutions were found for problems identified in terms of footwear through direct contact with two types of industry, in the area of footwear and textiles. The possibility of reutilization of the leather to later develop the collection was identified.

It was during the research on materials in the footwear industry that a new question was raised, which materials were used in the components of a shoe. It was verified that the insoles could be made with fabrics, which could give greater comfort to the footwear. Following a survey carried out in the textile industry, it was verified that there was a specific waste, the sides of the fabrics called selvedge.

Once the concrete collection and analysis of the data was done, the prerequisites were then tested and proved, through direct contacts, action research, in order to find answers to these issues.

Based on the literature, the interview of the focus group through questionnaires and direct observation it was concluded that it is possible to develop new products from different waste using a careful design methodology. The flexibility of the methodology applied to Design often refers us to proposals addressed and appropriate to the development and improvement of the product. It can be concluded that active research has shown that the results of the issues raised and addressed identify a real need for proposals for solutions to this problem. As such, the characteristics of the solution proposals requires an understanding of comfort, functionality and design.

### References

1. Araújo, M.D.: Tecnologia do vestuário. Fundação Calouste Gulbenkian, Lisboa (1996)
2. Drummond, J.J., Oliveira, W.A., Botelho, R.D.: Moda corporativa: uma análise pelo design, materiais e ergonomia. Buenos Aires: Centro de Pesquisa e Desenvolvimento em Design e Ergonomia; Escola de Design/Universidade do Estado de Minas Gerais (2009)
3. Doordan, D.P.: On Materials. Design Issues, no. 19 (2003)
4. Manzini, E.: A matéria da invenção. Centro Português de Design, Lisboa (1993)
5. Martins, B., Couto, R.: Fundamentos, propostas e perspectivas para o design comprometido com questões sociais. In: Congresso Brasileiro de Pesquisa e desenvolvimento em design, no. 7, Paraná (2006)
6. Munari, B.: Das coisas nascem coisas. Edições 70, Lisboa (1981)

7. Gonçalves, E., Lopes, L.D.: Ergonomia no vestuário: conceitos de conforto como valor agregado ao produto de moda. Florianópolis: UDES/CEART. Modapalavra. Estação das letras editora Ltda., vol. 4 (2006)
8. Cardoso, C., Picoli, J.: 9º Colóquio de Moda, obtido a 30 janeiro (2019), de Colóquio de Moda (2003). [http://www.coloquiomoda.com.br/anais/anais/9-Coloquio-dModa\\_2013/COMUNICAÇÃO-ORAL/EIXO-2-EDUCAÇÃO\\_COMUNICAÇÃO-ORAL, Metodologia-de-projeto-de-Bruno-Munari-aplicado-ao-design-de-superficie-demoda.pdf](http://www.coloquiomoda.com.br/anais/anais/9-Coloquio-dModa_2013/COMUNICAÇÃO-ORAL/EIXO-2-EDUCAÇÃO_COMUNICAÇÃO-ORAL, Metodologia-de-projeto-de-Bruno-Munari-aplicado-ao-design-de-superficie-demoda.pdf)
9. Couto, H.A.: Contribuições da ergonomia, higiene, segurança e medicina do trabalho para a qualidade de vida (2005). <http://www.erglota.com.br/ergonomia>. Acesso em 25 janeiro 2019



# Effect of Body Weight of Wheelchair Care Recipient on Physical Activity Intensity of Assistant Person

Haruka Sugiyama<sup>1</sup>(✉), Yohsuke Yoshioka<sup>1</sup>, Masaki Takahashi<sup>2</sup>,  
Cheng Jiayu<sup>2</sup>, Mitsuaki Shiraishi<sup>3</sup>, Fumitake Hakozaiki<sup>3</sup>,  
Satoshi Kamen<sup>4</sup>, Yoshihide Tokuda<sup>5</sup>, and Ken Nunota<sup>6</sup>

<sup>1</sup> Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba, Japan  
gentle834l@chiba-u.jp,  
yoshioka.yohsuke@faculty.chiba-u.jp

<sup>2</sup> Bunka Gakuen University, Yoyogi 3-22-1, Shibuya-ku, Tokyo, Japan  
masa-takahashi@bunka.ac.jp, 12110802051cjj@gmail.com

<sup>3</sup> Chiba Institute of Technology, 2-17-1 Tsudanuma, Narashino, Japan  
mitsuaki.shiraishi@it-chiba.ac.jp,  
hakochoan8716@icloud.com

<sup>4</sup> Nissin Medical Industries Co., Ltd., Kitanagoya, Japan  
s-kamen@wheelchair.co.jp

<sup>5</sup> Teikyo Heisei University,  
2-51-4 Higashi Ikebukuro, Toshima-ku, Tokyo, Japan  
ytokuda@thu.ac.jp

<sup>6</sup> National Institute for Land and Infrastructure Management, Tsukuba, Japan  
nunota-k92ta@mlit.go.jp

**Abstract.** The purpose of this study is to verify the intensities of physical activity of the assistant person who are helping the movement of a patient riding on a wheelchair. The effects of the body weight of the care recipient on the wheelchair and the obstacle on moving route on the intensities of physical activity were analyzed by the results of the behavioral experiment with the measurement of gas concentration in the exhaled breath.

**Keywords:** Physical activity intensity · Activity level ·  
Respiratory metabolism · Barrier-free human factors · Architectural design

## 1 Introduction

In recent years, the overall life expectancy has been extended due to the advances in medical care, but the healthy life expectancy has not been extended much. Therefore, the burden of medical expenses and nursing care expenses tends to increase as the elderly become older.

Especially for the elderly, daily physical activity in the house greatly affects health maintenance. Even by changing the furniture arrangement and the floor plan, the mental burden associated with in house activity is reduced and as a result, the total amount of activity may increase.

Likewise, it is fully conceivable that the burden associated with nursing care actions changes depending on the floor plan.

It would be ideal to provide a floorplan that would reduce the burden on both the residents and caregivers.

In this research, we describe the influence of elements such as the steps in the house and the body weight of the care recipient on the amount of physical activity of the caregivers.

## 2 Purpose

This study was carried out with the purpose of assessing the intensities of the physical activity of the caregiver helping a wheelchair-bound patient move. The effects of the body weight of the care recipient in a wheelchair and the obstacles in a movement route on the intensities of physical activity were quantitatively analyzed by the results of a behavioral experiment measuring gas concentration in exhaled breath.

## 3 Method

An experiment aimed at acquiring activity data was conducted at the Institute for Building Research (Tsukuba city, Japan). We asked male and female subjects to perform actions such as walking and wheelchair assistance and measured the amount of activity and exercise intensity. The subjects were also asked to wear a portable exhaled breath analyzer (VO2000/S&ME) on their faces and to place a small activity meter (Active style Pro HJA-750C/OMRON) at their waist on their back during the experimental procedure. Subject information was inputted into each measuring instrument in advance, and the metabolic equivalent of task (METs) value indicating the intensities of physical activity was calculated after taking into account their age, body weight, and height.

### 3.1 Measurement Equipment and Scale of Activity Amount

- Portable exhaled breath analyzer (VO2000/S&ME)

Detect exhaled oxygen and carbon dioxide every 10 to 60 s. Input subject information beforehand and process fluctuation with dedicated software to calculate basal metabolism and METs value. In the experiment, the measurement interval was set to 10 s.

- Small activity meter (Active style Pro HJA-750C/OMRON)

Identify walking and living activities with built-in accelerometer. After inputting the subject information in advance, the activity intensity “METs” is calculated every ten seconds.

- Borg scale

Borg Scale was adopted as a method for measuring the subjective burden degree (subjective exercise intensity (RPE)) during exercise. It is a technique to select subjective exercise intensity in 15 stages and devised so that ten times the number becomes nearly a heart rate (Fig. 1).



- METs

METs is a unit of physical activity intensity. It indicates how many times the oxygen consumed by the exercise corresponds to the basic metabolism. The calculation formula of METs is as follows.

$$\text{METs} = \text{Oxygen intake at activity} \div \text{Oxygen intake at rest}$$

Perceived Exertion Rating	Description of Exertion
6	
7	extremely light
8	
9	very light
10	
11	fairly light
12	
13	somewhat hard
14	
15	hard
16	
17	very hard
18	
19	extremely hard
20	

**Fig. 1.** Ratings of perceived exertion by Borg Scale



**Fig. 2.** State of installation of the measuring equipment (Exhalation metabolism meter/activity meter)

### 3.2 Measurement Procedure

First of all, the examinee was fitted with an exhaled breath analyzer and an activity meter while sitting. Regarding the exhaled breath analyzer, calibration was performed before wearing (Fig. 2).

A resting time (sitting position) of 2 min was allowed before and after the experiment, during which the subjective exercise intensity by the Borg scale was measured. After the resting time, the examinee stood up quickly and walked or assisted the wheelchair for about 8 min.

The amount of activity data was acquired from each measuring instrument and METs value was calculated based on the subject's information (weight, height, age) inputted in advance into each measuring instrument.

### 3.3 Experimental Conditions

The following three experimental conditions were used in this experiment. In each experimental condition, the subjects were directed to walk around the experimental space eight times in a circle.

- Normal Walk Condition

The subjects were directed to continue walking at their normal speed without any load.

- Wheelchair Assistance Condition

The subjects were directed to walk around the experimental space while pushing a wheelchair on which one of the several care recipients with different body weights was sitting. The weight of the care recipients was divided into three categories: 45 kg as Light Weight, 65 kg as Medium Weight, and 85 kg as Heavy Weight.

- Wheelchair Assistance and Step condition

The subjects were directed to go up and down a plate of 1 m  $\times$  1 m arranged in the center of the experimental space while pushing a wheelchair on which one of the care-recipients was sitting, once per cycle. The height of the step plate was set in two sizes of 5 cm and 10 cm.

## 4 Acquired Data

Acquired data from each measuring instrument under each experimental condition is summarized in Table 1.

For the METs value conversion data outputted from the exhaled breath analyzer, the mean value of the data outputted every 10 s was determined as a representative value.

**Table 1.** Experimental conditions and acquired data

Subject	Activity type	Body weight of care recipient	Obstacle	Mets by activity meter	Mets by exhaled breath analyzer	Borg scale before → after
M	Walking		No step	2.5	2.1	6 → 8
M	Wheelchair assistance	45 kg	No step	2	2.7	6 → 9
M	Wheelchair assistance	65 kg	No step	2.2	2.8	6 → 10
M	Wheelchair assistance	85 kg	No step	2.3	3	6 → 13
F	Walking		No step	2.5	2.4	6 → 8
F	Wheelchair assistance	45 kg	No step	2.2	2.9	6 → 10
F	Wheelchair assistance	65 kg	No step	2.6	3	6 → 10
F	Wheelchair assistance	85 kg	No step	2.7	3.3	6 → 11
M	Wheelchair assistance	45 kg	Step height 5 cm		2.6	6 → 10
M	Wheelchair assistance	45 kg	Step height 10 cm		2.5	6 → 13
F	Wheelchair assistance	65 kg	Step height 5 cm		4	6 → 9
F	Wheelchair assistance	65 kg	Step height 10 cm		4.4	6 → 11
M	Wheelchair assistance	65 kg	Step height 5 cm		2.5	6 → 9
M	Wheelchair assistance	65 kg	Step height 10 cm		3.1	6 → 13

# 5 Discussion

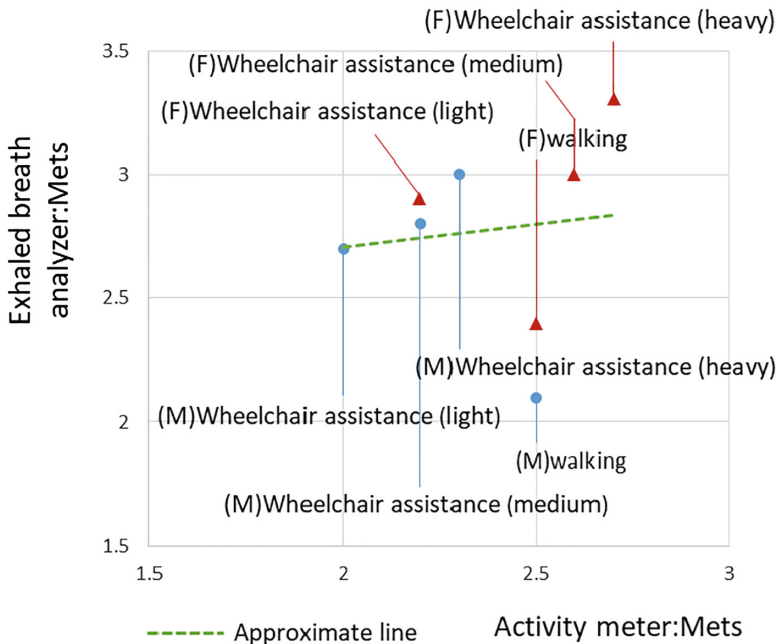
## 5.1 Comparison of METs Values According to the Exhaled Breath Analyzer and Activity Meter

The results indicated that the each METs value between the activity meter and the exhaled breath analyzer almost coincided in the Normal Walk Condition (Graph 1). However, in the Wheelchair Assistance Condition, the METs value of the activity meter was smaller than that obtained from the exhaled breath analyzer.

Comparing the METs value during wheelchair assistance, in male subjects, the METs value output from the activity meter varied from 2.0 to 2.3, whereas the METs value output from the exhaled breath analyzer varied from 2.7 to 3.0. On the whole, it is speculated that the measurement data by the activity meter was lower than the data obtained from the exhaled breath analyzer. Since the activity meter used in this experiment estimates the METs value according to the acceleration changing pattern, the physical activity intensity would be evaluated at a lower value than that of an actual “high load but slow movement” such as wheelchair assistance. For example, the METs value varying from 2.0 to 2.3 during the Wheelchair Assistance Condition was lower than the METs value of 2.5 in the Normal Walk Condition.

Conversely, in female subjects, the METs value according to the activity meter varied from around 2.2 to 2.7, whereas the value output from the exhaled breath analyzer varied between 2.9 and 3.3. Similarly, it is speculated that the measurement data obtained using the activity meter was evaluated as lower than that with the exhaled breath analyzer. However, in medium and heavy weight conditions, the measurement data of the activity meter was also higher than that in the normal walking condition.

In women subjects with low power, as the weight of the care recipient increases, the movement itself during assistance as measured by the acceleration sensor may be intensified.

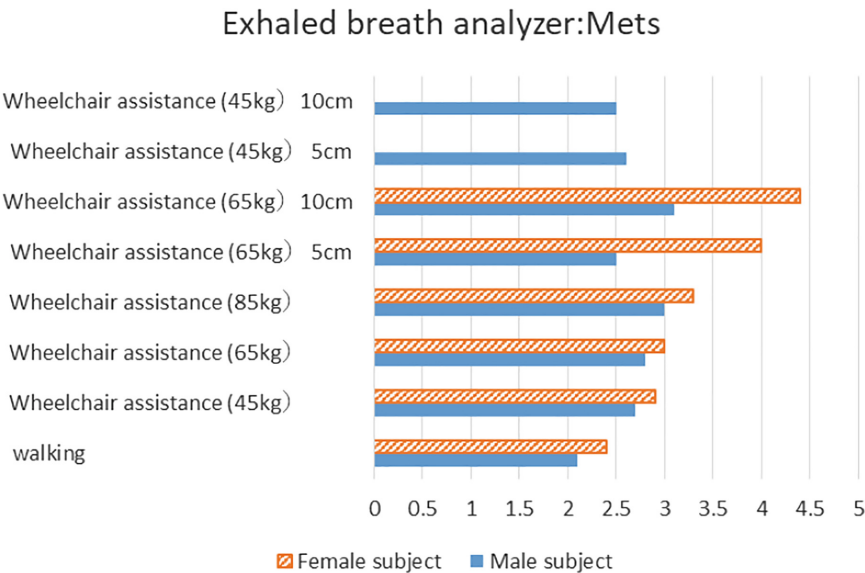


**Graph 1.** Comparison of METs values obtained using the exhaled breath analyzer and activity meter

### 5.2 Fluctuation of Mets Value Calculated from the Exhaled Breath Analyzer

In the comparison of the METs value by the exhaled breath analyzer under each condition, both male and female subjects showed higher values under the Wheelchair Assistance Condition (especially the condition with heavier weight care-recipients) in comparison to that under the Normal Walk Condition.

Particularly in female subjects, the heavier the weight of the care-recipient, or the higher the height of the step, the higher the METs value tended to be (Graph 2).



**Graph 2.** METs value calculated from the exhaled breath analyzer

## 6 Conclusion and Future Prospects

This study was conducted as part of a project of the National Institute for Land and Infrastructure Management in Japan, “Establishment of visualization method of barrier-free effect according to life stage”. This project is aimed at establishing a method to visualize the burden on residents and caregivers by developing a system that calculates the amount of activity assumed for each floor plan of a house. We are planning to measure the activity data in real houses and investigate the health-related outcomes in terms of floorplans.

In this experiment, we were able to gather data on the physical activity intensity of a caregiver for a wheelchair-bound patient who was anticipated to be affected by the physical factors of a house.

In addition, comparison with the exhaled breath analyzer confirmed that the precision of the METs value calculation using an activity meter was insufficient. Thus, when using the activity meter as a substitute for the breath analyzer, it is recommended that measures such as applying a correction factor according to the type of motion be employed.

## References

1. U.S. Department of Health and Human Services: Physical Activity and Health: A Report of the Surgeon General. International Medical Publishing (1996)
2. Meisner, B.A., Weir, P.L., Baker, J.: The relationship between aging expectations and various modes of physical activity among aging adults. *Psychol. Sport Exerc.* **14**, 569–576 (2013)
3. Wasserman, K., Whipp, B.J., Koyl, S.N., Beaver, W.L.: Anaerobic threshold and respiratory gas exchange during exercise. *J. Appl. Physiol.* **35**(2), 236–243 (1973)
4. Schon, S., Theodore, S.J., Güntner, A.T.: Versatile breath sampler for online gas sensor analysis. *Sens. Actuators: B. Chem.* **273**, 1780–1785 (2018)
5. Kendrick, K.R., Baxi, S.C., Smith, R.M.: Usefulness of the modified 0-10 Borg scale in assessing the degree of dyspnea in patients with COPD and asthma. *J. Emergency Nurs.* **26** (3), 216–222 (2000)
6. Rhodes, R.E., Horne, L.: Deepening the measurement of motivation in the physical activity domain: introducing behavioural resolve. *Psychol. Sport Exerc.* **14**, 455–460 (2013)
7. Iizuka, Y., Takahashi, M., Inoue, J., Akiba, N., Tamaki, M., Tsujimoto, W., Nagayama, Y.: Development of the steps simulations in the house planning part 1. Results of the pre-investigation concerning of living activity and number of steps and the outline of main survey. In: Summaries of the 23th Annual Conference of Japan Society for Interior Studies, pp. 45–46 (2011)
8. Takahashi, M., Iizuka, Y., Inoue, J., Akiba, N., Tamaki, M., Tsujimoto, W., Nagayama, Y.: Development of the steps simulations in the house planning part 2. Results of the main survey and the steps simulations using the act coefficients. In: Summaries of the 23th Annual Conference of Japan Society for Interior Studies, pp. 47–48 (2011)
9. Tarui, K., Yoshimura, M., Shiraishi, M., Sugano, Y., Ueno, H., Nunota, K.: A questionnaire survey about housing and housework. A study on the evaluation program of houses based on indoor moving activity and amount of exertion part 1. In: Summaries of the 23th Annual Conference of Japan Society for Interior Studies, pp. 91–92 (2011)
10. Yoshimura, M., Tarui, K., Shiraishi, M., Ueno, H., Sugano, Y., Nunota, K.: Monitoring of activities of daily living. A study on the evaluation program of houses based on indoor moving activity and amount of exertion part 2. In: Summaries of the 23th Annual Conference of Japan Society for Interior Studies, pp. 93–94 (2011)
11. Shiraishi, M., Tarui, K., Yoshimura, M., Ueno, H., Sugano, Y., Nunota, K.: A measurement of energy consumption and degree of load on housework. A study on the evaluation program of houses based on indoor moving activity and amount of exertion part 3. In: Summaries of the 23th Annual Conference of Japan Society for Interior Studies, pp. 95–96 (2011)



# Research on Body Pressure Distribution of Mattress for Different Genders

Huimin Hu<sup>1,2</sup>, Mengjing Cai<sup>3(✉)</sup>, Pu Hong<sup>3</sup>, Yinxia Li<sup>3</sup>, Ling Luo<sup>1,2</sup>,  
and Haimei Wu<sup>1,2</sup>

<sup>1</sup> Ergonomics Laboratory, China National Institute of Standardization,  
Beijing, China

{huhm, luoling, wuhm}@cnis.gov.cn

<sup>2</sup> SAMR Key Laboratory of Human Factors and Ergonomics,  
China National Institute of Standardization, Beijing, China

<sup>3</sup> School of Mechanical Engineering, Zhengzhou University,  
Zhengzhou, Henan, China

1223274297@qq.com, Hongup1001@163.com,  
liyxmail@126.com

**Abstract.** This paper researched the pressure distribution on mattresses for different genders. A total of 72 subjects were selected in this experiment and the ratio of male and female was 1:1. Seven mattresses with different hardness were selected. The body pressure measure system (BPMS) was used to get the pressure distribution data, and subjective comfort evaluation questionnaire was used to get the subjective comfort score of the mattress. Results indicated that the back pressure and waist pressure of subjects with different genders were different. The back contact area, waist contact area and hip contact area of subjects with different genders were different, too. The subjective comfort evaluation was combined to determine the maximum pressure value and contact area recommendation value of different parts of the body, which can provide technical guidance for the ergonomic design of the mattress and reference for consumers.

**Keywords:** Gender · Body pressure distribution · Subjective evaluation

## 1 Introduction

According to statistics, the quality of sleep is directly related to the health of people and the efficiency of work [1]. Because of the bed as a sleep-affecting important factor, mattresses have become the focus of many consumers. Especially with the development of technology and the improvement of living standards, people's awareness of health and comfort has gradually strengthened and the requirements for mattresses have become higher and higher. In order to ensure people's high-quality sleep, the types of mattresses developed by mattress designer are gradually diversified. The designer must consider not only human sleep physiology and behavioral characteristics, but also human-bed interface relationship characteristics, especially the interface relationship characteristics that have an important influence on human spine morphology and spine health. The living habits, cultural background and body characteristics of Chinese

people are quite different from those of other ethnic groups. Therefore, the relevant design data parameters of foreign countries cannot be directly copied to the humanized design of mattresses, which must be based on the requirements of the sleep characteristics of Chinese people.

Physical and psychological factors can affect sleep quality, such as temperature, humidity, mattress hardness, pillows, blankets, and the sleeping position of the body [2]. At present, the methods for measuring the comfort of mattress mainly include objective measurement and subjective evaluation. In the literature, various objective methods (e.g. pressure measurements, three-dimensional scanning technology [3], temperature distribution [4], EMG etc.) are used to quantify the subjective comfort/discomfort of mattress. Objective methods have the advantage of being less time consuming, less dependent on a large number of subjects, less prone to measurement error [5]. In the literature, Liming Shen used the body pressure distribution to study the relationship about body characteristics and the spring mattress, the influence of the bed system on sleep comfort and the comfort design of the zoned spring mattress [6]. Peter Buckle et al. evaluated the mattress by body pressure and subjective rating comfort, studied six types of sleep surfaces and considered the mattress tested to be more comfortable than the wooden reference surface [7]. Low F Z compared the body contact pressure profiles of 2 types of mattresses by a pressure mat sensor. The data indicated that the latex mattress was able to reduce the peak body pressure on the torso and buttocks and achieve a higher proportion of low-pressure regions compared with the polyurethane mattress [8].

Nowadays, there are three-zone, five-zone, seven-zone and even nine-zone mattresses on the market. However, the difference in pressure distribution of zoned mattresses caused by gender differences was rarely studied. Research showed gender was an important factor in determining sleep behavior, sleep architecture, and sleep disorder prevalence and presentation [9]. Gu found that men and women have different body parts due to differences in body shape. Female waist and hip are the main parts that affect comfort. In addition to the comfort of the waist and hip, males are also very concerned about comfort of back [10]. In addition, the male need a softer mattress surface to disperse the human-bed interface pressure compared to the female [11]. However, there was no recommendation for comfortable pressure distribution for different genders. Gender is one of the main factors affecting the physiological structure and psychological characteristics of human. What's more, there has been interest in gender differences in car seats [12]. Therefore, this paper used the method of subjective and objective combination to explore the differences in the pressure distribution between different genders.

## 2 Experiment

### 2.1 Subjects

Healthy subjects over the age of eighteen were recruited. The actual total number of persons participating in research of this experiment was 72. The participants had no history of back, shoulder, or neck pain for the past month. Research showed that the



distribution of body pressure of the mattress has a great relationship with the human body parameters, such as height and weight. In order to ensure that the subjects had a good representativeness, the proportion of the subjects was selected based on the Chinese adult human body size database. This study mainly considered the selection of subjects from the aspects of the degree of influence on body comfort (age, gender, and BMI parameters). The main characteristics of the subjects were summarized in Table 1.

**Table 1.** Participants. (The data was expressed as: average value  $\pm$  standard deviation)

Gender	Age	Height	Weight	BMI	N
Male	41.28 $\pm$ 14.3	170.92 $\pm$ 5.56	68.58 $\pm$ 10.59	BMI < 20	8
				20 $\leq$ BMI $\leq$ 25	16
				BMI > 25	12
Female	40.92 $\pm$ 14.12	158.44 $\pm$ 5.69	57.34 $\pm$ 10.04	BMI < 19	8
				19 $\leq$ BMI $\leq$ 24	16
				BMI > 24	12

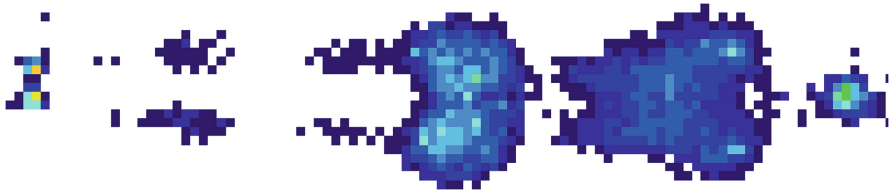
## 2.2 Experimental Equipment

**Mattress.** 7 types of mattresses with different hardness were selected for the experiment. The hardness rating of experiment mattress was measured by a roll gauge. The hardness ratings of 7 mattresses were 0.7, 2.3, 3.2, 4, 4.5, 5.3 and 7.2, respectively. The bigger the hardness rating, the softer the mattress. The mattress with a hardness rating of 0.7 was the hardest and the mattress with a hardness rating of 7.2 was the softest. The hardness ratings division was reasonable, and the cover range was wide. Details of the experimental mattress were shown in Table 2.

**Table 2.** Experimental mattress information

S/N	Hardness rating	Dimension (cm) length * width * height
A	0.7	200 * 100 * 13
B	2.3	200 * 100 * 11.75
C	3.2	200 * 180 * 23
D	4	200 * 180 * 29
E	4.5	200 * 180 * 29
F	5.3	200 * 180 * 28
G	7.2	200 * 180 * 30

**Body Pressure Measure System.** The pressure distribution test was carried out by the Tekscan pressure sensor. The size of the mattress was 578 mm  $\times$  1768 mm and the test range was 0–28 kPa. This system can be used for static and dynamic measurement of pressure distribution on any contact surface. The pressure distribution map captured by the system was shown in Fig. 1. The Tekscan mattress pressure sensor was used to test the pressure distribution data, such as pressure, peak pressure and contact area of the human-bed interface. Data can be collected in different parts of human body on the pressure distribution map.



**Fig. 1.** Pressure distribution map

## 2.3 Procedures

The following experimental procedure was carried out for each subject:

1. Each subject was informed about the study and gave a written informed consent.
2. Before the test, the subjects were informed of experiment purpose, experiment contents and way of testing, and assistance was given to them to get familiar with the subjective comfort rating scale.
3. The gender, age, and height and weight of the subjects were record.
4. The subjects carried out different forms of experience according to the actual sleeping positions at home during the process for not less than 3–5 min, and then completed the subjective feeling evaluation after experiencing the mattress. The subjective comfort during the experience process was rated into five classes according to the actual feeling, including the rating of comfort experience in back comfort, waist comfort and hip comfort. The 5-level evaluation standard was selected. 5, 4, 3, 2, and 1 respectively correspond to each subjective evaluation: very comfortable, comfortable, general, uncomfortable, and very uncomfortable.
5. After subject lay down, calibration was carried out on body weight of subject. BPMS was carried out the pressure value test for 25 s consecutively (200 frames in total, 0.125 s/frame, with collection frequency of 8 Hz). Subjects maintained a supine posture, kept their legs naturally separated, put their arms on the chest, and rest their head, as shown in Fig. 2.
6. Replace the mattress and repeat steps 2–5.



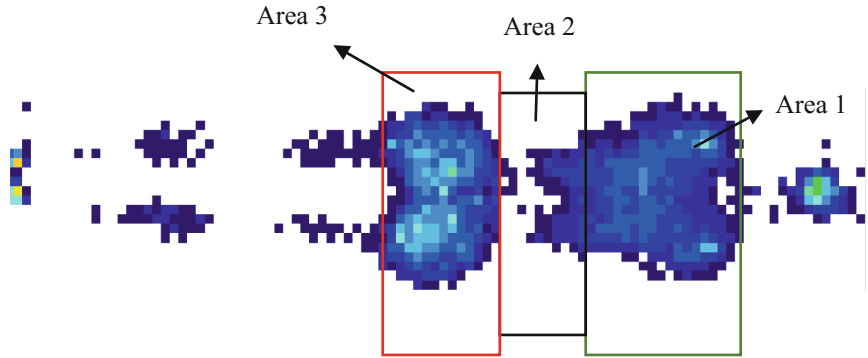
**Fig. 2.** Supine posture

## 2.4 Data Analysis

Subjective scores of 72 subjects were counted. The back area, waist area, and hip area were selected in the pressure distribution map. The pressure, peak pressure and contact area of the corresponding area were extracted. On the basis of characteristic areas contacting with the horizontal area when lying in the supine position, different parts of human body were defined as below:

- Back area: The seventh cervical vertebra to the twelfth thoracic vertebra (Fig. 3: Area 1)
- Waist area: The first lumbar vertebra to the fifth lumbar vertebra (Fig. 3: Area 2)
- Hips area: The fifth lumbar vertebra to hip stripe (Fig. 3: Area 3).

Independent sample T test was used to determine whether there was a difference between pressure distribution and gender. The significance level was defined as  $p < 0.05$ .



**Fig. 3.** The back area, waist area, and hip area were selected in the pressure distribution map

### 3 Results

Significant differences were found for pressure and peak pressure of back and waist of different genders ( $p < 0.05$ ). Significant differences were found for contact area of back, waist and hip of different genders ( $p < 0.05$ ). The significance results of pressure, peak pressure and contact area of different genders was shown in Table 3.

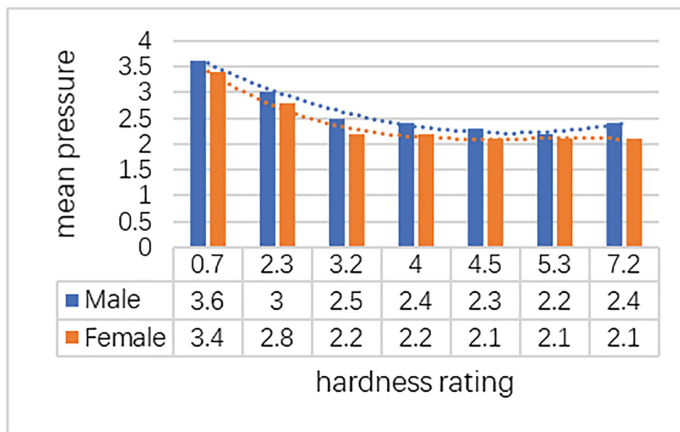
**Table 3.** Pressure, peak pressure and contact area of different genders and significant results

	Gender	Pressure			Peak pressure			Contact area		
		Mean	SD	P	Mean	SD	p	Mean	SD	p
Back	Male	2.6	0.84	0.002	6.1	2.27	0	851.96	219.91	0
	Female	2.4	0.68		5.3	1.86		684.25	179.33	
Waist	Male	2.2	0.59	0	4.3	1.43	0	344.58	119.41	0
	Female	1.8	0.4		3.2	1.01		224.18	86.02	
Hip	Male	3.2	0.9	0.401	7.3	3.08	0.163	738.08	148.61	0.014
	Female	3.1	0.79		7	3.1		771.19	153.21	

\*The unit of the pressure and peak pressure is kPa. The unit of the contact area is  $\text{cm}^2$ .

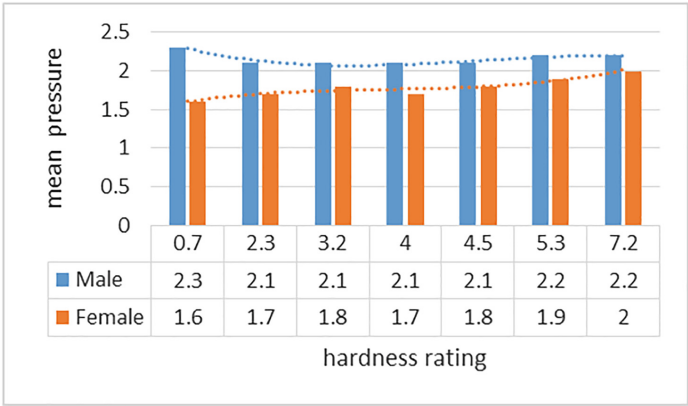
#### 3.1 Mean Pressure

Significant differences were found for pressure of back and waist with different genders ( $p < 0.05$ ). Mean pressure of back and waist of male was higher than that of female. The distribution of mean pressure of the back and waist for different genders were shown in Figs. 4 and 5. And it can be seen from the dotted line in the figure that the difference of mean pressure of different genders. Therefore, mean pressure of back and waist of different genders was different on mattresses with different hardness rating. No significant difference was found for pressure of hip of different genders ( $p > 0.05$ ).

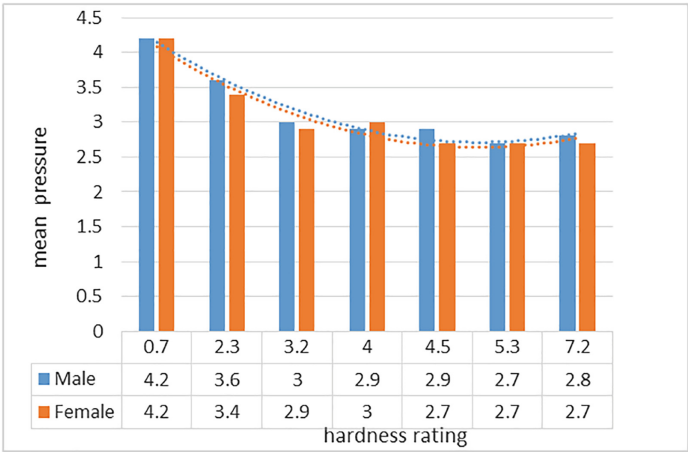


**Fig. 4.** Mean pressure histogram of back of different genders in each test mattress. And the dotted line represents the trend line of mean pressure with hardness rating.

In Fig. 6, the distribution of mean pressure of hip of different genders was shown. It could be seen from Fig. 6 that with the change of hardness rating, there was no obvious change between male and female.



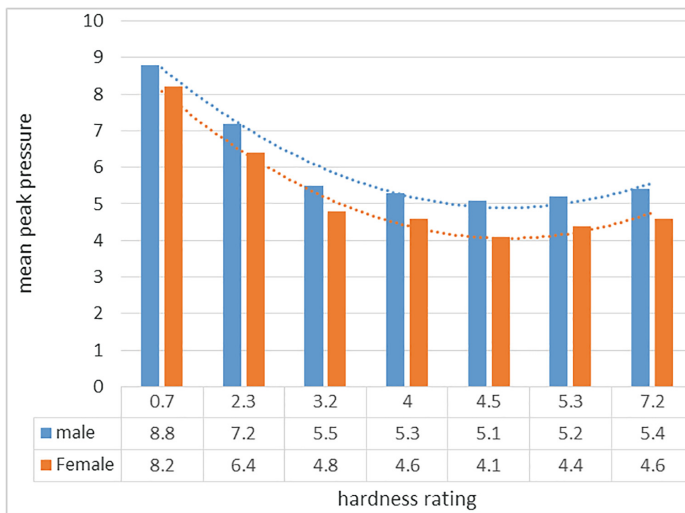
**Fig. 5.** Mean pressure histogram of waist of different genders in each test mattress. And the dotted line represents the trend line of mean pressure with hardness rating.



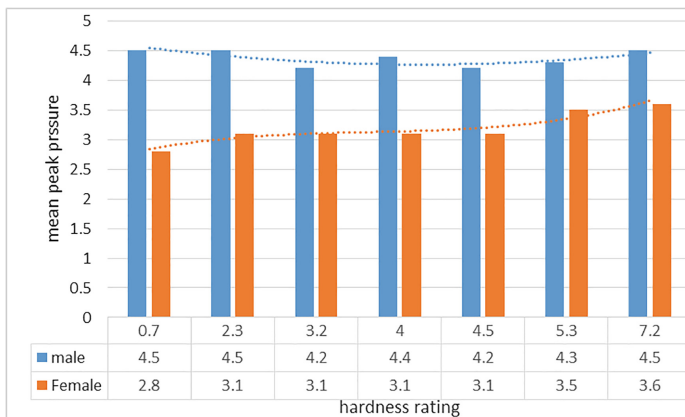
**Fig. 6.** Mean pressure histogram of hip of different genders in each test mattress. And the dotted line represents the trend line of mean pressure with hardness rating.

### 3.2 Mean Peak Pressure

Significant differences were found for peak pressure of back and waist of different genders ( $p < 0.05$ ). Mean peak pressure of back and waist of male was higher than that of female. The distribution of mean peak pressure of the back and waist for different genders was shown in Figs. 7 and 8. And it can be seen from the dotted line in the figure that the difference of mean peak pressure of different genders. Therefore, mean peak pressure of back and waist of different genders was different on mattresses with different hardness rating. No significant differences was found for peak pressure of hip of different genders ( $p > 0.05$ ). In Fig. 9, the distribution of mean peak pressure of the

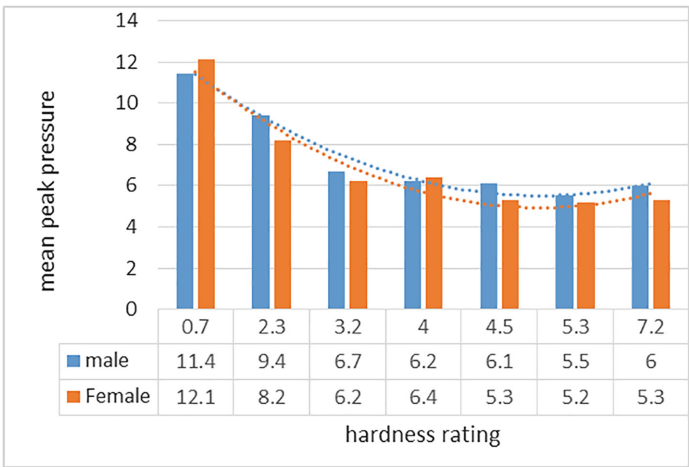


**Fig. 7.** Mean peak pressure histogram of back of different genders in each test mattress. And the dotted line represents the trend line of peak pressure with hardness rating.



**Fig. 8.** Mean peak pressure histogram of waist of different genders in each test mattress. And the dotted line represents the trend line of mean peak pressure with hardness rating

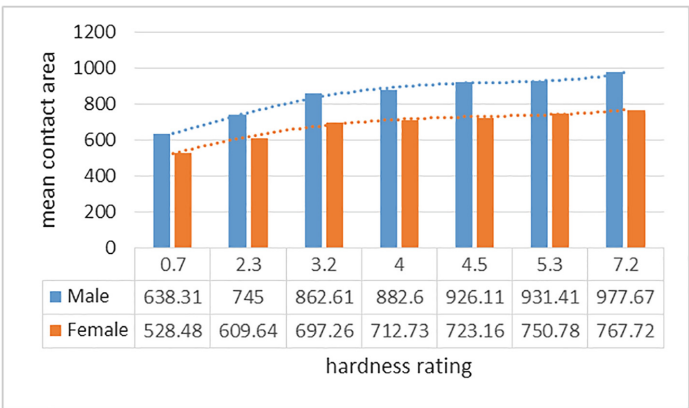
hip for different genders was shown. It could be seen from Fig. 9 that with the change of hardness rating, there was no obvious change between male and female.



**Fig. 9.** Mean peak pressure histogram of hip of different genders in each test mattress. And the dotted line represents the trend line of mean peak pressure with hardness rating

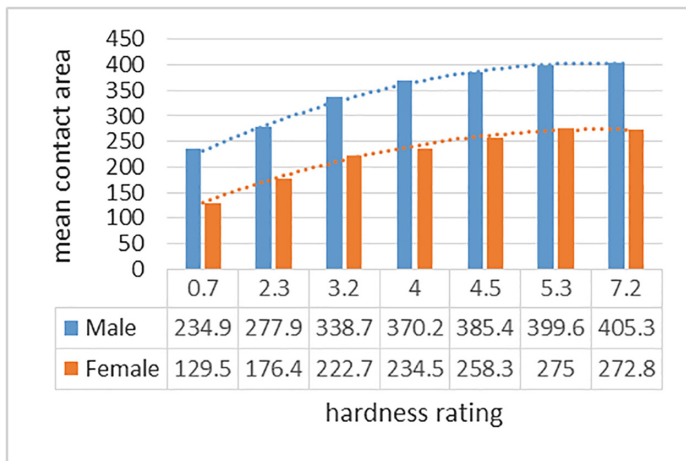
**3.3 Mean Contact Area**

Significant differences were found for contact area of back, waist and hip of different genders ( $p < 0.05$ ). Mean contact area of back and waist of male was higher than that of female. The distribution of mean contact area of the back and waist for different genders was shown in Figs. 10 and 11. Mean contact area of hip of female was higher than that of male. The distribution of mean contact area of hip for different genders was shown in Fig. 12. And it can be seen from the dotted line in the figure that the

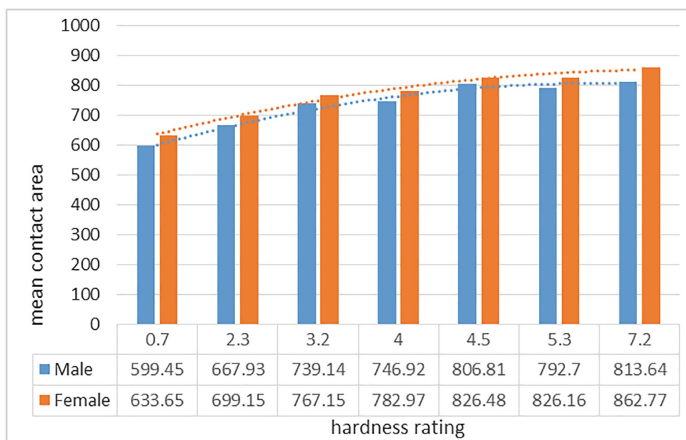


**Fig. 10.** Mean contact area histogram of back of different genders in each test mattress. And the dotted line represents the trend line of mean contact area with hardness rating.

difference of mean contact area of different genders. Therefore, mean contact area of back, waist and hip of different genders was different on mattresses with different hardness rating.



**Fig. 11.** Mean contact area histogram of waist of different genders in each test mattress. And the dotted line represents the trend line of mean contact area with hardness rating.



**Fig. 12.** Mean contact area histogram of hip of different genders in each test mattress. And the dotted line represents the trend line of mean contact area with hardness rating

### 3.4 Subjective Score

Subjective comfort scores of different genders were shown in Table 4. For male, the mattress with the highest score for back comfort was mattress E, the mattress with the highest score for waist comfort was mattress E and F, and the mattress with the highest



score for hip comfort was mattress D. For female, the mattress with the highest score for back comfort was mattress F, the mattress with the highest score for waist comfort was mattress D, and the mattress with the highest score for hip comfort was mattress C and D. It may be the reason that during sleep, the male prefers slightly softer mattresses and the female prefer slightly harder mattresses during sleep. In addition, the hardness of the mattress required for different parts of different genders was different. Thus, in the process of designing zoned mattress, the mattresses can be designed in consideration of the parts of human body for different genders.

**Table 4.** Subjective comfort scores

S/N	Back comfort		Waist comfort		Hip comfort		Average	
	Male	Female	Male	Female	Male	Female	Male	Female
A	2.94	3.31	2.86	2.75	3.08	3.25	2.96	3.1
B	3.56	3.56	3.33	3.39	3.53	3.58	3.47	3.51
C	4.03	4	3.61	3.72	3.78	4.03	3.81	3.92
D	4.06	4.14	3.92	3.97	3.97	4.03	3.98	4.05
E	4.19	4.22	4.03	3.89	4.06	4	4.09	4.04
F	4	4.22	4.03	3.92	3.97	3.97	4	4.04
G	3.89	3.86	3.78	3.67	3.86	3.72	3.84	3.75

## 4 Discussion and Conclusion

The pressure and contact area with a higher subjective evaluation score were recommended as the recommended ranges. Suitable maximum pressure ranges of back, waist and hip, for male were 5.1–5.5 kPa, 4.1–4.5 kPa and 5.4–9.4 kPa, respectively, and the maximum contact area was 862.61–977.67 cm<sup>2</sup>, 338.70–405.33 cm<sup>2</sup>, and 667.93–813.64 cm<sup>2</sup>, respectively. Suitable maximum pressure ranges of back, waist and hip, for female were 4.1–6.4 kPa, 3.1–3.6 kPa and 5.2–8.2 kPa, respectively, and the maximum contact area was 609.64–67.72 cm<sup>2</sup>, 222.73–275.04 cm<sup>2</sup> and 699.15–862.77 cm<sup>2</sup>, respectively.

This research analyzed the pressure distribution and subjective evaluation of mattresses for different genders. The maximum pressure and the maximum contact area of the three parts of the body were obtained based on the subjective comfort score. The following conclusion could be drawn that different genders were suitable for different maximum pressure and contact area in the back, waist and hip in the design of the zoned mattress. Hence, it is necessary to consider the difference in pressure distribution between male and female in the design of the zoned mattress.

**Acknowledgements.** This research was supported by 2017NQI project (2017YFF0206603) and Project of the President's Fund for China National Institute of Standardization for 2018 and 2019 (522018Y-5984; Study on ergonomic evaluation criteria of backpack products based on body pressure distribution and movement gait).

## References

1. Hou, J., Shen, L.: Discussion on the mattress comfortableness in different groups. *J. Furnit.* (2013)
2. Sdol, E.: *International Journal of Industrial Ergonomics*. International Journal of Industrial Organization (2009)
3. Wu, J., Yuan, H., Li, X.: A novel method for comfort assessment in a supine sleep position using three-dimensional scanning technology. *Int. J. Ind. Ergon.* **67**, 104–113 (2018)
4. Lee, Y.-C.: Evaluating the effect of mattress topper thickness and firmness combination on pressure and temperature distribution. National Tsing Hua University
5. De Looze, M.P., Kuijt-Evers, L.F.M., Van Dieen, J.: Sitting comfort and discomfort and the relationships with objective measures. *Ergonomics* **46**, 985–987 (2003)
6. Chen, Y., Shen, L.: Relationship between mattress comfort and sleep quality. *J. Anhui Agric. Univ.* (2012)
7. Buckle, P., Fernandes, A.: Mattress evaluation—assessment of contact pressure, comfort and discomfort. *Appl. Ergon.* (1998)
8. Low, F.Z., Chua, C.H., Lim, P.Y., et al.: Effects of mattress material on body pressure profiles in different sleeping postures. *J. Chiropr. Med.* **16**, 1–9 (2017)
9. Baker, F.: Sex differences in sleep. *Encycl. Sleep* (2013)
10. Gu, L.: Study on the relationship between the characteristics and the comfort level of spring soft mattress. Nanjing Forestry University (2009)
11. Chen, Y.: The effect of the firmness of mattresses on the comfort based on body pressure distribution. *J. Anhui Agric. Univ.* (2018)
12. Gyi, D.E., Porter, J.M.: Interface pressure and the prediction of car seat discomfort. *Appl. Ergon.* **30**, 99–107 (1999)



# Universal Design for Enhancing Accessibility of the Visually Impaired in Touristic Environments

Carlos Arce-Lopera<sup>(✉)</sup>, Juan Jimenez Garcia, Camilo Montoya,  
and Jose Giraldo

Engineering Faculty, Universidad Icesi, Cl. 18 #122-135, 760031 Cali, Colombia  
{caarce, jcjimenez, camilomontoya,  
josegiraldo}@icesi.edu.co

**Abstract.** Designing for accessibility and inclusion requires careful consideration of specific requirements. In particular, Universal Design promotes inclusion by enhancing access but without hindering the user experience for others. One of the principles of Universal Design is that the information must be perceptible, i.e. all given information must be presented using different sensory perceptual strategies. Here, different interaction design strategies were tested for a system that aimed at creating meaningful experiences for the visually impaired in a recreational environment. Volunteers with visual impairment participated in the evaluation of the system and were instructed to interact with the system using a mobile phone. Experimental results revealed that a combination of audio and tactile stimuli was the best combination to increase information recall. However, careful design of the tactile interaction must be met to avoid cognitive overload that could interfere with the experience.

**Keywords:** Universal Design · Visual impairment · Accessibility

## 1 Introduction

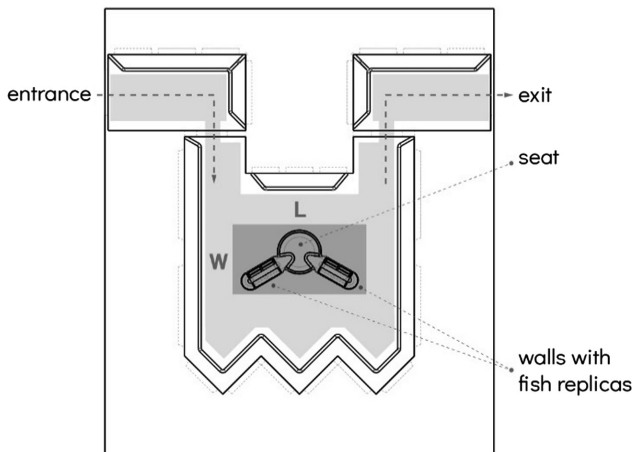
It is estimated that, worldwide, there are more than 250 million visual impaired people, of whom nearly 36 million are blind and around 217 million have moderate to severe vision impairment [1]. This represents an important potential customer base for the tourism and the retail markets [2, 3]. However, low consideration on the particular needs and requirements concerning safety and security of this population is still a concern [3, 4]. Moreover, the motivation to participate and engage in outdoor recreational activities can be driven by careful design of those experiences. Unfortunately, the lack of cognitive, physical and sensorial access to exhibits and information displays are common in both the touristic and retail environments, which are still being designed to be visually enjoyed [5]. Some researchers focused on identifying the main difficulties and needs experienced by visually impaired people. Several problems concerning the lack of staff trained on dealing with disabilities were described [2, 4, 6]. In addition, orientation and mobility problems in indoor environments were among the barriers that had negative effect on visit experiences [6]. Finally, the physical and intellectual

accessibility of the information was identified as a major cause that hinder the motivation and sense of autonomy for the visually impaired. Specifically, the lack of sufficient or supporting multi sensorial information was suggested as critical. Adding multisensory information proved to enhance user engagement in touristic environments and informal learning environments, such as museums, science centers, zoos and aquariums [5, 7].

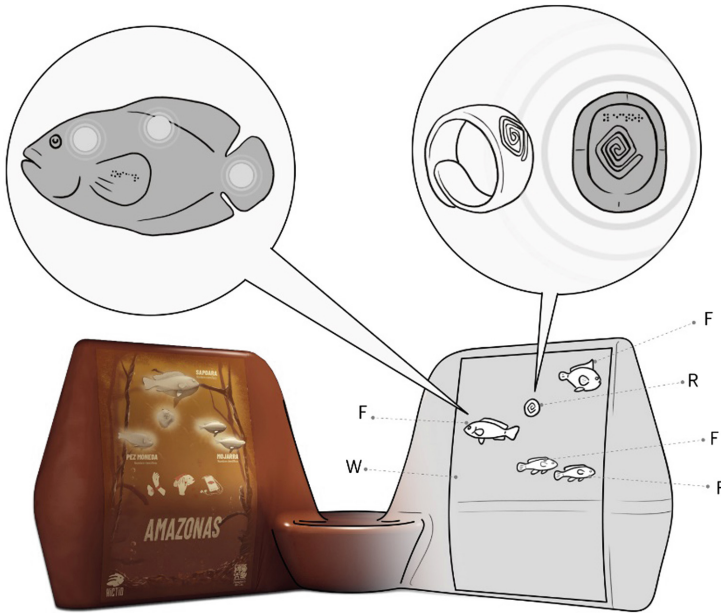
The present article aims to describe a carefully design system to enhance accessibility of the visually impaired in a touristic environment. Moreover, a prototype of the interaction using different perceptual modalities was tested to support the creation of meaningful experiences for the visually impaired.

## 2 Methods

A system was designed to enhance the accessibility and inclusion of the visually impaired in an aquarium located in the City Zoo of Cali, Colombia. This location was selected because it was considered the most underrated and frightening place of the City Zoo by the visually impaired. Therefore, an intervention in the aquarium could have a greater impact on the overall experience of visitors. The main reasons the aquarium was perceived as unwelcoming for visually impaired visitors was due to the physical characteristics of the space. The aquarium at City Zoo of Cali is an enclosed space of approximately 25 m<sup>2</sup> with air conditioning. Figure 1 shows the floor map of the aquarium space. The sound in this small space reverberates throughout the room. This reverb effect is particularly discomforting when the room is full of young and active screaming young children. In the center of the main room, a four by two meters' space was assigned to the centerpiece of the proposed system.



**Fig. 1.** Floor map of the aquarium space. The dark grey rectangle is the designed space for the system.

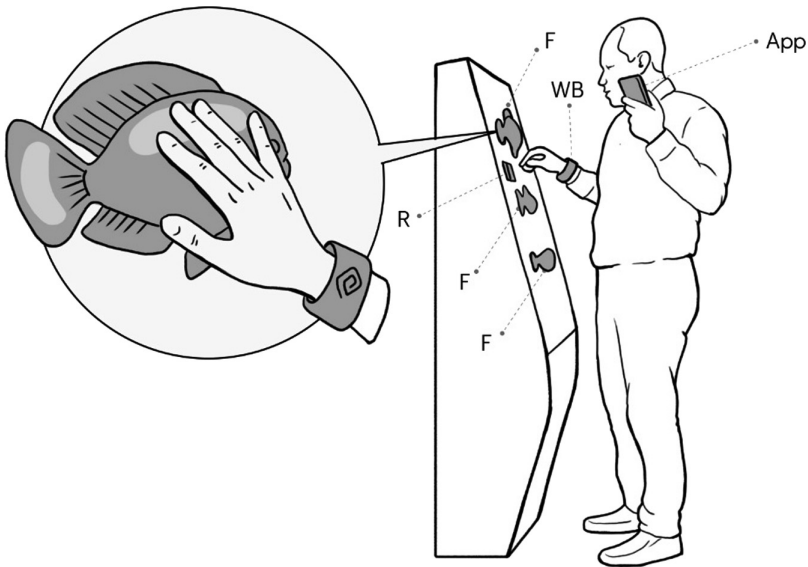


**Fig. 2.** Frontal view of the centerpiece of the designed system. Vibro-tactile replicas of the fishes (F) in the aquarium were inserted in four vertical walls (W). The elements are linked and controlled by a mobile application, a RFID wristband and guided using BLE beacon technology (R).

The system was composed by a set of interacting technological elements: (i) a RFID wristband given to each participant at the entrance; (ii) a mobile application with an audio narration that guided the user through the aquarium visiting experience; (iii) a Bluetooth Low Energy (BLE) beacon to mark the locations; and (iv) the centerpiece, a large piece of furniture that provided sitting and allowed for the location of vibro-tactile objects (Fig. 2). Each wristband had braille instructions on how to download the accompanied mobile application that guided the experience. Also, this procedure permitted participants to link their information with the bracelet and the mobile application.

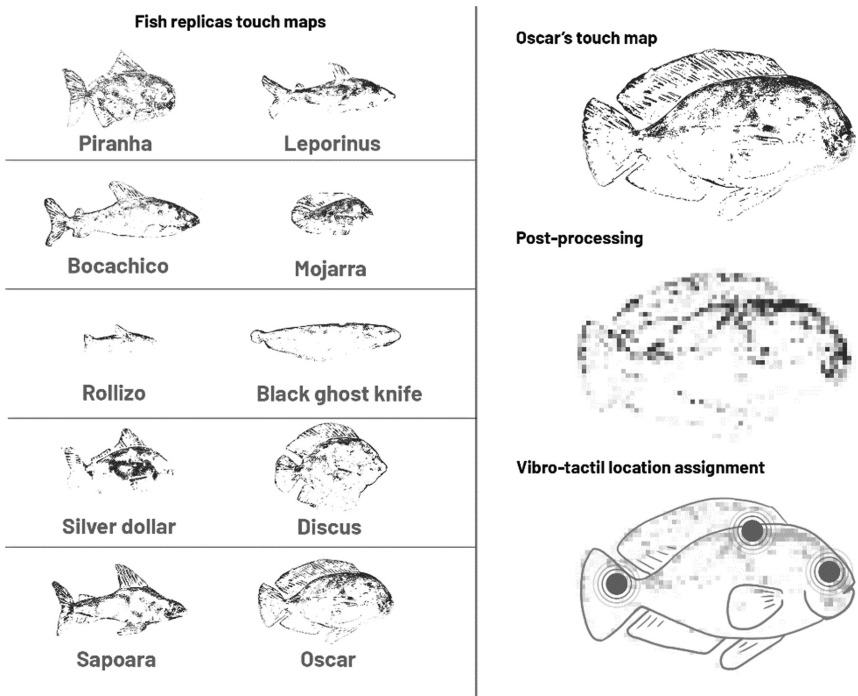
First, the mobile application described the rules and instructions of the entire interaction. The application served as a fish net to collect fishes on the visiting path. Each location was marked by a BLE beacon. Therefore, the mobile phone could guide each participant depending on his or her location. When a participant arrived at a beacon in front of a fish tank, the mobile application described the fish. Then, the application requested the user to perform a gesture on the phone to catch the fish. When the gesture was correctly performed, the system guided the user to the centerpiece of the system. This central part had two vertical walls that held physically correct replicas of three different types of fishes inserted on each side. Therefore, the system could hold a maximum of twelve types of fishes.

In addition, for each type of fish, BLE beacons were used with the RFID wristbands to assign an order to the interaction. This way only one participant could interact with one fish at a time. In this space, participants had to touch the fish replicas to activate the audio narration that explained further details on the habitat and behavior of the fishes (Fig. 3). To activate the audio narration, all replicas had capacitive sensors. Also, to enhance the haptic interactions, vibro-tactile motors were inserted on critical locations of each fish. The actual location of the vibro-tactile motors and capacitive sensors depended on the type of fish. The locations were selected after considering how visually impaired participants interacted with the replicas. Figure 4 shows in black dots the places where visually impaired subjects touched the replicas for ten types of fish.



**Fig. 3.** Lateral view of the interaction with the centerpiece of the designed system. Vibro-tactile replicas of the fishes (F) are accompanied by audio narration (App) of their characteristics. The wristband (WB) serves to guide the user toward the BLE beacon (R).

The system provided an indoor guidance system based on BLE beacons technology that could improve the sense of autonomy for the visually impaired. Moreover, the interaction with the fish exhibit was enhanced by adding to traditional audio narratives two different types of haptic interactions: gestures on the mobile phone and vibro-tactile enhanced replicas of the fishes. To test the designed interaction, a prototype was implemented using the information of ten types of fishes. The objective was to test for information recall depending on the type of interaction.



**Fig. 4.** On the left is the touch map of the replicas for ten fishes. Black dots represent the location where the visually impaired touched the replicas. The density of the touch determined the location of the vibro-tactile motors and capacitive sensors. On the right, an example of the assignment of the motor location for the fish Oscar.

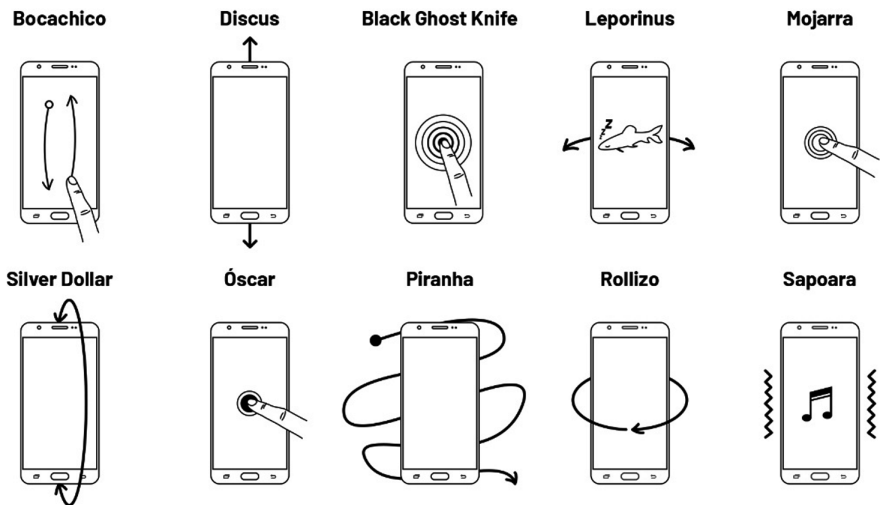
## 2.1 Subjects

Six young male volunteers with age ranging from 14 to 36 years old participated in the evaluation. All volunteers had visual impairment and were accustomed to use mobile technology using headphones. Two of the volunteers were born blind. The remaining participants had lost their sight due to accidents or eyesight illnesses. All of them were tested for their ability to perform tasks using the mobile phone and proved highly fluent in the use of assistive technologies for mobile devices (e.g. Talkback or Voiceover). All volunteers had experience visiting the City Zoo of Cali at least once while visually impaired.

## 2.2 Experimental Design

Participants were instructed to interact with the system using a mobile phone with the application pre-installed. Randomized between-subject evaluations of the interaction with the system were conducted. The performance for three different sensory strategies was tested. The first strategy had only audio information (unimodal) delivered through the mobile application. This was set as the control condition because visually impaired

users were accustomed to use audio in mobile applications as source of information. The other two sensory strategies had a combination of kinesthetic information and sound (multimodal). Therefore, the second strategy was the combination of carefully designed gestures [8] on the phone that simulated different fish behavior activating sound narratives. Figure 5 shows the ten gestures selected for the test. Each gesture was different and was associated to a different fish. All gestures were tested for simplicity but also represented a meaningful interaction related to some characteristic of each fish. For example, for the black ghost knife fish, the interaction was to simply hold one finger on the phone until the participant hear a sound and felt a vibration. The audio narration described how the sound and vibration was meant as an analogy to a sonar system trying to locate the fish. The narration continues explaining that the fish is nocturnal and very hard to catch.



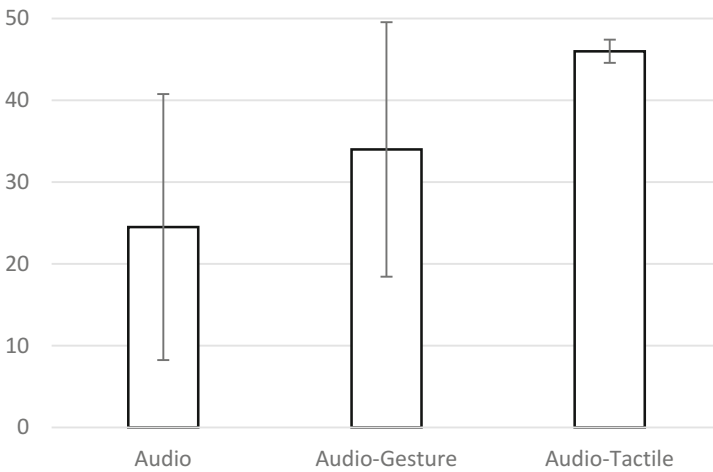
**Fig. 5.** Gestures designed for the mobile application. Each different interaction was associated to a different fish.

Finally, the third strategy used ten physical objects with the shape of each fish. The fish were embedded in a vertical platform in the centerpiece for appropriate reach and manipulation. When participants touched these objects, sound narratives were activated. Using these three strategies, information of ten different fish were presented. After task completion, subjects were required to answer questions related to details given in the interaction with each fish to test specific information recall. Participants were required to list by name all the fish presented, to identify the number of fishes on the test, to recall which one was the largest, the smallest and their habitat.



### 3 Results

Experimental results showed that the audio-only strategy gave the worst overall results in information recall with an average score of 25 out of 50 (see Fig. 6). In comparison, in the multimodal strategies, participants scored an average of 40. These results may indicate that the addition of a modality in the interaction can greatly influence information recall. However, in the audio-only condition, participants were able to list the name of seven out of ten fishes. In comparison, the participants in the multimodal conditions only listed four names of fishes on average. This question was the only one in which the control condition ranked better than the other two. These results may indicate that the audio-only strategy may be adequate when the task is based on name recall.



**Fig. 6.** Results of the information recall test for the three conditions. Bars denote average results and error bars standard deviation.

In addition, for the audio-only condition, the test lasted 7 min on average but the participant's time perception was 10 min on average. Higher time perception may indicate low user engagement [9]. On the other hand, for the audio-tactile tests, participants interacted with the interface for about 12 min but the perceived time was 6 min on average. Smaller perception time could be associated with increased attention on the task and increase engagement with the interaction. Similarly, for the audio-gesture test, participants interacted for about 15 min on average with a perceived temporal demand of about 12 min.

When the information recall was related to comparison between fishes (e.g. determining which one is the biggest or smallest) the multimodal strategies gave the best results. This type of questions required a higher level of reasoning beyond simple memorization. Particularly, the questions related to size comparisons and habitat details were answered correctly by the participants in the audio-tactile condition. In the audio-gesture strategy, users had an average score of 34 compared to the average

score of 46 for the audio-tactile strategy. These results may indicate that the designed gestures, in spite of been carefully designed and adapted for the visually impaired [9], added extra burden on information that could overwhelm the cognitive load of the users and limit the information recall. Finally, high variability was present on the audio-gesture and the audio-only conditions, which may indicate that the performance on information recall may rely on personal ability. To be able to verify for individual differences further research is needed. Particularly, by augmenting the sample size, better understand of the difference between these three types of strategy can be disclosed.

## 4 Conclusion

An indoor guiding system was designed to enhance the accessibility of the visually impaired in an aquarium of the City Zoo of Cali, Colombia. The system consisted of technology elements that allow users to interact with the fish exhibits using a multi-modal interface. Audio narratives using a mobile application guided the interaction using both gesture-based tasks and vibro-tactile replicas of the fishes on a vertical wall. Testing the multimodal interactions reveal that multimodality ensures greater information recall. However, careful design must be met as not to overload the interaction with information which may diminish the user experience and engagement.

## References

1. Bourne, R.R., et al.: Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. *Lancet Glob. Health* **5**, 888–897 (2017)
2. Edwards, K., Rosenbaum, M.S., Brosdahl, D., Hughes, P.: Designing retail spaces for inclusion. *J. Retail. Consum. Serv.* **44**, 182–190 (2018)
3. Devile, E., Kastenholz, E.: Accessible tourism experiences: the voice of people with visual disabilities. *J. Policy Res. Tour. Leis. Events* **10**, 265–285 (2018)
4. Yu, H., Tullio-Pow, S., Akhtar, A.: Retail design and the visually impaired: a needs assessment. *J. Retail. Consum. Serv.* **24**, 121–129 (2015)
5. Vaz, R., Fernandes, P.O., Rocha Veiga, A.C.: Designing an interactive exhibitor for assisting blind and visually impaired visitors in tactile exploration of original museum pieces. *Procedia Comput. Sci.* **138**, 561–570 (2018)
6. Poria, Y., Reichel, A., Brandt, Y.: People with disabilities visit art museums: an exploratory study of obstacles and difficulties. *J. Herit. Tour.* **4**, 117–129 (2009)
7. Jeon, M., Winton, R.J., Henry, A.G., Oh, S., Bruce, C.M., Walker, B.N.: Designing interactive sonification for live aquarium exhibits. Presented at the HCI International 2013 - Posters' Extended Abstracts (2013)
8. Vatavu, R.-D.: Improving gesture recognition accuracy on touch screens for users with low vision. In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, pp. 4667–4679. ACM, New York (2017)
9. O'Brien, H.L., Cairns, P., Hall, M.: A practical approach to measuring user engagement with the refined user engagement scale (UES) and new UES short form. *Int. J. Hum.-Comput. Stud.* **112**, 28–39 (2018)



# Toothbrush Innovation Design Based on Man-Machine Engineering Research

Peng Han<sup>(✉)</sup>

Art Design Institute, Beijing Forestry University, Beijing 100083, China  
hanpengdesign@163.com

**Abstract.** **Objective** It discusses and researches how to better develop the use function of toothbrush, adds practical function tip replaced periodically. Based on the characteristics of the use of toothbrush and the user psychological needs, it studies the toothbrush appearance design again, perfects the effect of toothbrush. **Method** It researches the reference factors in the design of toothbrush, investigates and analysis the existing toothbrush market, based on the man-machine engineering theory, analysis the form, the material, and the operation of toothbrush, establishes the research direction. **Result** It optimizes and innovative designs the toothbrush from the form, the material and the prompt replacement function, gives the design scheme, provides the reference for the research of toothbrush product design.

**Keywords:** Human-machine engineering · Innovative design · Toothbrush · Tip replacement

## 1 Introduction

Brushing teeth is an important personal hygiene habit to ensure oral hygiene and health as well as to clean the surface of teeth. Brushing teeth can effectively remove plaque and food residues on the surface of teeth. Developing regular brushing habits is the most basic and effective way to prevent oral diseases. It is also the simplest and most commonly used oral health care measures [1].

Good toothbrush design can effectively remove plaque. Prevention of plaque deposit and accumulation. It can also play an auxiliary massage role on the gums, enhance the firmness of the teeth, and promote oral health [2]. As a tool for brushing teeth, toothbrushes need to be replaced regularly. The length of the replacement cycle directly affects the effect of removing dental plaque by toothbrushes. Dentists usually advise that toothbrushes should not be used for more than three months: a toothbrush that has been used for more than three months will greatly reduce the effectiveness of plaque removal, so adults usually change toothbrushes at least once every three months [3].

## 2 Ergonomics Analysis

In modern product design, the research of ergonomics is particularly important [4]. The innovative design of toothbrushes needs to be based on ergonomics to analyze the shape of toothbrushes, redesign and redevelop the existing ways of use, and improve the function of toothbrushes [5]. In order to improve the use value, more humane protection of people's oral health.

### 2.1 Human-Machine Configuration Analysis

The design of toothbrush mainly includes four parts: brush head, brush hair, brush neck and brush handle. Four parts are organically combined, and the ergonomics of each part will affect the effectiveness of toothbrush after use [6]. Therefore, human-machine factors must be considered in toothbrush design. Effectiveness and safety are its basic functional requirements.

**Brush Head.** Brush head is the main component of toothbrush. It needs to be operated in oral cavity. Generally, it is designed to be circular arc [7]. Because the action of brushing teeth is completed in the oral cavity, the design of toothbrush should satisfy the flexible movement of upper and lower, left and right, straight line and oblique line in the narrow oral space. Usually the shape of the brush head is approximate ellipse and the smoothness of the edge is guaranteed. According to the relevant human body size data, the size range of adult brush head is 11–15 mm, and the length is 18–35 mm. The thickness of brush head should not be too thick, less than 5 mm, on the basis of ensuring safety. Children's toothbrushes should be designed and processed separately according to the human-machine dimensions of children.

**Brush Hair.** Brush hair are the most elaborate part of toothbrushes. The scale range of brush hair has its corresponding national standard [8]. The size of toothbrushes for adults, children and children decreases in turn. The length of the brush surface is less than 42 mm, the height of the brush is less than 13 mm, and the diameter of the brush hair is between 0.2 and 0.3 mm. Users need to choose carefully according to their dental status and use.

**Brush Neck.** The neck brush is the connecting part between the brush head and the brush handle. The shape of the neck brush is usually designed to be a smoother arc. So in the process of toothbrush operation, the brush handle can have certain elasticity. To meet the flexibility of the brush head in the operation of the molar region of the mouth. The length of neck brushing is usually about 50 mm. Sometimes the design of the brush neck extends to the brush handle or becomes an integral part of the brush handle. In this respect, ergonomics has relevant research data.

**Brush Handle.** Brush handle is the only part that contacts with human hand in the process of brushing teeth. It is usually designed to be convenient for human hand to hold. The design of brush handle is the most diversified. People can choose toothbrushes with different shapes, colors and materials according to their preferences. However, regardless of the design purpose, the overall design idea of the brush handle is still to meet the needs of human-machine grasp. The length of the brush handle is

usually about 120 mm, but there are also special design scales of the brush handle for convenient reception and electric toothbrush.

## 2.2 Man Machine Material Analysis

The material of toothbrush mainly includes main body material and brush hair material.

**Main Body Material.** General toothbrush parts (No electric toothbrush included) are divided into main parts and decorative parts. Hard glue material (ABS) is generally selected from brush head to brush handle in the main part. From the analysis of ergonomics, this material satisfies the strength of toothbrush, and is easy to combine with other materials, which is conducive to multi-color moulding. Decoration part is generally soft, mostly using thermoplastic elastic materials (TPE). This material has good processability and high quality elastic function, and is easy to dye [9]. As a decorative part, it has good fusion with the main part, rich color change, soft touch and not easy to fall off. In recent years, some toothbrushes are made of more green corn plastic.

**Brush Hair Material.** Brush hair is the part that directly contacts the tooth surface and internal oral tissues when brushing teeth. Brush hair needs to carry toothpaste to complete the work of cleaning teeth together. The choice of brush hair material directly affects the comfort of the brushing process and the cleaning effect after brushing. At present, nylon silk, natural bristle material, silica gel material and bristle material with bamboo charcoal C active ions are the most common and mature brush hair materials on the market.

## 2.3 Man-Machine Operation Analysis

When brushing one's teeth, one usually holds a toothbrush handle in one hand. The hand drives the arm to swing together, so that the brush head can complete the corresponding movement up and down, left and right, front and back in the oral space. The strength requirement is not high, but the mobility requirement of wrist joint and upper arm around shoulder joint is high.

**Operational Comfort Analysis.** In the process of brushing teeth, the closer the wrist is to the natural position, the more comfortable and not easy to fatigue. For example, the inner side of molars is brushed horizontally, the outer side of molars is brushed vertically, and the outer side of front teeth is brushed horizontally. When the wrist is in the lateral position of the ulnar-radial joint, it will feel the most difficult to operate and uncomfortable state. Such as brushing the medial side of the posterior molar on the same side of the hand horizontally, brushing the medial side of the anterior teeth vertically before and after, brushing the medial side of the anterior teeth vertically before and after, and brushing the medial side of the anterior teeth vertically, etc. [1].

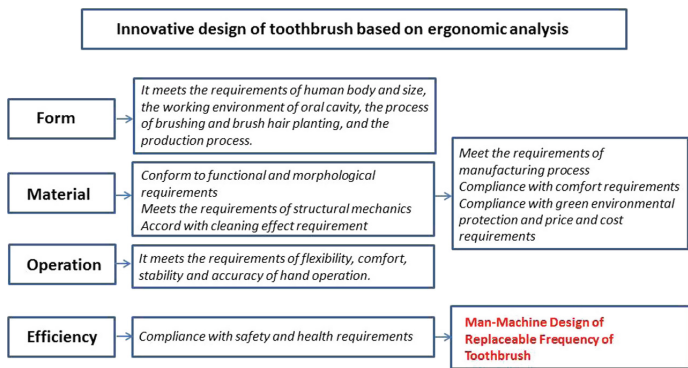
**Analysis of Brush Handle Holding Mode.** According to the ergonomics analysis of the strength and intensity required for brushing teeth, the way of holding toothbrush in adults' hands is usually not five-fingered. Generally, the thumb, forefinger and middle finger coordinate with the palm to complete the operation process of holding

toothbrush. The remaining two fingers work together to maintain the stability and accuracy of the toothbrush movement. Here, the length and shape of the brush handle should be designed reasonably, which should be adapted to the physiological characteristics of the palm [10].

### 3 Innovative Design Based on Ergonomic Analysis

#### 3.1 Design Thinking

Based on the analysis of ergonomics, the innovative design idea of toothbrush is determined. The relationship between toothbrush and ergonomics is people-oriented. It is suitable for people’s physical and mental activities and perception needs [11]. It can achieve the best use efficiency and is designed for health, safety, high efficiency and comfort. The design idea based on the above man-machine requirements is shown in Fig. 1.



**Fig. 1.** The design idea based on man-machine need

#### 3.2 Innovative Design Based on Ergonomic Analysis

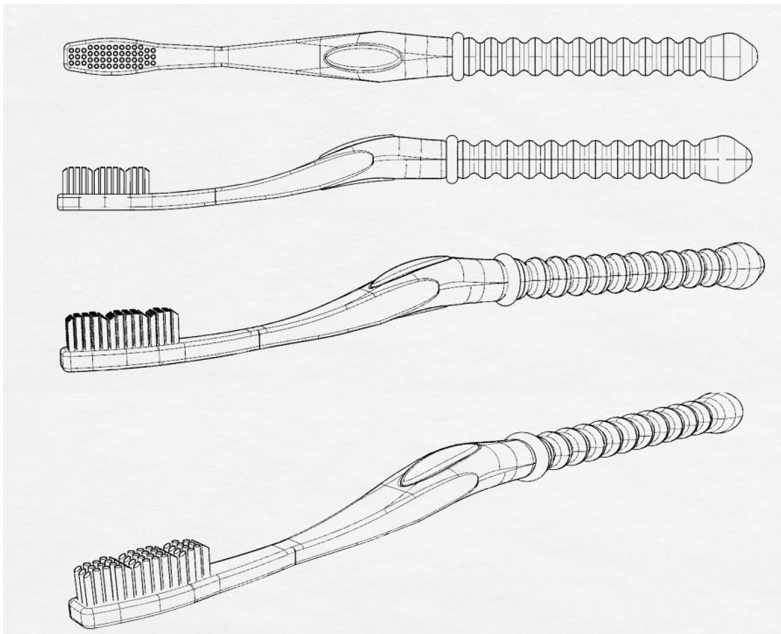
##### Functional Innovation Design:

After a long period of development, the shape of toothbrush has basically established its range of human-machine modeling size. The general innovative design points are electrification, new materials and new functions. The innovations set forth in the following design schemes are new functions.

Generally speaking, toothbrushes sold on the market are used for 1 to 2 months, or 2 to 3 months. After using a toothbrush for a period of time, the bristles will bend and deform, and the top will become thinner, which will affect the effect of toothbrushing to a certain extent. Timely replacement of toothbrush and effective removal of dental plaque are very important to maintain periodontal health. Therefore, adults should change their toothbrushes at least once every three months. Li et al. [3]. have been

proved by experiments, It is suggested that toothbrushes should be replaced at least every three months.

At present, most people change their toothbrushes on the basis of observing whether the bristles are deformed or curled, and some people observe whether the bristles are discolored. Such visual and sensory judgment often delays the best time to replace toothbrushes, resulting in oral health problems. Therefore, whether the toothbrush can be used as a reminder for replacement is a problem that needs to be solved in the ergonomic efficiency design of toothbrush. Drawing design for the problem is carried out, as shown in Fig. 2.



**Fig. 2.** Toothbrush design sketch

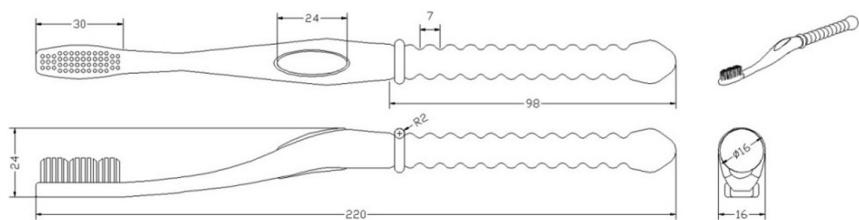
### **Design Explanation:**

- (1) This scheme is designed for ordinary adults. In this scheme, the month when the toothbrush was last replaced is determined by simply pulling the rubber ring. The user can choose the month when the toothbrush is next replaced according to his oral condition. The handle has 12 uniform digital grooves marked from 1 to 12 months. The user moves the rubber ring into the groove of the initial month of use, so that it is convenient to remember the month when the toothbrush was last replaced, which can effectively indicate when to replace it next time.

- (2) The groove design on the model meets the needs of the hand-held anti-skid human-machine when people use toothbrush, and also meets the needs of simple toothbrush production process, without increasing the production cost of toothbrush.
- (3) The elastic rubber ring is easy to operate and has good matching with the toothbrush. It is not easy to loosen and fall off during use.
- (4) The main material of the scheme is hard rubber (ABS), thumb press, digital decoration and rubber ring are thermoplastic elastomer (TPE), and nylon filament is used as brush hair material.

### Man-Machine Size:

On the basis of sketch design, the design scheme must undergo repeated iteration and refinement of the design process, and finally draw the man-machine dimension map, as shown in Fig. 3.



**Fig. 3.** Dimension chart (Unit: millimeter)

- (1) Brush head. According to the size of adult body and the requirement of brush hair planting technology, the width of brush head is 11–15 mm, the length is 30 mm, and the thickness of brush head is 4 mm.
- (2) Brush hair. According to the size of adult oral cavity, the length of brush hair distribution is 28 mm, the width is 9–13 mm, the height of brush hair is 11 mm, and the diameter of brush wire is 0.2 mm.
- (3) Brush neck. Set the brush head and thumb press between the brush neck, length 55 mm, width 7–14 mm, thickness 4–10 mm.
- (4) Brush holder. The brush handle is set from the thumb press to the end of the grip, the length is 135 mm and the diameter is 14 mm to 16 mm.
- (5) Adjustable rubber ring. The inner diameter is 13 mm, the outer diameter is 15 mm and the rubber ring thickness is 2 mm (Table 1).

**3D Rendering.** Computer aided design software Rhino and Keyshot are used to model and render the final three-dimensional shape, as shown in Fig. 4.

Operational instructions are shown in Fig. 5.

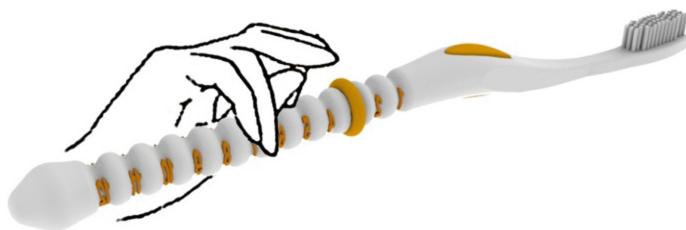


**Table 1.** The main dimensions of toothbrushes.

Parameter	Symbol	Set size
Length	a	220
Width	b	24
Brush head length	c	30
Brush head width	d	11 ~ 15
Brush hair height	e	11
Diameter of brush handle	f	14 ~ 16
Adjustable inner diameter of rubber ring	g	13
Adjustable outer diameter of rubber ring	h	15



**Fig. 4.** Toothbrush effect chart

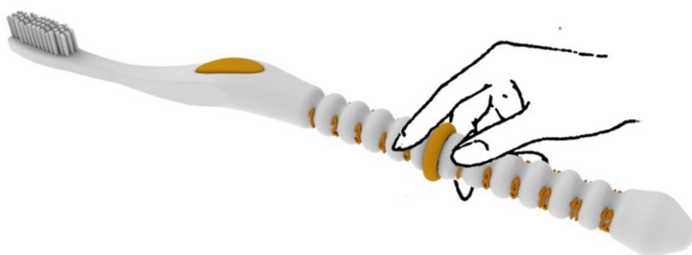


The user replaced the toothbrush in March and moved the ring rubber band into the groove of Number 3.



**"June, it's been three months!"**

Two to three months later, it's easy for users to see how long the toothbrush lasts. Replace the toothbrush before the bacteria on the brush hair multiply.



**After replacing the new toothbrush, move the rubber band into the digital groove of the current month.**

**Regular replacement of toothbrushes is no longer complicated.**

**Fig. 5.** Operation instructions

## 4 Conclusion

Based on the analysis of ergonomics, innovative design of ordinary adult toothbrushes is carried out with the aim of meeting the requirements of human-machine, improving the use efficiency and realizing the function of prompting replacement. The design scheme includes the realization of man-machine size, material and prompting function, and the final scheme form is checked by computer-aided software. It has certain significance for the study of human-machine and practical value of toothbrush.

**Acknowledgments.** The author is grateful for the support of the Fundamental Research Funds for the Central Universities (No. 2015ZCQ-YS-01).

## References

1. Bai, P., Bai, B.: Health care toothbrush design based on the human-machine engineering. *Chinese J. Ergonomics* **19**(6), 75–77 (2013)
2. Zhu, L.-F., Zheng, Y.-Q., Yan, F.-H.: Department of periodontology, school of stomatology. *J. Oral Res.* **26**(1), 67–70 (2010)
3. Li, X.-J., Luo, L., Huang, H., et al.: Old and new toothbrush clear plaque effect comparison. *J. Guangxi Med. Univ.* **25**(4), 251–252 (2008)
4. Zhu, Z.-J., Lei, W., Li, B., et al.: Appearance improvement design of LED chip detection machine based on human-machine engineering. *J. Mach. Des.* **31**(11), 111–114 (2014)
5. Li, H., Lan, H.-L.: Outdoor portable kettle design based on pattern design. *Packag. Eng.* **36**(8), 51–54 (2015)
6. Li, M.: Analysis the ergonomics of the design of toothbrush. *Sci. Technol. Inf.* **3**, 329–346 (2012)
7. Li, G.: The developing course of toothbrush design and development trend. *Oral Care Ind.* **16**(4), 45–46 (2002)
8. GB 19342-2003, Toothbrush[S]
9. Kuang, T.-G., Li, S.-Z., Huang, C.-Y.: Design of injection moulds for two-component toothbrush handles. *China Plast.* **22**(11), 76–77 (2008)
10. Cheng, G.: The analysis and designing of toothbrush in ergonomics. *Modern Manuf. Eng.* **26**(8), 33–34 (2003)
11. Gao-Fei, W.: User perception in product design. *Packag. Eng.* **36**(10), 85–88 (2015)



# Study on the Influence of BMI Difference on Pressure Distribution of Mattress

Huimin Hu<sup>1,2</sup>, Pu Hong<sup>3(✉)</sup>, Mengjing Cai<sup>3</sup>, Yinxia Li<sup>3</sup>,  
Hong Luo<sup>1,2</sup>, and Haimei Wu<sup>1</sup>

<sup>1</sup> China National Institute of Standardization, Beijing, China  
{huhm, luohong, wuhm}@cnis.gov.cn

<sup>2</sup> SAMR Key Laboratory of Human Factors and Ergonomics, Beijing, China

<sup>3</sup> School of Mechanical Engineering, Zhengzhou University, Zhengzhou,  
Henan, China  
hongpul001@163.com, 1223274297@qq.com,  
liyinxia@zzu.edu.cn

**Abstract.** Mattress is a necessity in everyone's life. Studies show that the BMI difference is one of the factors affecting the comfort of the mattress. The difference affects the pressure distribution in the contact surface of the mattress. In this study, seven mattresses of different hardness were selected, and pressure distribution test with 72 subjects was carried out to collect the pressure of seven parts of the body. The trend of pressure changing with BMI was got by difference and correlation analysis. It can be concluded that head pressure decreases with the increase of BMI. Back pressure, waist pressure, hip pressure, thigh pressure, calf pressure and whole body pressure increase with the increase of BMI. The research results can provide reference for the mattress design suitable for people with different BMI.

**Keywords:** BMI difference · Pressure distribution · Mattresses

## 1 Introduction

We spend approximately one-third of our life in bed, and a synergy of psychological, physiological, and the comfort of the mattress affects the quality of sleep. Difficulties in the test of comfort properties arise from the fact that comfort in a bed is a complex phenomenon, consisted of subjective feeling and physical properties of the interface between a mattress and the human body [1].

Due to differences in human characteristics, different people have different requirements for mattresses. The feeling of using mattresses is different, especially for people of different heights and weights [2]. At present, many scholars have studied the pressure distribution. They carried out a small sample experiment, and the number of subjects is usually less than 20, and the number of test mattresses is less than 3 [3, 4]. Shelton and Lott et al. studied the pressure of the mattress interface of people with different heights and weights. The study found that people with lower weight had higher pressures at the site of the bones, and such people thought the mattress was too hard [5]. Huang et al. used the methods of surface pressure measurement and subjective

comfort evaluation to study the comfort of several mattresses, and found that body characteristics have an effect on the surface pressure of the mattress [6].

In order to make the experimental results less affected by individual differences, a larger sample size experiment was carried out. In this study, seven mattresses of different hardness were selected. BMI (Body Mass Index) is a number calculated by dividing weight (kg) by the square of height (m). When it comes to comparing and analyzing a person's physical characteristics, BMI is a neutral and reliable indicator. So pressure distribution test of 72 subjects with different BMI was carried out to collect the pressure of seven parts of the body. The trend of pressure changing with BMI was got by difference and correlation analysis. The results of this study can provide a reference for mattress design for people with different BMI.

## 2 Method

### 2.1 Experimental Design

First, seven mattresses with different hardness were selected as experimental samples, and 16 thin subjects, 32 normal subjects and 24 fat subjects were recruited. The pressure distribution at the body-bed interface was measured by Tekscan mattress pressure test system. The pressure in eight parts of the body was collected, including the head, neck, back, waist, hip, thighs, calves and whole body. Then, each participant provided subjective comfort evaluation to 7 mattresses after an experience of no less than 10 min. Finally, the relationship between BMI and mattress pressure were determined by one-way ANOVA and Pearson correlation coefficients.

### 2.2 Subject

This paper mainly studies the influence of BMI difference on pressure distribution of mattress. Age, gender, height, weight and BMI as the basis for selecting subjects [7]. Therefore, according to the distribution ratio of BMI in China (2:4:3), 72 health subjects were recruited, including 16 thin subjects, 32 normal subjects and 24 fat subjects. Half of the men and women (see Table 1).

**Table 1.** Subject information table

BMI group	Gender	BMI	N	Age (years)	Height (cm)	Weight (kg)	BMI
Thin group	Male	BMI < 20	8	38.3	173.1	58.6	18.9
	Female	BMI < 19	8	42.5	170.5	65.0	22.3
Normal group	Male	20 < BMI < 25	16	41.3	169.8	80.1	28.0
	Female	19 < BMI < 24	16	36.5	160.3	46.0	17.9
Fat group	Male	BMI > 25	12	41.6	157.3	55.2	22.2
	Female	BMI > 24	12	43.1	158.4	68.4	27.2

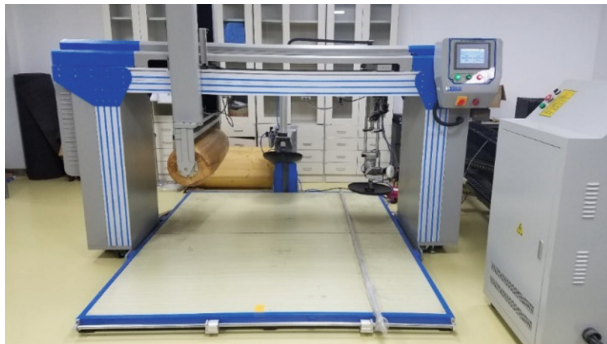
### 2.3 Apparatus

**Tekscan Body Pressure Measurement System.** The experimental device used in this experiment is the Tekscan BPMS system (Fig. 1) in the United States. The system is divided into two parts: hardware and software, including pressure sensor, USB controller and computer software system. The sensor is only 0.1 mm thick and is very flexible, thus creating better conditions for measuring the pressure between various contact surfaces. The measurement accuracy is  $\pm 5\%$ .



**Fig. 1.** Main part of body pressure measure system, it includes two sensors (left) and a USB handle (right).

**Mattress.** In order to ensure the representativeness of the experimental mattress, the mattress hardness test system (see Fig. 2) is used to measure the hardness rating of various mattresses.



**Fig. 2.** Mattress hardness measure system.

Finally, according to the hardness rating of the standard “QBT 1952.2-2011 Upholstered furniture-Spring mattress [8]”, 7 mattresses with different hardness were selected as experimental samples, and the hardness rating of each mattress were 0.7, 2.3, 3.2, 4, 4.5, 5.3 and 7.2 (the hardness rating range is 0–10, the bigger the hardness rating is, the softer the mattress is).

## 2.4 Task and Procedure

1. Each subject was informed about the study and gave a written informed consent
2. Before the test, the subjects were informed of experiment purpose, experiment contents and way of testing, and assistance was given to them to get familiar with the subjective comfort rating scale.
3. The age, gender, height, weight and BMI of the subjects were recorded.
4. The subjects completed the pressure distribution test of 7 mattresses in a supine position (see Fig. 3).



**Fig. 3.** The experimental scene.

## 2.5 Data Analysis

The pressure values of 8 parts were extracted from the Tekscan software. Differences of the eight parts pressure between different BMI groups were compared by one-way ANOVA. Differences of  $p < 0.05$  were considered significant for all statistical analyses. The correlation between pressure and BMI is determined by the Spearman correlation coefficient. Correlation is significant at the 0.05 level. Correlation coefficient  $R < 0$  is negative correlation.  $R > 0$  is positive correlation. Finally, the trend of pressure with BMI was got.

### 3 Results

#### 3.1 Differences

Mean pressure and difference results of 72 subjects were shown in **Error! Reference source not found.** Significant differences between BMI groups were found for pressure of head, back, waist, hip, thighs, calves and whole body ( $p < 0.05$ ). No significant differences between BMI groups were found for pressure of neck ( $p > 0.05$ ) (Table 2).

**Table 2.** Pressure of different group and difference results.

	BMI groups	N	Pressure (kPa)	SD	Sig.
Head	Thin	16	0.39	0.11	0.000
	Normal	32	0.34	0.08	
	Fat	24	0.33	0.08	
Neck	Thin	16	0.16	0.08	0.053
	Normal	32	0.14	0.06	
	Fat	24	0.14	0.07	
Back	Thin	16	0.24	0.09	0.013
	Normal	32	0.25	0.08	
	Fat	24	0.26	0.07	
Waist	Thin	16	0.18	0.06	0.000
	Normal	32	0.19	0.05	
	Fat	24	0.21	0.05	
Hip	Thin	16	0.28	0.09	0.000
	Normal	32	0.31	0.08	
	Fat	24	0.33	0.08	
Thighs	Thin	16	0.12	0.04	0.000
	Normal	32	0.14	0.04	
	Fat	24	0.15	0.04	
calves	Thin	16	0.18	0.05	0.000
	Normal	32	0.19	0.04	
	Fat	24	0.21	0.04	
Whole body	Thin	16	0.24	0.07	0.001
	Normal	32	0.25	0.06	
	Fat	24	0.27	0.06	

#### 3.2 Correlation

Back pressure, waist pressure, hip pressure, thighs pressure, calves pressure and whole body pressure were significantly positively correlated with BMI ( $R > 0$ ,  $p < 0.05$ ). Negative correlation were found for head pressure and BMI ( $R < 0$ ,  $p < 0.05$ ) (Table 3).

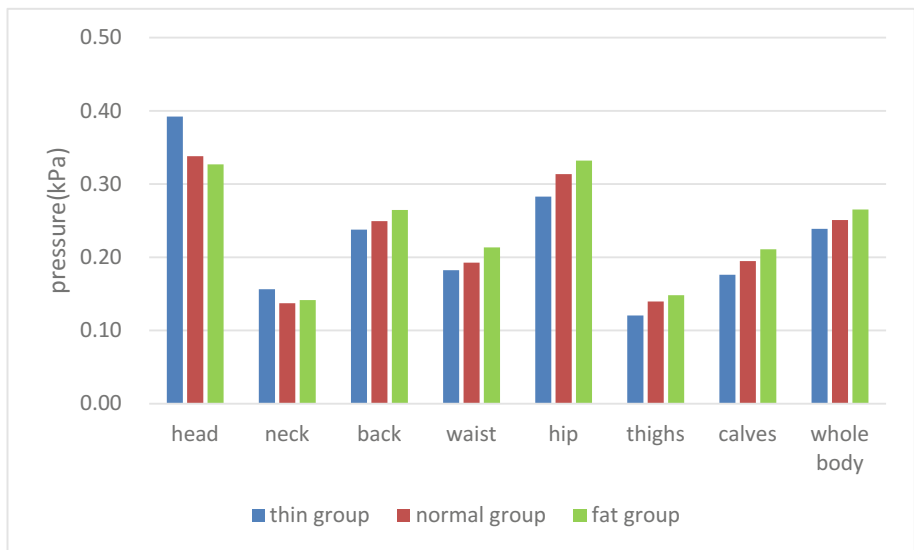


**Table 3.** Correlation coefficient (R) and significance (Sig.) between BMI and stress.

		Pressure							
		Head	Neck	Back	Waist	Hip	Thighs	Calves	Whole body
BMI	R	−0.281	−0.02	0.178	0.284	0.192	0.243	0.234	0.160
	Sig.	0.000	0.609	0.000	0.000	0.000	0.000	0.000	0.000
	N	504	504	504	504	504	504	504	504

### 3.3 Change Trend

Based on the results of the difference and correlation analysis, it can be clearly seen from Fig. 4 that the pressure change trend as the BMI increases.



**Fig. 4.** Comparison of body pressure between different BMI groups

Head pressure decreases as BMI increases. There was no significant change in neck pressure. In the experiment, the subjects used the pillow according to their own habits. When the subjects were lying down, the pillow only supported the head, and the neck was not supported by the pillow, which would cause the neck pressure to be small. Some of the subjects used the pillow to support the neck more, which would cause the neck pressure to be big. This is probably the reason why the trend of neck pressure is not obvious. Back pressure, waist pressure, hip pressure, thighs pressure, calves pressure and whole body pressure increase with increasing BMI.

## 4 Conclusion

Through the pressure test and statistical analysis, the trend of the pressure of various parts with the increase of BMI is obtained. It can be concluded that head pressure decreases with the increase of BMI. Back pressure, waist pressure, hip pressure, thigh pressure, calf pressure and whole body pressure increase with the increase of BMI. The change of BMI has a significant influence on the pressure of the mattress contact surface. In other words, the body type has a significant influence on the pressure on the contact surface of the mattress. The research results can provide reference for the mattress design suitable for people with different BMI.

**Acknowledgments.** This research is supported by 2017 National Quality Infrastructure (2017NQI) project (2017YFF0206603) and China National Institute of Standardization through the “special funds for the basic R&D undertakings by welfare research institutions” (522018Y-5984).

## References

1. Lee, H., Park, S.: Quantitative effects of mattress types (comfortable vs. uncomfortable) on sleep quality through polysomnography and skin temperature. *Int. J. Ind. Ergonomics* **36**(11), 943–949 (2006)
2. Yan, S.: Research on the features of body pressure distribution on multi-type spring mattresses and their personalized design. Doctoral Dissertation, Nanjing Forestry University (2012)
3. Low, F.Z., Chua, C.H., Lim, P.Y., Yeow, C.H.: Effects of mattress material on body pressure profiles in different sleeping postures. *J. Chiropractic Med.* **16**(1), 1–9 (2017)
4. Zhu, Y., Zhang, X., Shen, L., Fang, F.: Research on the effect of body height on zonal spring mattress design. In: *Advances in Physical Ergonomics and Human Factors*. Springer, Cham (2016)
5. Shelton, F., Lott, J.W.: Conducting and interpreting interface pressure evaluations of clinical support surfaces. *Geriatr. Nurs.* **24**(4), 222–227 (2003)
6. Huang, D., Qiu, W., Lin, R.: Research on the characteristics of different types of mattresses with surface pressure and subjective comfort. Chang Gung University
7. Hu, H., Yao, Y., Zhao, C., Yang, F., Luo, L., Li, Y., et al.: Study on human body dimensions used for ergonomic design and evaluation of mattress. In: *Advances in Physical Ergonomics and Human Factors*. Springer, Cham (2016)
8. QBT 1952.2-2011 Upholstered furniture-Spring mattress



# A JACK-Based Ergonomic Analysis and Design of the Cockpit of Agricultural Material Handling Vehicle

Sen Gu<sup>1</sup>, Sheng Su<sup>1(✉)</sup>, Cheng Huang<sup>2</sup>, Zhiqiang Song<sup>1</sup>,  
and Shasha Yuan<sup>1</sup>

<sup>1</sup> School of Design Art and Media, Xi'an Technological University,  
Xi'an, Shanxi, China  
304772975@qq.com

<sup>2</sup> Northwest Institute of Mechanical and Electrical Engineering,  
Xi'an, Shanxi, China

**Abstract.** The JACK ergonomic analysis software was used to simulate and analyze the driver's driving posture and operating behaviors in the cockpit to simulate and optimize the driving comfort of the driver operating a certain model of agricultural material handling vehicle. Through simulation and analysis of the six tools, Comfort Assessment, Lower Back Analysis, Static Strength Prediction, Etc., it was found that the vehicle cockpit's curve of the waist part of the seat was reasonable, but the design had poor comfort levels on the shoulder and neck part, which not only caused fatigue when the vehicle was operated for a long period of time, but also made it challenging for the knees and ankles from sustaining prolonged work at the cockpit. On this basis, the research proposed ergonomic optimization and improvement was also conducted. The research provides a significant basis of reference for designing the cockpits of special-purpose agricultural vehicles.

**Keywords:** Material handling vehicle · Cockpit · Ergonomic simulation · JACK

## 1 Introduction

In today's modernized agriculture, special-purpose agricultural vehicles are getting increasingly diversified, and the ergonomic elements in the cockpit design directly influence the comfort and safety of driving. As one of the special-purpose agricultural vehicles, material handling vehicles are broadly used for wood and cotton handling. When operating a material handling vehicle, prolonged and frequent operations are required in order to gain a good grasp over the control of the running and stopping of the handler and the movements and displacement of the hydraulic gripper. The nature of these operations dictates that cockpit arrangements must be in line with the ergonomic requirements to ensure that drivers can relatively maintain a state of comfort at work. In the "cockpit-seat-man" system, the seat plays an important connecting role as all the other arrangements in a cockpit need to be based on the seat's position and size. The proportion and size of the seat, as well as the curve of its back cover, directly

determine the riding comfort for the driver; in the meantime, the important operating components, such as the steering wheel, pedals, and shift lever, are closely associated with the position of the seat in the cockpit, and indirectly influence the comfort level of drivers. Therefore, the cockpit of the material handling vehicle shall be sufficiently comfortable and safe.

Presently, the design and development of special-purpose agricultural vehicles are still in their infant stages, the cockpits are not arranged by taking the characteristics, application environments and operating states of the special-purpose vehicles into full consideration and not designed on the basis of the uniqueness of the special-purpose vehicles, and there is still room for improvement in terms of their ergonomic qualities and level of comfort. To provide a more comfortable operating environment for the driver which not only reduces fatigue and misoperation, but also increases productivity and safety, by taking a certain model of material handling vehicle (as shown in Fig. 1) as an example and using the JACK ergonomic virtual simulation software, ergonomic simulation and analysis were carried out to the comfort level, lower back force, static force strength, reach zones, visual zones and obscuration zones of the driver in the cockpit, existing problems were found on the basis of the analysis result, and improvement suggestions and design scheme were proposed [3].



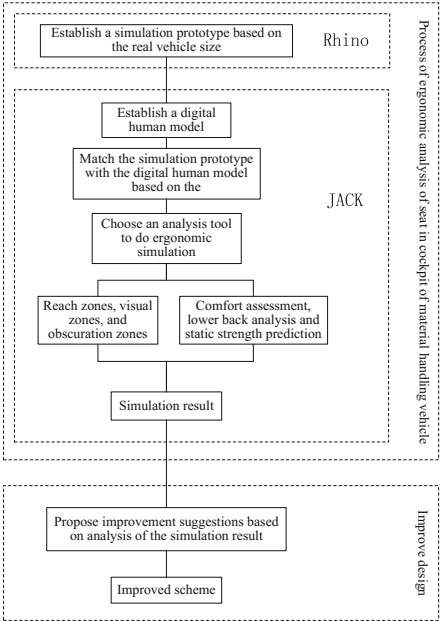
**Fig. 1.** A certain model of material handling vehicle

## 2 An Ergonomic Analysis and Optimization Method of the Cockpit of Material Handling Vehicle

Siemens JACK is ergonomic analysis software developed by Siemens Industrial Software Co., Ltd. The JACK software has advantages of real-time data visualization, and straight and quick data comparison. As professional ergonomic analysis software, JACK can create a digital human model matching the user group of the simulated product, be compatible with various model formats, import a digital product model created in another piece of software into the analysis scenario, stipulate the interaction behaviors between the human and product, and provide valuable analysis result through simulation.

In the analysis of the cockpit of the material handling vehicle with the JACK ergonomic analysis software, a simulation model was established based on the cockpit of the real material handling vehicle; a digital human model was established based on the human body sizes of the user group while making references on the GB10000

Human Dimensions of Adults; the data on the user's real-life operating and driving postures was used to match the simulated cockpit model with a digital human model, allowing it to present a natural operating and driving state [2]. Six tools, which included Comfort Assessment, Lower Back Analysis, Static Strength Prediction, Reach Zones, Vision Cons and Obscuration Zones, were used as necessary in simulation to analyze the ergonomics of the cockpit environment and driving seat of the material handling vehicle; finally, guidance was provided to the design improvement based on analysis of the simulation result. See Fig. 2 for the detailed method process.

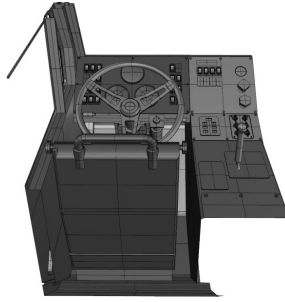


**Fig. 2.** Process of ergonomic analysis and optimization method of cockpit of material handling vehicle

### 3 Ergonomic Simulation of Cockpit of Material Handling Vehicle

#### 3.1 Establishment of Cockpit Simulation Model

When ergonomic analysis was conducted to the overall environment of the cockpit of the material handling vehicle, a 3D model entity of the cockpit was established based on the actual size in RHINO. The model included a cockpit structure part, seat, steering wheel, dashboards, pedals, operating lever and various functional buttons. Only parts and components necessary for the analysis were reserved during modeling to improve the software computing speed [5]. The final model was shown in Fig. 3.



**Fig. 3.** Virtual model of cockpit of material handling vehicle

### 3.2 Establishment of Driver Human Model

The digital human model created in JACK included 68 segments, 69 joints and a 135° range of free movement. Compared to other software, the digital human model created in JACK was closer to the real human body state and thus its simulation result was more worthy of reference.

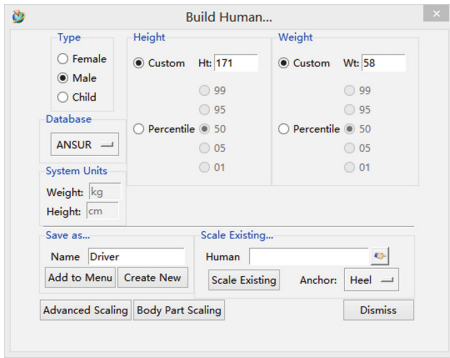
Ergonomic simulation and analysis of the vehicle cockpit are usually performed on the basis of three different position relations between the digital human model and seat: 95% human size and the seat at the rear-most and lowest position; 5% human size and the seat at the fore-most and highest position; 50% human size and the seat at the standard position. To allow the seat in the cockpit of the material handling vehicle to meet the comfort demand of the drivers of most human sizes, the digital human model was established based on the 50% human size and simulation was conducted by adjusting the seat to the standard position [6].

According to the research, men aged 20–45 are the major driver group of material handling vehicles. To further improve the simulation reliability and practicability, the average value of the 50% human size of the two groups, men aged 18–25 and those who aged 26–35 was used as the basic data for establishing the digital driver model. The major human size data of the 18–25 age group and 26–35 age group in GB/T 14779-1993 Design and Requirements for the Templates of Human Body and GB10000 Human Dimensions of Adults was referenced. See Table 1.

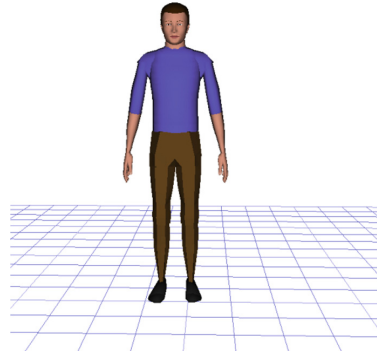
**Table 1.** Table of 50% human sizes

Age Group		18–25	26–35
Item	Height (mm)	1686	1683
	Weight (kg)	57	59

According to GB/T 12985, men’s height shall be the sum of their height data and 25 mm heel height. Eventually, the tool Custom was used to establish the digital driver model (as shown in Fig. 4), with a height of 1710 mm and a weight of 58 kg (as shown in Fig. 5).



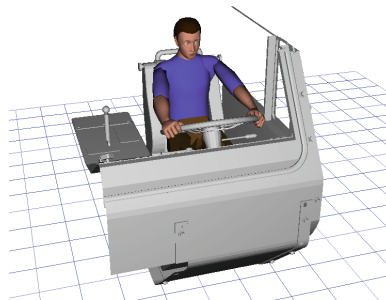
**Fig. 4.** Project field to create digital human model



**Fig. 5.** Digital human model

### 3.3 Driving Posture Arrangement

The cockpit environment model created with RHINO was exported as a “.wrl” format file well compatible with JACK, and then imported into JACK to arrange the driving postures of the digital human model. The posture of the digital human model and arrangement of the cockpit environment were restrained, and the sitting posture and position of the virtual human model were adjusted, so that the H-point of the virtual human model was in the middle of the seat. The virtual human model was also adjusted to the driving posture. For the key angles of the human body, comfortable sitting posture of a truck driver was referenced, i.e., the upper body part leaned slightly backward, the included angle between the upper body part and thigh was  $90^{\circ}$ – $115^{\circ}$ , the included angle between the thigh and calf was  $90^{\circ}$ – $135^{\circ}$ , and the included angle between the calf and sole was  $90^{\circ}$ – $110^{\circ}$ . The real driver operating posture was simulated, as shown in Fig. 6.



**Fig. 6.** Arrangement of cockpit and driving posture

### 3.4 Ergonomic Simulation and Analysis of Cockpit of Material Handling Vehicle

The tools including Comfort Assessment, Lower Back Analysis, Static Strength Prediction, Reach Zones, Vision Cons and Obscuration Zones in JACK were used to make ergonomic analysis of the comfort level, lower back force, static force strength, reach zones, visual zones and obscuration zones of the driver in the cockpit of the material handling vehicle, research ergonomic relations of the driver with the seat, steering wheel, dashboards and various operating devices, and propose the items which were unergonomic.

**Driver Comfort Analysis.** The tool Comfort Assessment in JACK aims to analyze the comfort level of a certain joint or the overall posture of the digital human model based on the given driving posture. When the driver maintains in the driving posture, this tool can provide 6 different databases for comfort analysis. For the driver, the body comfort depends on the angles of all the joints in the body, rather than the angle of a certain one. Therefore, the database Krist in Multi-Joint Comfort was used to analyze the multi-joint comfort of the driver, so as to research the driver's overall comfort in the driving posture.

Figure 7 shows the driver comfort evaluation result. The database Krist gives a score number of 0–80 to the comfort. The score is negatively correlated with the comfort. The body parts involved in the scoring items include the neck, shoulders, back, hip, arms and legs. The fatigue scores are also provided to evaluate how quick the driver can get fatigue, and “Comfort” is the overall evaluation of the comfort.

It can be seen from the chart that the scores of the driver's shoulders, neck and right leg were high, and directly influenced the values of fatigue and comfort. It can be analyzed that the driver was less comfortable at the shoulders, neck and right leg which would get fatigue the first after a long period of driving. In order to optimize the driver's driving comfort, it is necessary to optimize the design of the seat part above the shoulder and at the leg.

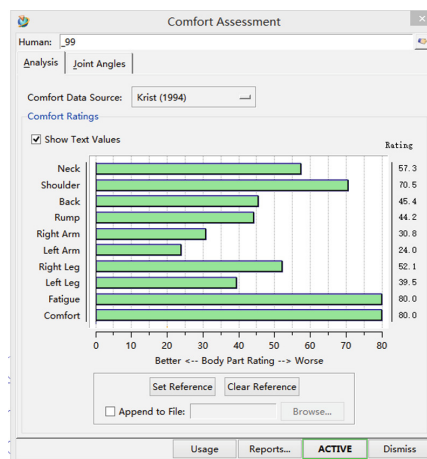


Fig. 7. Comfort analysis of driver of material handling vehicle

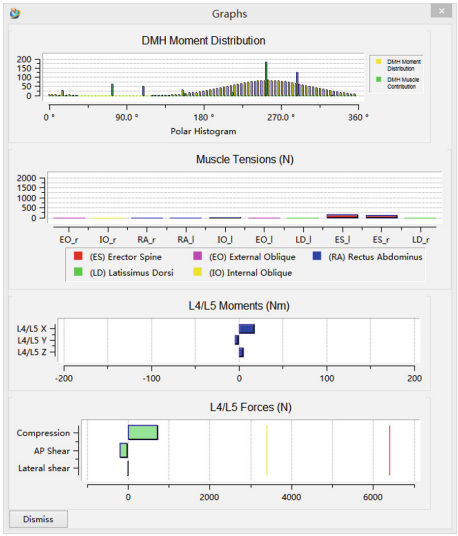


**Driver Lower Back Force Analysis.**

Lower back force analysis is one of the significant bases for evaluating if a seat design is ergonomic. When a person maintains in the sitting posture for a long period of time, muscles and ligaments on the spine get injured and lead to intervertebral disc aging, which, to some extent, might lead to diseases like protrusion of intervertebral disc. Design of the seat backrest and cushion shape, curve and angle can restrain the driver's sitting posture [1]. Reasonable seat design can balance the pressure on the driver's spine, so that the driver can drive and operate in comfortable sitting posture, and alleviate muscle strain; or else, it will be accelerated. Therefore, by conducting simulation with the lower back force analysis tool in the driver's working state, the lower back force of the driver when operating the vehicle on the seat can be evaluated.

The Lower Back Analysis module in JACK was used to analyze the complex lower back model of the digital human model created with JACK, calculate the pressure on the spine at L4/L5, compare the calculation data with the recommended values in the databases of the USA National Institute for Occupational Safety and Health, judge if the lower back force on the driver when driving the material handling vehicle was within the human tolerance range, and thus evaluate if the driving posture was comfortable [8].

During analysis, 2 kg downward loads were respectively applied to the hands of the digital human model to simulate the driver's driving state when holding the steering wheel. The final analysis result is shown in Fig. 8. In the analysis result, DMH Moment Distributed shows the influence of each joint moment to each muscle; Muscle Forces are the muscle forces, and it can be seen from the chart that the left and right erector spinae muscles ES-l and ES-r were under the largest forces in this driving posture; L4/L5 Moments are the moments at L4/L5 of the spine, with small moment values in each direction; L4/L5 Forces are the forces at L4/L5 of the spine, and it can be seen



**Fig. 8.** Driver lower back force analysis

from the chart that the compression and AP Shear were low at the L4 and L5 spine; they are green in the bar chart, indicating that the forces at the L4 and L5 spine were within the reasonable range. In summary, the driver's lower back part was under normal force when driving the material handling vehicle, and the seat waist curve was designed reasonably and thus could basically meet the comfort requirements.

**Driver Static Force Strength Analysis.** The material handling vehicle is a kind of special-purpose agricultural vehicle commonly used in modern agricultural production all over China. Its drivers have diversified body sizes. The seat mounting position in the cockpit of the material handling vehicle, as well as design of the backrest and cushion shape, curve and angle can restrain the driver's sitting posture. The seat shall be compatible with drivers of different body sizes as far as possible, so as to meet their basic driving comfort demands and allow them to drive or operate the material handling vehicle in the driving posture for a long period of time. The tool Static Strength Prediction in JACK assesses the percentage of digital human model working in a certain posture that can complete their work depending on their body sizes [4]. Figure 9 shows the analysis result.

It can be seen from the chart that in the regulated driving posture of the material handling vehicle, the values of the five parts, i.e., the wrist, elbow, shoulder, torso and hip were 100%; the value of the knee was 74%; the value of the ankle was 50%. It can be seen that the knee joint value was low, and the drivers of body sizes from 0% to 74% could operate by maintaining in this driving posture; the ankle joint value was the lowest, and the drivers of body sizes from 0% to 50% could operate by maintaining in this driving posture.

For static force strength analysis, the value of the item having the lowest value is usually used as the overall evaluation result [7]. The result shows that only the drivers of body sizes from 0% to 50% could operate by maintaining in this driving posture. Persons of higher-percentage body sizes have longer legs. Factors causing their discomfort may include: the cushion cannot well support the thighs of the group of higher-percentage body sizes; there's a smaller space for the legs; the inclination angles of the pedals do not allow long-term placement of the feet on them.

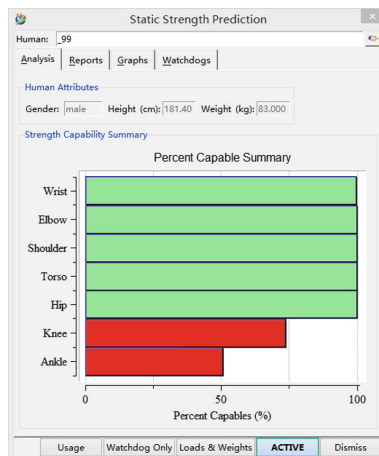
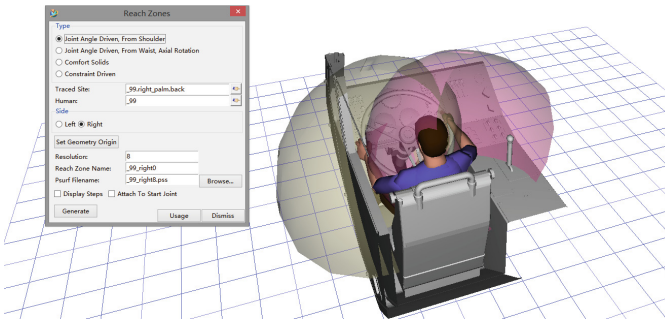


Fig. 9. Static force strength analysis of driving posture of material handling vehicle driver

**Driver Reach Zones Analysis.** The driver of the material handling vehicle as a special-purpose agricultural vehicle needs to operate other special equipment, in addition to the steering wheel and shift lever. According to the regulations, there can be only one passenger in the cockpit of the material handling vehicle, namely, the driver. There're buttons, shift lever and hydraulic gripper control panels in the cockpit, which need to be operated independently by the driver. Therefore, the reach zones of the driver shall be analyzed.

In JACK, the Reach Zones measures the maximum reach of the digital human model's arms. During the test, it shall be set that the moving area of the waist is interlocked with the shoulders based on the driving posture, to achieve the maximum reach. By adjusting the transparency of the reach zones generated with JACK, the generated reach zones can clearly show the relations of the driver with the instruments and control levers in the cockpit. Figure 10 shows the simulation result of the reach zones of the driver's hands, in which the gray part was the reach zone of the left arm, while the purple part was that of the right arm.

According to the simulation result, important operating devices including the steering wheel, shift lever and operating levers were all within the reach zones of the driver. However, some control buttons on the right of the dashboards were beyond the reach zone, meaning that the driver needed to move the waist substantially to reach these buttons.



**Fig. 10.** Simulation of hand reach zones of material handling vehicle driver

**Driver Visual Zones and Obscuration Zones Analysis.** The visual range has a direct influence on the safety and efficiency of material handling vehicle operation. When driving and operating the vehicle, the driver shall look straight ahead and the visual range shall be within the range of the front windshield, tachometer, speedometer, vehicle status indicator and other main dashboards. The tool Vision Cons in JACK can establish the visual range of the digital human model, and judge if the cockpit arrangement is reasonable by analyzing the relation between the vision cones and cockpit gauges or front windshield. Figure 11 shows the simulation result of the visual range of the digital driver model. The result shows that the visual zones of the driver were concentrated on the front windshield, and the main gauges were covered within

the visual zone edges, conforming to the ergonomic requirements for the cockpit arrangement.

When driving or operating the vehicle, the driver needs to observe the dashboards constantly to know the current vehicle state. When the dashboards are observed, the steering wheel blocks the visual zones to some extent. If the dashboards are blocked by the steering wheel, the efficiency for the driver to get information from the gauges will be reduced, extending the observation time and causing safety risks. The tool Obscuration Zones in JACK simulates the visual obscuration zones of the digital human model employing a certain angle of view. The simulation was conducted with the steering wheel set as the obscuration section and the boundary distance set to 20 cm. The simulation result is shown in Fig. 12. The result shows that the main gauges in the cockpit were well arranged, and the steering wheel did not block the dashboards at a certain angle of view of the driver who could get information clearly and quickly from the dashboards, conforming to the ergonomic requirements for the cockpit arrangement.

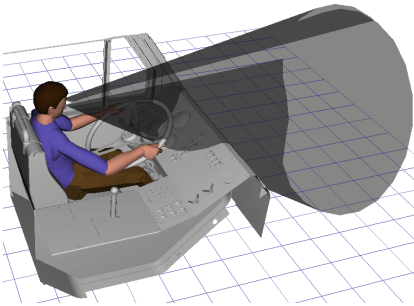


Fig. 11. Vision cones of vehicle driver

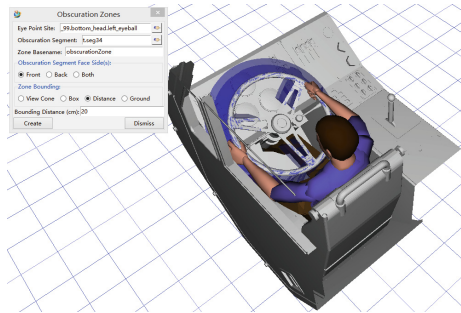


Fig. 12. Visual obscuration zones of vehicle driver

## 4 Optimal Cockpit Design

Through simulation and result analysis of the overall cockpit environment of the material handling vehicle by using the JACK ergonomic simulation software, suggestions to improve the seat and cockpit design were proposed:

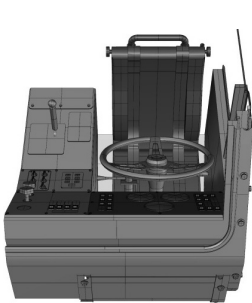
- (1) According to driver comfort analysis, it is suggested to add lateral supporting points on the seat to relax the shoulders, and add a headrest to share the pressure on the neck, improve the comfort and also guarantee the safety.
- (2) According to the static force analysis of the driver, it is suggested to add a cushion length adjusting device to satisfy the comfort demands of a larger user group and allow the seat to be more compatible with the body size; according to GBT11563-1995 Motor Vehicles - Procedure for H-point Determination and GB10000 Human Dimensions of Adults, it is suggested to optimize arrangement of the

H-point of the seat and enlarge the leg space appropriately, so that the driver can operate the accelerator pedal and brake pedal at comfortable angles of the right knee joint and right ankle joint.

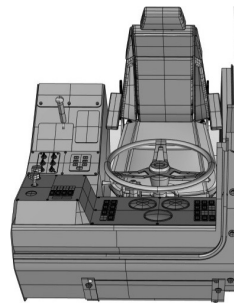
- (3) According to the reach zones analysis, it is suggested to optimize the design of the dashboards and other hydraulic gripper operating devices, e.g., the positions of the operating devices including the buttons, lever and switches, so that the driver can access most of the devices without any movement, to reduce the possibility of waist fatigue.

According to the above suggestions, the design was improved and the cockpit was optimized in such a way: coordinates of the H-point matching the driving posture for the agricultural vehicle were selected, the seat position in the cockpit was arranged by referencing the H-point, and the leg space was suitably increased; the arrangement of the dashboard on the right of the cockpit was improved, and the optimized hydraulic gripper operating devices were within the reach zones of the driver, thus reducing the bending angle of the driver's waist when operating the hydraulic gripper, and reducing the possibility of waist fatigue. The seat was optimized based on GBT 14779-1993 Design and Requirements for the Templates of Human Body: the lateral support structures were added on the seat to improve comfort of the shoulders and their fit with the seat; the adjustable headrest was added based on the human size to provide effective protection and buffering for the driver's head, alleviate pressure on the neck and reduce the possibility of atlas and axis injuries; a foldable extension cushion was added, so that the seat could provide sufficient support to the thighs of drivers of higher-percentage body sizes, alleviate their leg fatigue and reduce pressure on the knee joints.

The optimized cockpit improved the driver's comfort to some extent and achieved the purpose of ergonomic optimization. Figures 13 and 14 show the comparison between the final optimized scheme of the overall cockpit arrangement of this material handling vehicle model and the original cockpit; Figs. 15 and 16 show the comparison between the optimized scheme of the cockpit seat and the original seat; Fig. 17 shows the extended state of the cushion length adjusting device; Fig. 18 shows its folded state.



**Fig. 13.** Before overall cockpit optimization



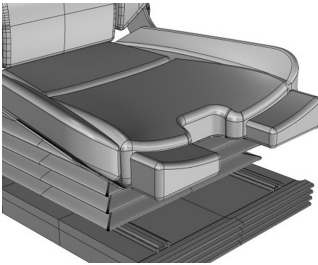
**Fig. 14.** After overall cockpit optimization



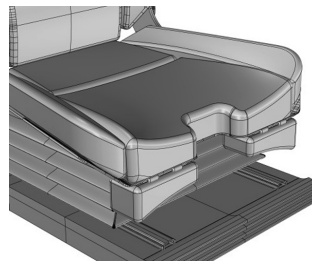
**Fig. 15.** Original seat



**Fig. 16.** Optimized seat



**Fig. 17.** Extended state



**Fig. 18.** Folded state

## 5 Conclusion

In this research, the JACK ergonomic software was used to establish the digital human model, virtually simulate the driving posture of the material handling vehicle driver, and respectively analyze and evaluate the ergonomics of the comfort level, lower back force, static force strength, reach zones, visual zones and obscuration zones. Finally, the following conclusion was reached:

- (1) When the driving posture is maintained, the driver was less comfortable at the shoulders and neck, some drivers easily have knee joint and ankle joint fatigue, and some control buttons on the right of the dashboards are beyond the driver's reach zones.
- (2) It was proposed to add the lateral supporting points on the seat to relax the shoulders, and add the headrest to share the pressure on the neck, improve the comfort; optimize the H-point arrangement, and enlarge the leg space; optimize the dashboard arrangement to reduce the driver's overall fatigue. This research provides a good reference for designing the driving environments of cockpits of special-purpose agricultural vehicles and improving the driver's operating comfort.

**Acknowledgements.** This study is supported by the Project supported by the National Social Science Foundation of China (Project No. 51675530).

## References

1. Fritzsche, L.: Ergonomics risk assessment with digital human models in car assembly: simulation versus real life. *Hum. Factors Ergon. Manuf. Serv. Ind.* **20**, 287–299 (2010)
2. Carey, E.J., Gallwey, T.J.: Evaluation of human postures with computer aids and virtual workplace designs. *Int. J. Prod. Res.* **40**, 825–843 (2002)
3. Chaffin, D.B.: Improving digital human modelling for proactive ergonomics in design. *Ergonomics* **48**, 478–491 (2005)
4. Chaffin, D.B.: Development of computerized human static strength simulation model for job design. *Hum. Factors Ergon. Manuf. Serv. Ind.* **7**, 305–322 (1997)
5. Duffy, V.G., Fallon, E.F.: Digital human modeling and workplace evaluation: using an automobile assembly task as an example. *Hum. Factors Ergon. Manuf. Serv. Ind.* (2010)
6. Aromaa, S., Väänänen, K.: Suitability of virtual prototypes to support human factors/ergonomics evaluation during the design. *Appl. Ergon.* **56**, 11–18 (2016)
7. Kamp, I.: The influence of car-seat design on its character experience. *Appl. Ergon.* **43**, 329–335 (2012)
8. Liu, Y., et al.: A study on objective evaluation of vehicle steering comfort based on driver's electromyogram and movement trajectory. *IEEE Trans. Hum.-Mach. Syst.* (2017)



# Research on Comfort of Mattresses with Different Hardness Based on Body Pressure Distribution

Huimin Hu<sup>1,2</sup>, Pu Hong<sup>3(✉)</sup>, Mengjing Cai<sup>3</sup>, Hong Luo<sup>1,2</sup>,  
and Haimei Wu<sup>1</sup>

<sup>1</sup> China National Institute of Standardization, Beijing, China  
{huhm, luohong, wuhm}@cnis.gov.cn

<sup>2</sup> SAMR Key Laboratory of Human Factors and Ergonomics, Beijing, China

<sup>3</sup> School of Mechanical Engineering, Zhengzhou University, Zhengzhou,  
Henan, China  
hongpul001@163.com, 1223274297@qq.com

**Abstract.** About 35% of a person's life is spent in bed. With people's living standards improve, more and more people are paying attention to mattress comfort. Studies have shown that the pressure distribution between the mattress and the human body affects people's sleep quality, and the pressure distribution is one of the main indicators to measure the comfort of the mattress. In this paper, the comfort of mattresses with different hardness is studied. The pressure distribution and the subjective comfort score are analyzed with the trend of the mattress hardness. The recommended values of the mattress hardness and the pressure are obtained. The research results can provide basis and reference for the design of the mattress.

**Keywords:** Comfort · Different hardness · Pressure distribution · Mattresses

## 1 Introduction

One third of a person's life is spent in sleep. Sleep quality has an important impact on people's social interaction, mood, quality of life, work efficiency, etc. Mattress comfort is an important factor affecting sleep quality [1]. Mattress comfort is a complex phenomenon based on subjective perception and physical characteristics of the human-bed interface. Among them, the mechanical comfort is defined as "part of the overall comfort". Contact surface pressure, pressure distribution and pressure load action time are the main indicators affecting mechanical comfort [2]. And some studies have shown that the human-bed interface pressure distribution has a significant impact on mattress comfort [3]. Therefore, in order to improve the comfort of the mattress, it is necessary to study the pressure distribution between the mattress and the human body contact surface.

Many scholars have studied the comfort of mattresses. Fang [4] used the body pressure distribution test system to analyze the effects of mattresses with different hardness on the pressure distribution of different body types. It is concluded that the



hardness of the mattress is an important factor affecting the comfort of the mattress. Moreover, studies have shown that mattresses with different elastic modulus have different effects on comfort, and mattresses with medium elastic modulus are most comfortable [5]. Similarly, Wang and others [6] believe that the hardness of the mattress directly affects the quality of sleep. Compared with the hard mattress and the soft mattress, the moderately soft mattress helps to improve the quality of sleep. In addition, Chen [7] believes that unreasonable pressure distribution will reduce the comfort of lying and the quality of sleep.

In summary, the hardness of the mattress is one of the main factors affecting the pressure distribution of the mattress, and the pressure distribution is an important indicator to measure the comfort of the mattress. Therefore, this paper studies the comfort of different hardness mattresses. The pressure distribution and the subjective comfort score are analyzed with the trend of the mattress hardness. The recommended values of the mattress hardness and the pressure are obtained.

## **2 Method**

### **2.1 Experimental Design**

First, seven mattresses with different hardness were selected as experimental samples, and 72 subjects were recruited. The pressure distribution at the human-bed interface was measured by Tekscan mattress pressure test system. The pressure on the mattress contact surface of the three parts of the body (shoulder-back, waist and hip) is mainly collected. Then, each participant provided subjective comfort evaluation to 7 mattresses after an experience of no less than 10 min. The evaluation included shoulder-back comfort, waist comfort and hip comfort. Finally, the least square method is used to draw the trend line of pressure and subjective score with mattress hardness. The hardness rating of the mattress suitable for Chinese people's habits is obtained, and the pressure value when the subjective comfort is high is obtained.

### **2.2 Subject**

This paper mainly studies the mattress comfort based on the pressure distribution. The research shows that the pressure is related to the weight of the subject, and the pressure distribution of the mattress has a great relationship with the body characteristics such as height and weight. In order to ensure the representativeness of the subjects, this study divided the proportion of the subjects according to the Chinese adult body size database. Age, gender, height, weight and BMI as the basis for selecting subjects. Therefore, 72 subjects without spinal disease were selected (see Table 1).

**Table 1.** Subject information table

Gender	Age group	BMI group	N	Age (years)	Height (cm)	Weight (kg)	BMI
Male	18–40	BMI < 20	4	24.6	176.8	59.88	19.12
		20 < BMI < 25	8	27.14	172.29	66.44	22.36
		BMI > 25	6	33	172	84.83	28.75
	40–60	BMI < 20	4	52	169.33	57.33	18.73
		20 < BMI < 25	8	57.89	168.67	63.46	22.3
		BMI > 25	6	49.67	167.5	75.35	27.25
Female	18–40	BMI < 19	4	23.25	158.75	43.93	17.43
		19 < BMI < 24	8	29.33	160.11	54.71	21.13
		BMI > 24	6	32	159.2	71.4	28.08
	40–60	BMI < 19	4	49.75	161.75	48	18.34
		19 < BMI < 24	8	53.86	154.57	55.69	23.26
		BMI > 24	6	54.29	157.57	65.34	26.27

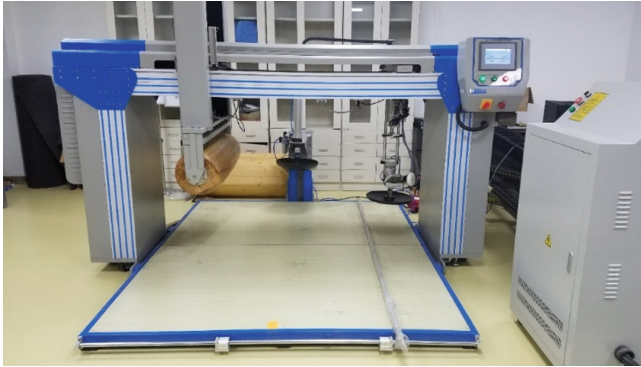


**Fig. 1.** Main part of Body Pressure Measure System, it includes two sensors (left) and a USB handle (right).

### 2.3 Apparatus

Tekscan body pressure measurement system. The experimental device used in this experiment is the Tekscan BPMS system (Fig. 1) in the United States. The system is divided into two parts: hardware and software, including pressure sensor, USB controller and computer software system. The sensor is only 0.1 mm thick and is very flexible, thus creating better conditions for measuring the pressure between various contact surfaces. The measurement accuracy is  $\pm 5\%$ .

Mattress. In order to ensure the representativeness of the experimental mattress, the mattress hardness test system (see Fig. 2) is used to measure the hardness rating of various mattresses.



**Fig. 2.** Mattress hardness measure system.

Finally, 7 mattresses with different hardness were selected as experimental samples, and the hardness rating were 0.7, 2.3, 3.2, 4, 4.5, 5.3 and 7.2 respectively (The hardness level range is 0–10, the bigger the hardness level, the softer the mattress) (Table 2).

## 2.4 Task and Procedure

1. Each subject was informed about the study and gave a written informed consent
2. Before the test, the subjects were informed of experiment purpose, experiment contents and way of testing, and assistance was given to them to get familiar with the subjective comfort rating scale.
3. The age, gender, height, weight and BMI of the subjects were recorded.
4. Subjects provided subjective comfort evaluation for 7 mattresses after an experience of no less than 10 min (five-level rating scale).
5. The subjects completed the pressure distribution test of 7 mattresses in a supine position (see Fig. 3).

## 2.5 Data Analysis

The shoulder-back, waist and hip pressure values were extracted from the Tekscan software, and the trend line of pressure and subjective scores with mattress hardness was drawn using least squares method. The goodness of fit ( $R^2$ ) of all trend line is bigger than 0.9. According to the trend line, the 25% hardness rating with a higher subjective evaluation score is regarded as the recommended hardness rating. When the subjective comfort score is bigger than 3.5, the mean pressure value of each part of the body is calculated.

**Table 2.** The experimental mattress information


Hardness rating	Picture	Size (cm) Length*width*height
0.7		200*100*13
2.3		200*100*11.75
3.2		200*180*23
4		200*180*29
4.5		200*180*29
5.3		200*180*28
7.2		200*180*30



Fig. 3. The experimental scene.

### 3 Results

#### 3.1 Hardness Rating

It can be seen from Figs. 4, 5 and 6 that as the hardness of the mattress increases, the subjective scores of the shoulder-back, waist and buttocks increase first and then decrease. The subjective scoring of the hardest or softest mattress is low, and the slightly harder mattress is more comfortable. According to the trend line equation, the recommended hardness rating for the shoulder-back is 3.5–6. The recommended hardness rating for the waist is 3.27–5.77. The recommended hardness rating for the hip is 3.58–6.08.

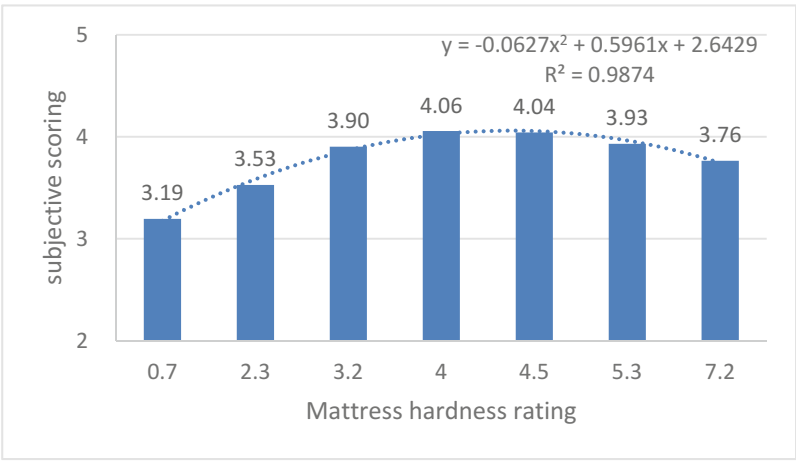
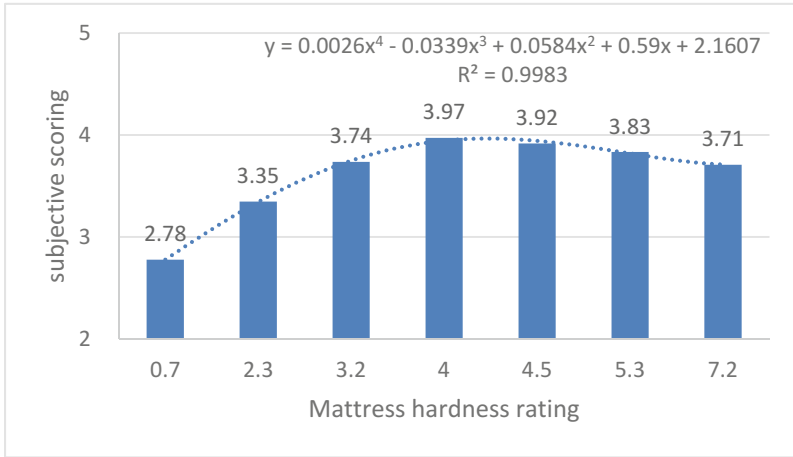
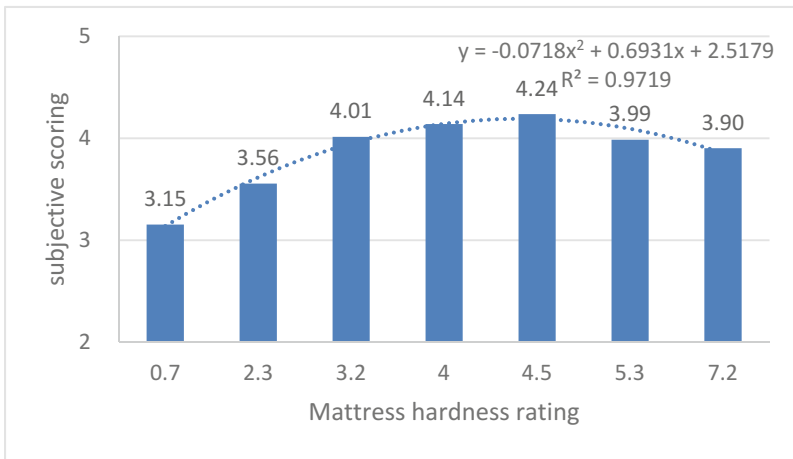


Fig. 4. Trend line of shoulder-back subjective score with hardness rating (dotted line). The upper right equation is the fitting equation of the trend line,  $R^2$  is the goodness of fit ( $R^2 > 0.8$ ).



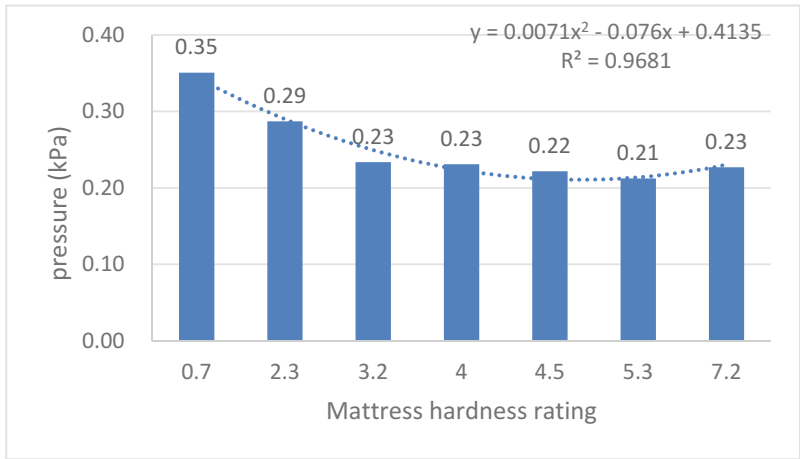
**Fig. 5.** Trend line of waist subjective score with hardness rating (dotted line). The upper right equation is the fitting equation of the trend line,  $R^2$  is the goodness of fit ( $R^2 > 0.8$ ).



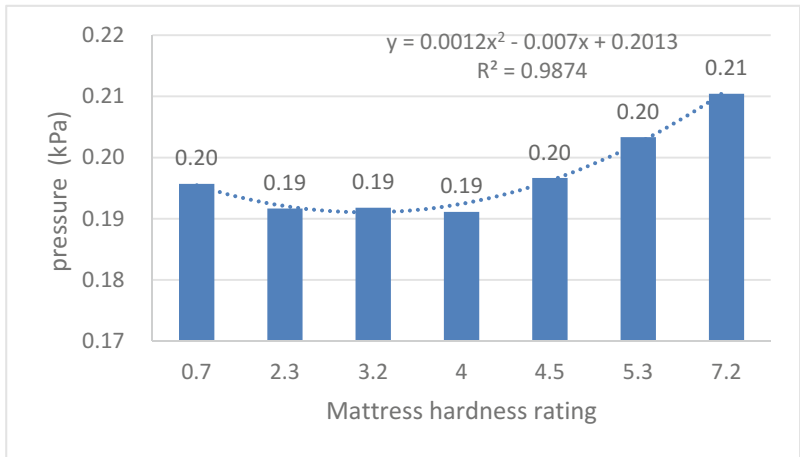
**Fig. 6.** Trend line of hip subjective score with hardness rating (dotted line). The upper right equation is the fitting equation of the trend line,  $R^2$  is the goodness of fit ( $R^2 > 0.8$ ).

### 3.2 Pressure

It can be seen from Figs. 7, 8 and 9 that as the hardness of the mattress increases, the pressure on the shoulder-back, waist and hips decreases first and then increases. It can be found that the pressure of the shoulder-back, waist and buttocks is larger on a harder or softer mattress, and the pressure on a mattress with moderate hardness is smaller. Combined with the results of the previous analysis, it can be inferred that when the pressure of shoulder-back, waist and buttocks is small, the comfort is high.

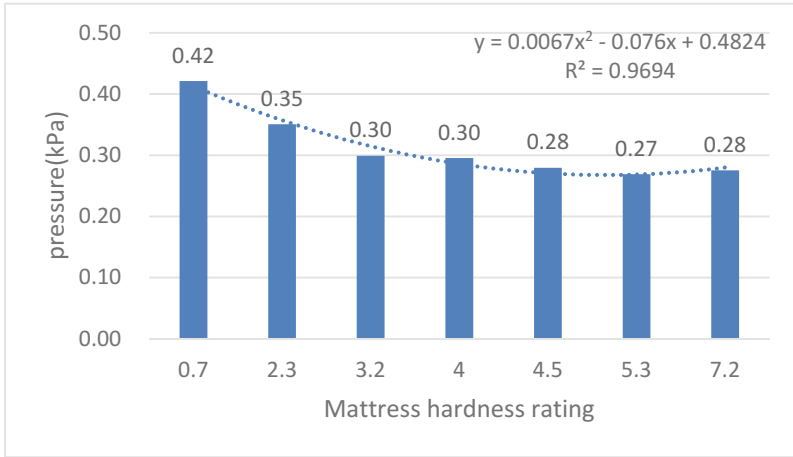


**Fig. 7.** Trend line of shoulder-back pressure with hardness rating (dotted line). The upper right equation is the fitting equation of the trend line,  $R^2$  is the goodness of fit ( $R^2 > 0.8$ ).



**Fig. 8.** Trend line of waist pressure with hardness rating (dotted line). The upper right equation is the fitting equation of the trend line,  $R^2$  is the goodness of fit ( $R^2 > 0.8$ ).

According to the trend line equation, when the subjective score is bigger than 3.5, the mean shoulder-back pressure is 2.1–3.01 kPa, the mean waist pressure is 1.91–2.13 kPa, and the mean hip pressure is 2.67–3.71 kPa. The shoulder-back and hip are more convex relative to the waist, which causes the hips and shoulder-back pressure to be bigger than the waist.



**Fig. 9.** Trend line of hip pressure with hardness rating (dotted line). The upper right equation is the fitting equation of the trend line,  $R^2$  is the goodness of fit ( $R^2 > 0.8$ ).

## 4 Conclusion

In this paper, the subjective comfort scores of the three parts of the body (shoulder-back, waist and buttocks) are analyzed with the change of mattress hardness. It is found that as the hardness of the mattress increases, the subjective comfort scores of various parts of the body increase first and then decrease. When the subjective score is higher, the recommended hardness rating of the shoulder-back is 3.5–6. The recommended hardness rating of the waist is 3.27–5.77. The recommended hardness rating of the buttock is 3.58–6.08. In general, a slightly harder mattress is more in line with Chinese usage habits. Then the pressure values of the three parts of the body are analyzed with the change of mattress hardness. It is found that as the hardness of the mattress increases, the pressure value of various parts of the body decreases first and then increases. When the subjective score is higher than 3.5, the mean pressure of the shoulder-back is 2.1–3.01 kPa. The mean pressure of the waist is 1.91–2.13 kPa. The mean pressure of the buttocks is 2.67–3.71 kPa. Through the study of this paper, the hardness rating of the mattress suitable for Chinese people's habits is obtained, and the pressure value when the subjective comfort score is high was obtained. The research results provide a basis and reference for mattress design.

**Acknowledgments.** This research is supported by 2017 National Quality Infrastructure (2017NQI) project (2017YFF0206603) and China National Institute of Standardization through the “special funds for the basic R&D undertakings by welfare research institutions” (522018Y-5984).



## References

1. Krystal, A.D., Edinger, J.D.: Measuring sleep quality. *Sleep Med.* **9**(Suppl 1), S10–S17 (2008)
2. Hänel, S.-E., Dartman, T., Shishoo, R.: Measuring methods for comfort rating of seats and beds. *Int. J. Ind. Ergon.* **20**(2), 163–172 (1997)
3. Lee, H., Park, S.: Quantitative effects of mattress types (comfortable vs. uncomfortable) on sleep quality through polysomnography and skin temperature. *Int. J. Ind. Ergon.* **36**(11), 943–949 (2006)
4. Fang, F., Shen, L., Guo, Y.: Effect of mattress firmness on body pressure distribution in different body types. *J. Anhui Agric. Univ.* **43**(2) (2016)
5. Li, L.: Study on effect of elasticity on the mattress comfort with objective and subjective methods. In: *International Conference on Mechanic Automation & Control Engineering*. IEEE (2011)
6. Wang, C., Zhuo, D., Xiong, Y.: Quality of sleep, as influenced by mattresses with various degree of firmness. *Chin. J. Rehabil. Med.* **24**(10) (2009)
7. Chen, Y., Shen, L., Guo, Y., Liu, S.: Study on bedrest comfort evaluation methods based on pressure distribution. *J. Anhui Agric. Univ.* (2013)

# **Cultural Aspects in Design and City Planning**



# Built Environment Preservation: A Process of Ergonomic Design

Conceição Trigueiros<sup>1</sup>(✉) and Mario Saleiro Filho<sup>1,2</sup>

<sup>1</sup> CIAUD-FA-UL, Lisbon, Portugal  
trigueiros.conceicao@gmail.com

<sup>2</sup> UFRRJ, Seropedica, Rio de Janeiro, Brazil  
saleirofilho@gmail.com

**Abstract.** Portugal due to this geographical latitude, similar to that of California, with climate comparable to those of South Africa, Chile and Australia, and its location in the Mediterranean basin comprises a series of natural factors that facilitate the propagation of forest fires. The disasters caused by climate change or natural causes in 2017 were extremely significant in the context of Portuguese architectural and urban heritage. Our concern regards the contemporary housing through the heritage perspective, with all its historic, architectural, cultural and social attributes. In terms of spatial framework, we have selected the three Portuguese villages, located in the region of District of Castelo Branco, and which were in the centre of the tragedy. The objective of this work is to discuss heritage preservation and rehabilitation politics, particularly the ones concerned to the built environment and its interface with nature, allied to the ergonomic approach in the design process.

**Keywords:** Preservation · Built environment · Process of ergonomic design

## 1 Introduction

The disasters caused by climate change or natural causes in 2017 were extremely significant in the context of Portuguese architectural and urban heritage. More than 500 fires broke out in the woods of central and north Portugal. The global warming was signaled by the specialists as the cause for doubling the number of fires outbreak and for the increase of severe drought in 80% and of extreme drought in 8% in Portuguese territory, mainly due to strong winds on the coast of Iberian peninsula brought by the Ophelia hurricane, rising the temperatures to above 30 °C. In regard to material damages, more than 500 houses were either partially or totally destroyed by the flames, as well as large enterprises with more than 400 employees and a series of roads and motorways were closed, leading to the death of circa 50 people.

Our concern regards the contemporary housing through the heritage perspective, with all its historic, architectural, cultural and social attributes. In terms of spatial framework, we have selected the Portuguese parishes (a municipal administrative subdivision) [1] of Álvaro, Madeirã and Sobral – at Oleiros municipality, district of Castelo Branco – that were in the epicenter of the tragedy. The objective of this work is to discuss heritage preservation and rehabilitation politics, particularly the ones

concerned to the built environment and its interface with nature, in connection to the ergonomics in the design process. Besides, we will register the interventions on the houses at these villages made by the FA-Universidade de Lisboa students and teachers, as well as the ones made by specialists of different areas. This work intends to highlight the importance of the built and natural heritage, redirecting their relevance in the world's agenda.

## 2 Fire Outbreaks in Portugal: A Brief Timeline

Portugal, due to this geographical latitude, similar to that of California, with climate comparable to those of South Africa, Chile and Australia, and its location in the Mediterranean basin comprises a series of natural factors that facilitate the propagation of forest fires. In addition, seasonal aspects such rainy periods and dry and hot summer also contribute to spread the flames and fumes more easily.

The occurrence of forest fires in Portugal is one of the highest in Europe. Between 1999–2008 the annual average of burnt area was 148.000 ha. It is relevant to indicate that, according to statistics, this figure has increased between 1980s and 1990s, as well as in the first half of the 2000s, becoming more and more frequent vast fire outbreaks [1].

Within Portuguese history, although there were not written documents registering large fire outbreaks before the XX century, we could mention some: in Dom Afonso V royal letter there was an intervention in 1464 due to fires in the fields that caused the erosion of the Rio Mondego basin [2]; in the XIX century, Silva e Batalha, indicated that between 1806 and 1814 the Leira National Woods had a series of fire outbursts [3]; Navarro highlights that between 1882–1883, a large fire outburst could have happened at the Bussaco woods [4]; in the 1960s, there were large forest fires within the region of Vale do Rio, at Leira district, at Figueiró dos Vinhos (in 1961), Viana do Castelo (in 1962), Boticas (in 1964) and Sintra (1966) [5].

The best documented fire outburst mentioned above is the one that happened in Sintra, between 06–12 September, causing the death of 25 military men of the Aircraft Artillery regiment (Regimento de Artilharia Antiaérea Fixa) of Queluz who were fighting against the flames that were rapidly spreading due to strong wind. In addition to the devastation of 5000 ha of its historical-natural heritage, particularly the Tapada do Mouro, several touristic-architectural landmarks were in risk areas, such as: the Seteais and Monserrate palaces, the Pena park, the São Pedro de Sintra village, amongst others. One of the causes could have been the dry bushes, that are easily combustible.

According to Lourenço's studies [6], until 1970s fires were not considered a main problem for the Portuguese forests. However, the accumulation of dry bushes in the woods, as the result for reducing the area for pasture, which was the consequence of the rural exodus after the 1950s, was one of the main causes for fires. This migration led to the uncontrolled growing of the vegetation in areas that were previously used as agricultural land, contributing therefore to spread fires during hot summer months. From the 1980s onwards, Lourenço (1986 and 1987) comments that fires had become more frequent in areas of 1000 ha, such as Vila de Rei and Ferreira do Zêzere, in 1986, and at Arganil, Oliveira do Hospital and Pampilhosa da Serra, in 1987.

The most tragic years in Portugal were 2003 and 2005, as approximately 426.000 ha and 340.000 ha, respectively, were burnt. In 2014, there was a reduction in area, downsizing to 20.000 ha. However, in 2016, after a rainy year, large firebreaks were seen in Portugal due to extreme climate conditions (temperatures hit above 40 °C throughout the country), leading to more than 100.000 ha of burnt area.

The large firebreak in Pedrógão Grande, in 2017, was considered the biggest national tragedy with more than 100 deaths, 440.000 ha of land and villages burnt, corresponding to 4 times more than the average registered 10 years before. In previous years, the area of burnt land (62%) was superior than the area of burnt villages (38%). However, in 2017, there were 266.000 ha of burnt villages (60% of the total) in contrast to 177.000 ha of burnt land (40% of the total). The district of Coimbra was the most affected, with 25% of the total burnt area of Portugal, followed by the Guarda district (14% of the total) and Castelo Branco (12% of the total). It is important to highlight that the sum of the burnt area is made through the analysis of cartographic data produced by the Department of Management of Public Areas and Forest Protection (Departamento de Gestão de Áreas Públicas e de Proteção Florestal), of ICNF, based on the national forest fires database statistics provided by the Forest Information Management System (Sistema de Gestão de Informação de Incêndios Florestais – SGIF).

Within this context, in the last 20 years, Proença-a-Nova, Oleiros, Sertã e Vila de Rei, all belonging to Beira Baixa and part of the inner pinewood area, were under threat, for more than 3 times, due to vast fire outbreaks.

### 3 The Fire at Oleiros in 2017

Oleiros is a municipality that belongs to the Castelo Branco district, located at the Beira Baixa sub-region, comprising an area of 471.09 km<sup>2</sup> and with 5205 inhabitants in 2016, of which 42% of officially registered as residents are adults with 65+ years. This municipality is subdivided in 10 areas: Álvaro, Cambas, Estreito – Villar Barroco, Isna, Madeirã, Mosteiro, Oleiros – Amieira, Orvalho, Sarnadas de São Simão and Sobral. Oleiros has the largest number of residents and also a large urban center, concentrating the administrative and economic activities of the village.

Different from the fire outbreak in Pedrógão Grande, the fires at Sertã, in Castelo Branco district, spreading to 600 ha reaching Orvalho parish, in Oleiro village, was caused by electric discharges. In July 2017, the danger of the propagation of the flames beyond the area already burnt in the parish of Mosteiro was high, leading to the rescue of circa 20 people. In the following month, Cambas saw the outbreak of fires that spread for 20 km and burnt a house. With the strong winds in the end of August, the parishes of Sarnadas de São Simão and Estreito – Vilar Barroco had their inhabitants evacuated and, simultaneously, 8 houses were consumed by the flames in the parish of Orvalho. In October, 15<sup>th</sup>, within few hours there were fires outbreaks in the parishes of Madeirã (at 17:00 h), Sobral (at 19:00 h) and Álvaro (22:00 h), consuming 15.000 ha of forests and 70 houses. In addition, more fires outbreaks were seen at Oleiros during the four following months (Fig. 1).



**Fig. 1.** The natural landscape burnt and the river Zêzere, Álvaro, Oleiros. Source: Architect Mario Saleiro Filho (2018)

## 4 Methodological Steps

The international community, particularly the Portuguese, was devastated by the consequences of the catastrophe caused by the fires outbreaks at Beira Baixa sub-region, which consumed forests, human lives and several houses in the countryside.

The Portuguese intelligentsia, restless in the face of this tragic episode, aimed to reverse the situation by concentrating its efforts to promote a more just world – particularly in regard to its human relations. This people were also aware that they could provide guiding tools capable of objectifying the construction of knowledge for the sake of a more human society – something that conforms to the contextual reason of our reflective concerns as educators in the field of architecture. Considering this and plagiarizing the refrain of the National Anthem of Portugal, we proclaim the motto: “To the arms”!

As a methodological step we assume that architecture is an optimistic action, and that the responsibility of the architect is, above all, to serve the society, uniting and connecting people to the natural world, preserving precious resources, as Steven Ehrlich states [7]. Thus we resort to this theoretical foundation based on the Portuguese practical context.

Portugal had seen in its recent history, after the Revolution of April 1974, the emergence of the Local Support Ambulatory Service (Serviço Ambulatório de Apoio Local – SAAL). This pioneer service had technical brigades coordinated by architects, with the support of the local councils which, together with the deprived population, aimed at improving the housing conditions and the social inclusion of the citizens returning from the former African colonies. The reinvention of the participatory architectural practice – designing with the residents and not for the residents – included

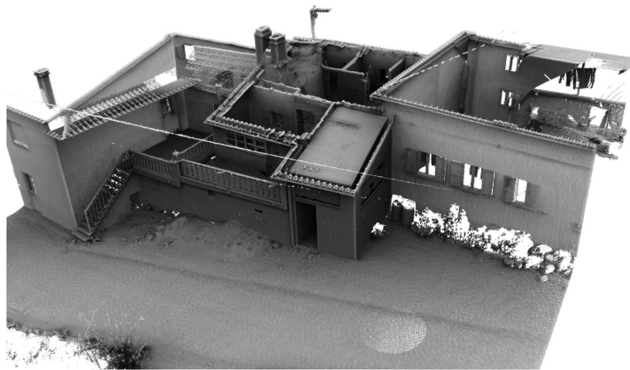
the following steps: from mapping the life conditions to the support to the residents, from the execution of the architectural plans to the monitoring of the land expropriation process. The principal objective was, undoubtedly, to think about collective processes as means for social transformation.

It could be highlighted that not all the processes developed at SAAL were completely successful. It is important to mention, however, that some internationally recognized Portuguese architects worked at the SAAL.

Having as a theoretical-practical foundation this historical and relevant experience, and facing the tragic consequences of the fires, the Faculdade de Arquitetura da Universidade de Lisboa understood that, to reach the best quality within the shortest period of time, the natural path to compose a design team would be via selecting under-graduation students that excelled during their academic course at the Institution.

The team (technical support) was composed of teachers and under-graduation students reconciling, therefore, practical and theoretical aspects of the architectural design discipline and its application in the real world, enhancing the final results. Under this perspective, it could be mentioned that the experience focused more on the fair architectural practice and less on its speculative value.

With the intention of mediate the architectural interventions within a socio-environmental and economic deprived context, a second methodological step was taken, where it was elaborated an innovative design process with an ergonomic approach, which was promptly supported by the Faculty and its various research groups. Our design mission aimed to reconstruct and rehabilitate the municipality of Oleiros following these phases: (I) the elaboration of a diagnostic and the identification of the villages and their houses that needed more technical assistance; (II) mapping of the natural and built affected zones through photographic survey as well as through cartographic maps. It is important to mention that the area of intervention was mapped in the early stages of the design process, which was vital to elaborate the photographic survey and the tridimensional model (Fig. 2).



**Fig. 2.** Mapping of a house – Sobral de Baixo, Oleiros. Source: Faculdade de Arquitetura da Universidade de Lisboa (2018)

These tridimensional models were sectioned using open-source digital programs in order to draw plans, sections and façades. A chromatic scheme was used to identify these drawings, varying from “red” to “blue”. It was determined that “red” would be the section plan and the other colors would symbolize the objects positioned at a distance from the observer, where “blue” would be the most distant (Fig. 3).



**Fig. 3.** The Chromatic Scheme – from “dark gray” (section plan) to “light gray” (most distant). Source: Architect Luís Ginja (2018)

With this method it was possible to draw the plans in computer aided systems, such as AutoCAD, as well as to rapidly sketch in conventional ways, proposing the interventions in the damaged buildings. This process also made possible the construction of tridimensional models of the area of intervention that became a recurrent tool to help the designing team to clarify some aspects not easily revealed by the photographs; (III) *in loco* surveys with the residents, with the support from the municipality representatives, were aimed to better understand the social reality, using mediation techniques where the interviewer and the interviewee change roles, and to give support for the organization and optimization of the housing spaces that would be rehabilitated by the design team; (IV) the elaboration of the digital executive design proposal in AutoCAD with plans, sections, façades, technical constructive details, in accordance with what was requested by the residents registered in the surveys, as well as a quote of the costs.

## 5 Villages, Houses, Typologies and Materials

Of the ten villages of Oleiros municipality, it was selected 5 with 14 propositions: 10 houses in Álvaro, 2 houses at Sobral de Cima and Sobral de Baixo and 2 other houses in Vilar Cimeiro na Madeirã. It is important to mention that all these houses were designed for a single family. Due to the fires, all these houses were without roofs, with their interiors destroyed and their façades in ruins.

**Álvaro.** Álvaro is part of the Shale Villages Program (Programa Aldeias do Xisto) since 2001. As it was a sustainable growth program and with cultural heritage characteristics, encompasses hotel, gastronomy, crafts, culture and radical sports services amongst others. The parish is located on a hill with cliffs facing the Zêzere river, and the settlement has a central street with particular attributes.

Of the 10 residences of this parish that were rehabilitated, 5 were located at the parish of Álvaro (4 were in the central axis of the settlement and 1 in the woods), and the other 5 distributed as follows: Gasparha (1), Longra (2), Horta Velha (1) and Val Vascos (1).



The 4 townhouses at the parish of Álvaro have similar typological characteristics as a consequence of the urban morphology of the site. All the façades of the two-story houses are facing the central street and are coated with white paint. The rear elevations are made of shale, indicating the tectonic and the name of the parish, and morphologically the houses were built following the slope of the hill. Of the other 6 houses of this parish, 4 were shale-shaped and 2 were coated in white paint.

**Sobral.** The parish of Sobral is composed of 14 settlements. Our interventions were concentrated in the areas known as Sobral de Baixo, on the hills close to the Zêzere river. The 2 houses are located in different, although nearby, sites: The first house is located within a more dense urban morphology, with its main street and several secondary lanes with shops; the other is located within a small nucleus comprising 8 houses at the south end of the main street. Both two-story townhouses have similar typological characteristics within their urban contexts, with façades and internal walls coated in white paint. One of the houses has its rear elevation covered with shale.

**Madeirã.** Madeirã is a parish with 15 settlements. Our interventions were proposed for the town of Vilar Cimeiro. They are 2 houses located equidistant from the middle of Madeirã main nucleus and the forest hills close to the Zêzere river. Both houses have annexes and the main difference between them is their size, one is more minimalist and the other is “solarenga” (i.e. refined, noble). The smaller house has one annex with walls covered with shale where the other annexes the walls are coated with white paint. The larger house, there is a veranda with views towards the landscape and an annex, all with walls coated in white paint.

## 6 Results and Conclusion

The idea of using a participative process, based on the SAAL experience of the 1970s, and translate it to contemporary times, establishing a network between students and teachers of the Faculdade de Arquitetura da Universidade de Lisboa, the municipalities’ representatives and the residents of specific sites was certainly a very enriching experience. It combined practical and theoretical aspects of the architectural design discipline and its application in the real world, enhancing the final results. In this sense, the methodological steps adopted were adequate to give a better idea of how to intervene in socio-environmental and economic deprived contexts.

Within the scope of this research, we aimed to understand, through a concise and systematized form, the potential of the natural and architectural heritage, indicating new forms to perceive the architectural education as well as the preservation of the built environment through the lens of environmental quality and family profiles.

It is important to point out that our approach to the population affected by the fires occurred systematically, interacting with the families, in a mixed situation where emotion and reason came to the surface, and where the act of listening and interpretation were balanced with concerns of financial restraints and the dimension of the fires.

In general, our main concern in regard to the architectural interventions in the rehabilitation of the houses was that they must be done quickly, in order to attend the family groups needs, following the diagnostics and presenting the solutions such as: (a) the spatial organization were reviewed because the former residential spaces were undersized, according to the current building standards; it was decided to elaborate more flexible plans, optimizing the space and the original use of the rooms (whenever possible) in the most cases; (b) It was observed that many of the *façades* in ruins were different from the original design [considering the shale villages] and its surroundings. It was proposed to recover the material of the volumetric typologies that faced the urban nucleus, so to make them more authentic, reversing the interpretation of “what is traditional in some situations is old fashioned”, contributing to safeguard the local culture.

It must be mentioned that in historic sites, particularly in villages and settlements, there is a close relationship between inhabitants, buildings and public spaces. Thus, with this innovative ergonomic process, it was intended to unite them even more, rewarding them with the preservation of their identity.

## References

1. Pereira, F.C.R., Carreiras, J.M.B., Silva, J.M.N., Vasconcelos, M.J.: Alguns Conceitos Básicos sobre Fogos Rurais em Portugal. In: Pereira, J.S., Pereira, J.M.C., Rego, F.C., Silva, João M.N.S., Silva, T.S. (eds.), *Incendios florestais em Portugal: caracterização, impactes e prevenção*, pp. 133–161. Instituto Superior de Agronomia, Lisboa (2006)
2. Martins, F.M.: *O Esforço do Homem na Bacia do Mondego*. Undergraduate thesis. Universidade de Coimbra (1940)
3. Silva, F.M.P., Batalha, C.: *Memória sobre o Pinhal Nacional de Leiria: Suas Madeiras e seus Produtos Rezinosos*. In: *Annaes Marítimos e Coloniaes Associação Marítima e Colonial*. Imprensa Nacional, Lisboa (1843). <http://mgrande.net/mg/histria/0-pinhal-nacional-de-leiria/>
4. Navarro, E.: *Quatro Dias na Serra da Estrela: Notas de um Passeio*. Livraria Civilização de E. da Costa Santos, Porto (1884)
5. *Proposta Técnica para o Plano Nacional de Defesa da Floresta contra Incêndios*, Instituto Superior de Agronomia para a Agência para a Prevenção de Incêndios Florestais (2005). PDF Edition
6. Lourenço, L.: Tipos de Tempo correspondentes aos Grandes Incêndios Florestais Ocorridos em 1986 no Centro de Portugal. *Finisterra* **XXIII**(46), 251–270 (1988)
7. Wing, S.: A Chat with Steven Ehrlich. Website Metropolis. <https://www.metropolismag.com/uncategorized/a-chat-with-steven-ehrllich>



# Lighting Design at Workplaces: What Should Be the Concerns for an Architect?

Sandra Preto<sup>(✉)</sup>

Faculty of Architecture, University of Lisbon, Lisbon, Portugal  
sandrapreto@hotmail.com

**Abstract.** The main goal of this article is to clarify and demonstrate that non-visual system should be taken into account at workplaces (offices) by architects, engineers and designers. Factors such as biophilia, the non-visual system, differences between natural and artificial light and illuminance, among others, should be important parameters when conceiving an indoor space especially a workplace environment. Health and wellbeing are much more than a layout or an image. Which questions should be questioned when conceiving a workplace and keep balance between the visual and non-visual systems? That is a question that should have an answer based on several factors, not just the ones concerned with the corporate image and preferences of the professionals in charge of the designing of workplace spaces. To achieve such goals, the research is conducted throughout a literature review and the analysis of two case studies: Camilo Castelo Branco Street and 24th July Avenue, both in Lisbon, Portugal. Lighting Design deserves much more attention.

**Keywords:** Lighting Design · Biophilia · Non-visual system · Natural and artificial light · Illuminance · Workplaces

## 1 Introduction

When conceiving an indoor environment, such as a workplace, there are many factors that are repeatedly ignored, such as biophilia, the non-visual system, the differences between natural and artificial light, illuminance levels needed at workplaces and the geographic location and many other characteristics. So, the literature review is going to clarify their importance. In order, to understand how these parameters are important two case studies are going to be analysed and discussed. The case studies are the buildings located in Camilo Castelo Branco Street and in 24th July (east and west buildings), in Lisbon. Information about the sun exposure in the city of Lisbon throughout the year, gathered in both case studies and their analysis will be presented. (This article is part of author's PhD thesis).

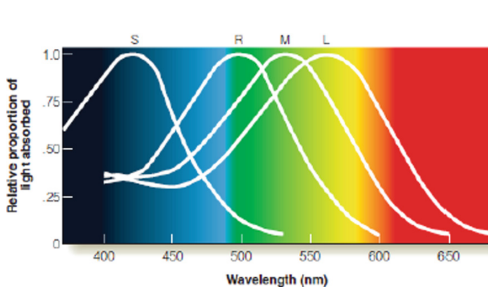
## 2 Literature Review

### 2.1 Biophilia

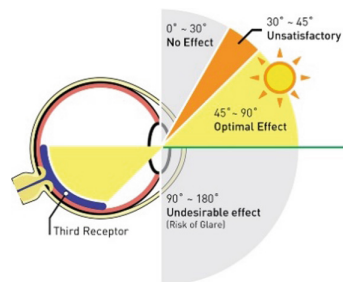
Natural environments, including gardens or landscapes, make human beings feel better and healthier, so, not surprisingly; the definition of biophilia is about the connection between nature and humans. Unfortunately, in the XX and XXI (so far) centuries, humans were, and continue being, apart from nature, and humans' wellbeing, especially, psychophysiological is at risk. In a city, for example, humans do not feel so healthy and happy, due to its artificiality. So, elements of nature should not be taken away from our lives [1, 2]. At workplaces, such as offices, we should have a view to a green (garden) or blue (sea or river) landscape, sadly, this is not always achievable [3]. Natural views decreases our stress level, and some urban scenes can also have a positive influence, eventhough it happens more slowly [1].

### 2.2 Non-visual System

Light influence our visual and non-visual (circadian system) systems [4, 5]. Humans have a light/dark cycle that occurs accordingly to the daily variations of light, which promote melatonin (darkness hormone), serotonin (mood hormone) and cortisol (stress hormone) production as well as sleeping-waking systems [6]. Human beings need light in the morning and darkness in the evening to balance circadian cycles. The same is to say, that humans need blue light spectrum during the day (not at any time and continuously) to improve concentration and alertness levels, but in the end of the day (late afternoon) it should be avoided because it may disrupt our circadian rhythm. Another important factor is the human retina, since is through the eye that light influence our visual and non-visual system. The retina has cones and rods (visual photoreceptors) which have different spectral sensitivities, whereas the rods efficiency has a peak of sensitivity at 505 nm, while the cone's peak sensitivity happens at 555 nm. However, there are also the non-visual (the so-called third photoreceptor, ipRGCs - intrinsically photopigment retinal ganglion cells) (Fig. 1).



**Fig. 1.** Spectral absorption of cones and rods (R). And cones at Long - (L), Medium - (M) and Short - (S) wavelengths. (adapted from Dartnall, Bowmaker & Mollon, 1983) [7]



**Fig. 2.** Biological effect of light on the human eye: The activating effect of light depends on the correct angle of incidence of the light at the eye [8].

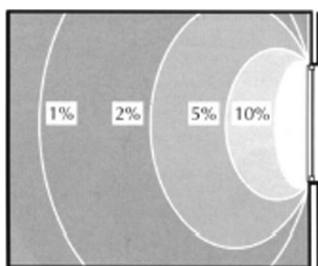
The non-visual (biological) effects of light are mediated by ipRGCs that contains the photopigment melanopsin, which is more sensitive to short-wavelength light at 480 nm (blue wavelengths). The sensibility of ipRGCs varies in the intensity, duration/pattern, and timing of light exposure. Moreover, the blue-light exposure is more effective at enhancing alertness and performance [9]. Nevertheless, the biological effect of light at the eye also depends on the correct angle of incidence [10] (Fig. 2).

### 2.3 Natural Versus Artificial Light

Natural and artificial light are very distinct, and the major difference is the dynamics in its intensity level (illuminance) and light spectrum. Daylight has a positive influence on human mood, however in indoor spaces the artificial lighting systems cannot have the same variation throughout the day. This dynamism depends on geographical location, particularly, latitude and altitude, as well as seasons. Light exposure, for instance, might be more effective in improving our alertness in the morning after awakening while in the evening exposure to light should be avoided. Moreover, questions of gender, chronotypes and age can also be affected by light differently, and that is why it is so difficult to conceive an environment, since we are all different [11, 12].

### 2.4 Illuminance

The difference between natural and artificial light is very significant, especially in its illuminance level, since natural light can reach 100.000 lx, with direct sunlight and 10.000 lx in an overcast day [13, 14]. However, when we think about non-visual stimulation we must know that different illuminances have dissimilar impacts and that 2.000 lx is the illuminance recommended for activating the circadian system [7, 15, 16]. During working days, since we reduce significantly our mental resources, which also decreases our alertness, increases psychological stress, and thus there is decrease in productivity. Higher illuminance levels, for instance can counteract our tiredness and help us to recover from it [15, 17]. Furthermore, the pupil dimension, the thickness of the lens, the increasing sensitivity to glare due to ageing, so we need higher illuminance levels [18, 19]. Illuminance levels are higher when windows are close to the working area and decreases as the distance increases (Fig. 3) [20]. Weather conditions, geographic location, season, time of day, and spatial location, and particularly the position and dimension of the windows, interior spaces can influence and result in a lack of light



**Fig. 3.** As the distance from window increases, the illuminance (natural light) decreases [21].

due to a lower illuminance level; this fact can be minimised by the support of artificial light [22]. Seasonal Affective Disorder (SAD) symptoms, for instance, are relieved with high levels of illuminance (artificial light when the daylight is insufficient).

## 2.5 Workplace

Humans non-visual system needs are often neglected at workplaces environments, and lighting design is, most of the times, based on aesthetic parameters and on corporate image. Only 20% of the offices have illuminances over 1.000 lx at the eye, which is considered biological darkness. The solution is a lighting system that combines general and local lighting in order to increase users/workers' wellbeing [19, 22]. To achieve a healthy lighting design layout, light direction should be considered vertical and horizontal light, and it is essential to reduce horizontal illuminance levels [14].

## 2.6 Lisbon

It is essential to analyse natural, and artificial, light regarding its geographical location, sun's position, the number of daily hours with sunlight, weather and built environment surrounding. Lisbon, according to the sun's path in the summer (21st June), the sun rises from the ENE, east-northeast, (azimuth  $60^\circ$ ) at 06.12 a.m. and the sunset happens at 09.05 p.m., when the sun is in the WNW, west-northwest (azimuth  $300^\circ$ ). During the winter (21st December), the sun rises from the ESE, east-southeast, at 07:51 a.m. (azimuth  $120^\circ$ ) and the sunset occurs from the WSW, west-southwest, at 5.18 p.m. (azimuth  $240^\circ$ ). So, in the summer there are about 15 h and in the winter there are 9 h of sun exposure (Fig. 4) [23].

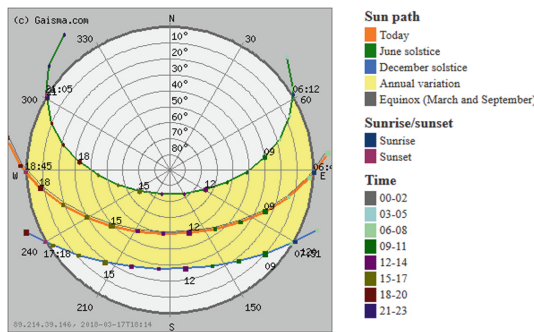
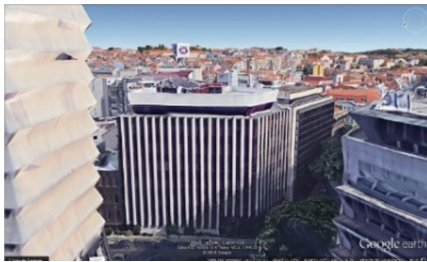


Fig. 4. Solar path diagram (Lisbon) [23].

## 3 Case Studies

### 3.1 Camilo Castelo Branco Street, 4th Floor, Lisbon

The first case study is the office building (Fig. 5) situated between the Camilo Castelo Branco Street and Actor Tasso Street in Lisbon, and part of the main façade is at Actor Tasso Street and has no obstacles and has a view to Eduardo VII Park (Fig. 6). From now on Camilo Castelo Branco building is referred as CCB.

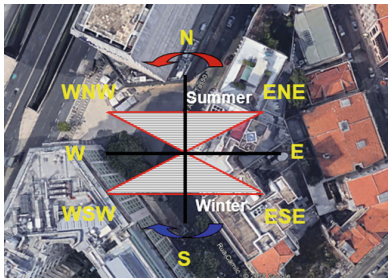


**Fig. 5.** View of the CCB (Actor Tasso Street) [24].



**Fig. 6.** Aerial view of the CCB to Eduardo VII Park [24].

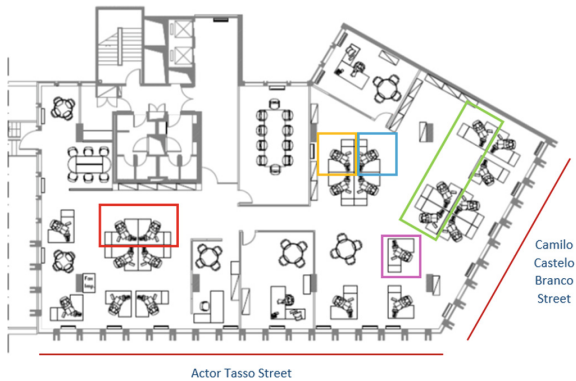
Regarding solar path diagram, as we can see (Fig. 7) the main façade is oriented to WSW and the façade facing Eduardo VII Park for WNW. In the winter, sun moves from ESE to WSW, the CCB façade is more fortunate with sunlight, whereas in the summer, when moving from ENE to WNW, the façade at Actor Tasso Street is the most privileged.



**Fig. 7.** Solar exposition of CCB. [adapted from 24]



**Fig. 8.** CCB façades. [adapted from 24]



**Fig. 9.** CCB, openspace on the 4th floor. (layout was ceded and adapted) [Author]



In the summer, the sun's rays of  $74^\circ$ , makes the light more oblique on the façades during the afternoon. While, in the winter, ray's of  $38^\circ$  are a little complicated to take advantage of, because there are other buildings nearby (Fig. 8).

The spatial layout is based on open space, meeting rooms and individual offices. As for the distance from the workstations to the windows, as can be seen in the spatial layout (Fig. 9) the workstations in red are over 6.80 m (from Tasso Street Actor), in orange distance is over 11.10 m (CCB), in blue distance is 9.60 m, in green is 4.50 m and finally, in rose the distance is over than 5.50 m from Actor Tasso Street.

As for illuminances, the measurements were carried out with a lux meter with a detachable sensor approved by PQI (Portuguese Quality Institute). Measurements were made on 22nd January 2018, at 10:00 a.m. and at 4:30 p.m. The illuminances were measured in the workstations closest to and far from the windows. In blue (rectangles) are the measurements under the luminaires/lamps and in red (rectangles) without luminaires/lamps above. In the morning, the highest illuminances did not happen on the east side as expected, and during the afternoon, the illuminances decreased, even with luminaires/lamps above. It was not possible to carried out the measurements in the summer (Fig. 10).



**Fig. 10.** Illuminances at workstations, CCB building, on the 4th floor. Illuminances at 10.30 a. m. (dark blue text) and at 4 p.m. (red text). (layout was ceded and adapted) [Author]

The artificial lighting in the building is recessed, direct, and the luminaires have aluminum reflectors with two fluorescent lamps, type TL5 HE 25 W/840, which means that it has a color temperature of 4.000 K (cold), with an IRC of 85 (the maximum is 100) and has an electronic ballast (less flicker). The luminaires are located in suspended ceiling based on rectangles with 0.30 m by 1 m, placed parallel to the Actor Tasso Street. Between each line of luminaires there are 6/7 acoustic metal ceiling tiles. One of the lines of luminaires is located (in the room parallel to the Actor Tasso Street) very close to the window, only 3 metal tiles away from the windows. There are not task lights. The angle of the luminaires, relative to the eye, lies in the  $0^\circ$ – $30^\circ$  and  $30^\circ$ – $45^\circ$ . As for the vertical blinds, these are in PVC (Polyvinyl chloride) in white stripes.



The materials, colours and finishes of the surfaces are relevant, since the comfort of the non-visual system depends on the visual system, the same is to say that the finish should be matt in order to do not produce glare and provoke eyestrain. The desks and furniture are white, there are frontal screens in wood on the desks, the chairs are black, the floor is grey, the walls and ceilings are white.

### 3.2 24<sup>th</sup> July Avenue, 3<sup>rd</sup> Floor, East and West Buildings, Lisbon

The two buildings are united by a central body are situated between 24th July Avenue and D. Luis I Street, the one on the right is going to be referred as west building and the one on the left east building (Fig. 11). On the waterfront (Fig. 12), is the Tagus River and its natural landscape where blue predominates, there are no buildings obstructing the view or the natural light. In the rear façade, the built environment is not very height (Fig. 12).

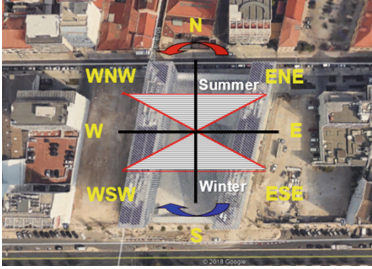


**Fig. 11.** Main façade (east building on the right) [24].



**Fig. 12.** Rear façade and waterfront [24].

Regarding the solar path diagram, as it can be seen in the Fig. 11, the main façade is facing south. However, the façades where the workstations are located are oriented to east and west. Both, in summer and in the winter, the building has more sunlight during the morning on the east façades and during the afternoon on the west façades. In the winter, the sun moves from ESE to WSW. While in the summer, moves from ENE to WNW which has more northern light, which is the most constant throughout the year (Fig. 13). Moreover, the waterfront façade (south) can take more advantage of sunlight, not only because it is facing south but also since it has no obstructions, just the Tagus River.

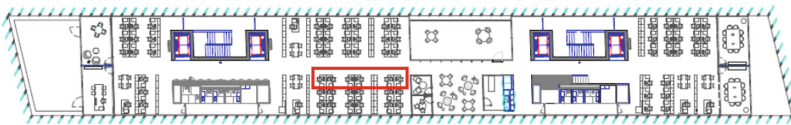


**Fig. 13.** Solar exposition of 24th July Avenue building. [adapted from 24]



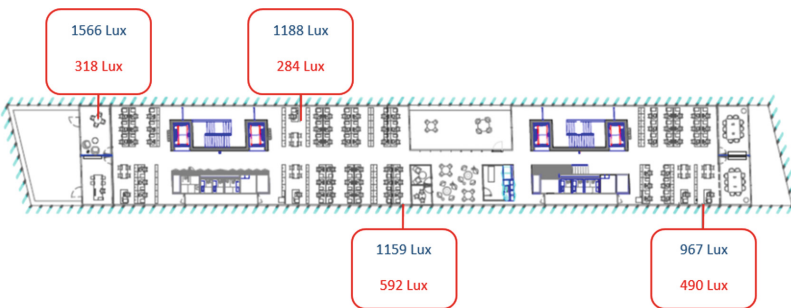
**Fig. 14.** Aerial view of 24th July Avenue building from east façade. [adapted from 24]

In the summer, the sun's rays of  $74^\circ$ , makes the light parallel (from ENE to WNW (Fig. 13) to D. Luís I Street (rear façade). While, in the winter, ray's of  $38^\circ$  has the same effect but in the main façade (south, from ESE to WSW) (Figs. 13 and 14).



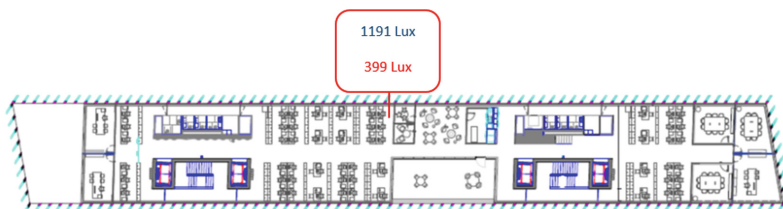
**Fig. 15.** Spatial layout openspace on the 3rd floor, east, at 24th July Avenue. (layout was ceded and adapted) [Author]

The spatial layout is based on open space, meeting rooms (Fig. 15), indoor and outdoor lounges, where workers can work and/or rest. As for the distance from the workstations to the windows, marked in red (Fig. 15), is greater than 4.66 m.



**Fig. 16.** Illuminances nearby the workstations, on the 3rd floor, east building (on the left is 24th July Avenue). Illuminances at 11.30 a.m. (dark blue text) and at 6 p.m. (red text). (layout was ceded and adapted) [Author]

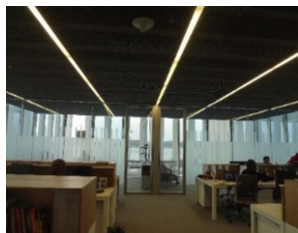
The illuminances's measurement were carried out with a lux meter with a detachable sensor approved by PQI (PQI) on 25th January 2018 at 10:30 p.m. and at 5:00 p.m. at 24th July Avenue. The illuminances were measured in the workstations next to the windows (Figs. 16 and 17). In the morning, the highest illuminances were measured on the east side as expected, and in the afternoon decreased greatly. Unfortunately, it was not possible to carried out the measurements in the summer.



**Fig. 17.** Illuminances nearby the workstations, on the 3rd floor, west building (on the left is 24th July Avenue). Illuminances at 11.30 a.m. (dark blue text) and at 6 p.m. (red text). (layout was ceded and adapted) [Author]

The artificial lighting in the building is recessed, semi-direct (due to frosted glass), and the lamps are fluorescent and compact fluorescent lamps, and has an electronic ballast (less flicker). The luminaires are arranged in five longitudinal strips, parallel to the length of the buildings (Fig. 18). Note that one of the luminaries is central and that the others appear to be equidistant, however, the last two (east and west sides) are very close to the windows (Fig. 19). There are not task lights. The angle of incidence of the luminaires, relative to the eye, is lateral. There is also the possibility of working outdoors (Fig. 20).

The roller blinds are in textile material and opens/closes automatically (DALI system) when the exterior illuminance is over 20.000 lx (Figs. 18 and 19).



**Fig. 18.** Distribution of luminaires (ceiling) [Author].



**Fig. 19.** Luminaires next to windows and roller blinds [Author].



**Fig. 20.** Outdoor on the 3rd floor. (west building) [25].

The colours and finishings of surfaces, such as desks and cabinets are matt white, and there are frontal screens in wood. The colour of the chairs are grey, red and green. The floor is grey, the walls are white and grey (concrete). The suspended ceiling is grey, but the real ceiling is painted in black, so the ceiling looks black.

## 4 Comparison Between the Case Studies

See Table 1.

**Table 1.** Comparison between the case studies. [Author]

Parameters	Camilo Castelo Branco Street	24 <sup>th</sup> July Avenue
Main Façade/Rear Façade	WSW/WNW	Sul/North
Distances from the windows	Yes. 11.10 m, 9.60 m, 6.80 m, 5.50 m and 4.50 m	Yes. 4.66 m
Windows (height)	From 0.70 m (height) to the suspended ceiling	From floor to the suspended ceiling
Illuminances near windows (morning)	156 lx, 793 lx, 931 lx, and 1000 lx	1566 lx, 1188 lx, 967 lx, 1159 lx and 1191 lx
Illuminances distant from the windows (morning)	600 lx, 519 lx e 600 lx	–
Illuminances near windows (afternoon)	649 lx, 349 lx, 696 lx and 618 lx	318 lx, 284 lx, 490 lx, 592 lx and 399 lx.
Illuminances distant from the windows (afternoon)	500 lx, 483 lx and 500 lx	–
Artificial lighting	Direct, recessed, fluorescent, aluminium reflectors, 4.000 K (cold), IRC 85, suspended ceiling rectangles: 0.30 m (width) by 1 m (length)	Semi-direct, recessed, fluorescent, frosted glass. No data (colour temperature, IRC and dimensions)
Distance between luminaires/lamps	6/7 acoustic metal tiles	East: 11.2 m, 25.8 m, 18.8 m, 18.8, 22.4 m and 14.1 m. West: 16 m, 20.8 m, 20.8 m, 22.1 m, 22.1 m and 12.9 m
Angle of incidence of the light at the eye	0°–30° and 30°–45°	Lateral
Colours and finishings of desks/chairs	White desks, frontal screens in wood/black	White desks, frontal screens in wood/grey, red and green
Colours and finishings of floor/walls/ceiling	Grey/white/white	Grey/white and grey/black

## 5 Conclusions

In both buildings, the distances of workstations are very far from the windows, for example in the building located in CCB there are distances greater than 11 m. Regarding the presence of nature views through windows, in both case studies there are natural views, the building in the CCB has views to Eduardo VII Park and the building on 24th July Avenue overlooks the Tagus River. Regarding illuminances, both have less than the 2.000 lx, which are required for the non-visual system. The lighting design is not concerned with the human needs, since fluorescent is appropriated to the visual system and has no effect on the non-visual system. The correct angle of incidence of the light at the eye should be between 45° and 90° to activate the ipRGCs, and either of the case studies has it. The distance between the luminaires ignores the workstation's positioning on the open space, and it is clear, especially in the building on 24th July Avenue, that the most important factor is aesthetics. As for the furniture, desks are white and have wooden frontal screens, which give a more noble appearance than the neutral of the grey floor, and white walls. In the building on 24th July Avenue, the coloured chairs are a good choice, but the black ceiling is not the best option. Nonetheless neither considers the non-visual needs of the workers.

## 6 Discussion

Lighting Design is much more than a layout or a corporate image, and is conceived by architects most of the times, and that is why the article's title begins with Lighting Design and ends with Architecture. However, both (sometimes) are unaware of the impact of light on the non-visual system in humans. The main goal of this article is to give some clues and is an attempt to awaken the curiosity of architects, designers and engineers on the non-visual system in humans.

Biophilia, for instance, is a good influence both in the mind (psychologically) and body (biological and physiologically), as stated, since the mind influences the body and vice-versa.

The non-visual system (circadian rhythm) is influenced by light and this should be used in a positive way. The lighting system is not irrelevant, due to its spectrum, for example, fluorescent light is, normally, in the green (a good option for the visual system) and yellow spectrums, whereas the LEDs are blue light (spectrum). Blue light has two sides, just like a coin, it could be good since it makes us more alert, focused, less prone to SAD, on the other side (of the coin) it can be harmful for our eyes (blue light hazard).

As for illuminance, more than 2.000 lx is biologically effective, less than that is considered as biological darkness. However, it should be carefully used, because too much illuminance at night, or late afternoon might unbalance our circadian rhythm.

Angle of incidence of the light at the eye is another crucial factor since the lateral light or right above our heads are not the best choices, as already stated (Fig. 2).

Geographic location, sun's position, seasons, the number of daily hours with sunlight, weather conditions, time of the day (morning, afternoon and evening) and built environment (surrounding) should not be disregarded.

Distance from the windows, especially when natural light is not enough for the non-visual system (2.000 lx) should be compensated with artificial light.

Surfaces and furniture colours and finishings, are also important, since glare and shadows are not welcome in our visual field.

Moreover, cultural and social background, individual preferences, pathologies, age and the tasks performed are all factors that should be considered when designing a workplace. Although, this article did not analysed all these issues.

In sum, Lighting Design is much more important than it seems.

## References

1. Uslaner, J.M., et al.: Orexin receptor antagonists differ from standard sleep drugs by promoting sleep at doses that do not disrupt cognition. *Sci. Transl. Med.* **5**(179), 179ra44 (2013)
2. Phillips: Physiological Effects of Light: How Light Regulates Sleep, Mood and Energy. [http://www.newscenter.philips.com/pwc\\_nc/main/standard/resources/corporate/press/2009/winter\\_blues/Blue\\_light\\_white\\_paper\\_Europe\\_Final.pdf](http://www.newscenter.philips.com/pwc_nc/main/standard/resources/corporate/press/2009/winter_blues/Blue_light_white_paper_Europe_Final.pdf)
3. Essilor: Blue Light Hazard: New Knowledge, New Approaches to Maintaining Ocular
4. van Bommel, W.J.M., van den Beld, G.J.: Lighting for work - a review of visual and biological effects. *Light. Res. Technol.* **36**(4), 255–269 (2004)
5. Ámundadóttir, M.L., et al.: Modeling non-visual responses to light: unifying spectral sensitivity and temporal characteristics in a single model structure. In: Proceedings of the CIE Centenary Conference “Towards a New Century of Light”, Paris, France, pp. 101–110 (2013)
6. Wright, K., Gronfier, C., Duffy, J., Czeisler, C.: Intrinsic period and light intensity determine the phase relationship between melatonin and sleep in humans. *J. Biol. Rhythm* **20**(2), 168–177 (2005)
7. Goldstein, E.B.: Sensation and Perception, 1st edn./8th edn. Wadsworth, Cengage Learning (2000/2007). ISBN 10 0-495-60149-7
8. Eagle Lighting Australia: Introducing Tunable White. <https://www.eaglelighting.com.au/news/news/tunable-white-1224>
9. Lockley, S.-W., et al.: Short-wavelength sensitivity for the direct effects of light on alertness, vigilance, and the waking electroencephalogram in humans. *Sleep* **29**(2), 161–168 (2006)
10. Chen, E.: Seeing Blue. <http://www.darksky.org/assets/documents/SeeingBlue.pdf>
11. Cajochen, C., et al.: Dose-response Relationship for Light Intensity and Ocular and Electroencephalographic Correlates of Human Alertness. [http://www.chronobiology.ch/wp-content/uploads/publications/2000\\_12.pdf](http://www.chronobiology.ch/wp-content/uploads/publications/2000_12.pdf)
12. Smolders, K.C.H.J., de Kort, Y.A.W.: Bright light effects on mental fatigue. *J. Environ. Psychol.* **39**, 77–91 (2014)
13. Rensselaer Polytechnic Institute: Human Eye Sensitivity and Photometric Quantities. <http://www.ecse.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/Sample-Chapter.pdf>
14. de Kort, Y.A.W.: Light and Quality of Life. [https://www.researchgate.net/publication/235675807\\_Light\\_and\\_Quality\\_of\\_Life](https://www.researchgate.net/publication/235675807_Light_and_Quality_of_Life)
15. Aries, M.: Human Lighting Demands - Healthy Lighting in an Office Environment. <http://alexandria.tue.nl/extra2/200512454.pdf>
16. Boyce, P.: The impact of light in buildings on human health. In: SHB2009—2nd International Conference on Sustainable Healthy Buildings, Seoul (2009)

17. Walerczyk, S.: Task Ambient Lighting Focus on DOE & California's New Title 24 with Tunable Task Lights. <http://lightingwizards.com/wp-content/uploads/2014/03/TASKAMBIENT-LIGHTING-fn.pdf>
18. Figueiró, M.: 24-Hr Lighting Scheme for Older Adult. <http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab092627.pdf>
19. Sleprojects.com: Smart Lighting Engineering – Human Centric Lighting. <http://www.sleprects.com/data/files/HUMAN%20CENTRIC%20LIGHTING%20%28english%29.pdf>
20. Newsham, G.R., et al.: Lighting Design for Open-Plan Offices. [https://www.nrc-cnrc.gc.ca/ctu-sc/files/doc/ctu-sc/ctu-n62\\_eng.pdf](https://www.nrc-cnrc.gc.ca/ctu-sc/files/doc/ctu-sc/ctu-n62_eng.pdf)
21. Tralau, B.: Human Centric Lighting. [http://www.ibe-biv.be/media/pdf/Studiedag\\_2014/06\\_Tralau.pdf](http://www.ibe-biv.be/media/pdf/Studiedag_2014/06_Tralau.pdf)
22. Terman, M., Schlager, D., Fairhurst, S., Perlman, B.: Dawn and dusk simulation as a therapeutic intervention. *Biol. Psychiatry* **25**, 960–970 (1989)
23. Gaisma.com. <https://www.gaisma.com/en/location/lisbon.html>
24. Google Earth
25. Archdaily.com. <https://www.archdaily.com.br/br/785804/edp-headquarters-aires-mateus>





# Design for the Model of Shared Office Space Based on the Logic of Behavior: A Case Study of Chinese Users

Zhang Ping<sup>(✉)</sup>, Yang Simeng, Liu Tingyu, and Zhang Liang

HeFei University of Technology, Hefei, Anhui, China  
zhangpl63@163.com

**Abstract.** Shared office space is on the rise in China, and at the same time, it is facing the challenge of improving service capacities. The traditional researches are mainly based on the logic of things in space, which emphasizes the rational configuration of the properties of “things”. This paper put forward a design model of Shared office space based on users’ logic of behavior. In the end, this paper got the types and demands of users and the characteristics of the behavior in sharing office space through analysis. Determined the requirements of which equipment would be used in Shared office space; Got the user’s logic of behavior and carried on the space plan of the equipment; Digital human model and equipment model were built and simulated. The simulation results of Shared office space design were evaluated comprehensively and the conclusion was drawn.

**Keywords:** Logic of behavior · Human factors · Environmental psychology · Human-machine interaction · Human-machine ergonomics · Simulation · The scenario theory

## 1 Introduction

Shared office space is also called joint office space: different companies, organizations or individuals share office environment in specially planned and designed office space. They complete projects independently from each other, and share information, knowledge, ideas and skills with other teams to integrate resources needed for work. However, the existing co-working space in China can be divided into three modes: Shared office space based on office behaviors, incubator providing entrepreneurial support and mass innovation space combining the former two functions together. This paper focused on the design model of Shared office space that provides workstations and limited services [1] (office infrastructure, network water and electricity, catering, etc.) for the settled teams and individuals.

In the traditional sense, design is understood as the design of objects. However, in the actual space, a series of interactive behaviors will be generated between users and objects. Therefore, interactive design is different from traditional design. Its core lies in the creation of “behaviors”, while objects are only the tools to realize behaviors. In view of these, Professor Xin Xiangyang put forward the difference between “logic of



things” and “logic of behavior”: one is to emphasize the reasonable configuration of the function of things, the other is to emphasize the reasonable organization of human behavior [2]. Since users would form specific behavior habits and operation modes in the process of learning and using products, while interactive products contain the task flows preset by designers. So, when the user behavior matching the product behavior, the gap between users and products could eliminate [3]. And the logic of behavior was the thinking method balanced designer default behavior and user behavior. It focused on user behavior, provided a different method in traditional way of thinking, changed the designer’s focus and rich the design concept.

Upon these, the traditional research on Shared office space mainly focused on the logic of physical in space, that is, the reasonable configuration of the property of “thing”. Starting from the logic of users’ behavior, this paper integrated the actions of “people” and “people”, the tools and media used and the scene elements [2], and proposes the design model of Shared office space through the process of people’s behavior and the way of interaction with space equipment.

## 2 Analysis of User Behaviors

### 2.1 Research on User Type

Shared office is an office mode with a fixed customer group, which has a specific occupation and age distribution (20–39 years old). The main users of Shared office space are innovative entrepreneurial teams or independent individuals, mainly include practitioners engaged in architecture, IT, design, music, art, literature and entertainment industries. These industries tend to have higher requirements for creative thinking in work, and tend to choose an open and flexible working environment, so as to enhance the possibility of communication and cooperation between peers or Cross-industry person.

Human behavior includes a series of actions, reactions and activities to meet their own needs. And the generation of behavior originated from the instinctive demand, the demand is the fundamental reason that causes motivation and then leads to the generation of behavior. In a specific natural and social environment, people will have different needs, so human behavior is always to achieve a certain need of the conscious or unconscious action. According to the results of the survey, the main customers of sharing office could be divided into four categories: entrepreneurs, cultural creative workers, Internet/IT workers and other freelancers [4]. Since different occupational characteristics of different groups led to different needs for space, so the office requirements of these four users were different, shown in Table 1.

**Table 1.** User types and requirements.

User type	The office needs
Entrepreneur	Gather resources
	Reach cooperation
	Exchange opinions
Cultural creative worker	Private office
	Exhibit
Internet/IT worker	Information equipment
	Flowing space
Other freelancer	Focused at work
	Improve facility
	Exchange from each other

## 2.2 Chinese User Behavior Orientation

Because cultural values will produce certain social norms, then ultimately affect the way people consumed. Therefore, the unique cultural background of China, such as practical rationality, the doctrine of the mean, the face image, the interpersonal relationship, the authority conformity, the philosophy of life, self-consciousness and interpersonal relationship, influence the values and purchase tendency of Chinese consumers [5].

According to the survey, Chinese users had the following characteristics in terms of consumption:

1. Face orientation: people often like to gain face when buying. They hoped to highlight personal status, economic strength and noble consumption taste.
2. Practical rationality: they pay attention to cost performance, like “shop around”, and preferred to pursue products with more functions.
3. Authority conformity: they tend to follow the consumption choices of the social mainstream and imitate the consumption patterns of people around.

Therefore, in the Chinese market, the design of Shared office space should provide more functional configuration as far as possible, and the placement of objects in the space should also be easy to find. Simple and mobile path, make people can find the location of the facilities they need on the flow line of the crowd.

## 2.3 User Motivation

Human needs are the basis and internal driving force for the behaviors, which will lead to the formation of motives and guide the generation of behaviors. While motives are the internal forces and psychological thoughts generated by behaviors to meet specific needs. According to behavioral-related theories, human behavior consisted of three

elements: the subject of behavior, the target of behavior and the operating tool. The subject usually refers to people, and the goal is the cause and internal drive of the behavior, which can have different forms to guide the generation and transformation of

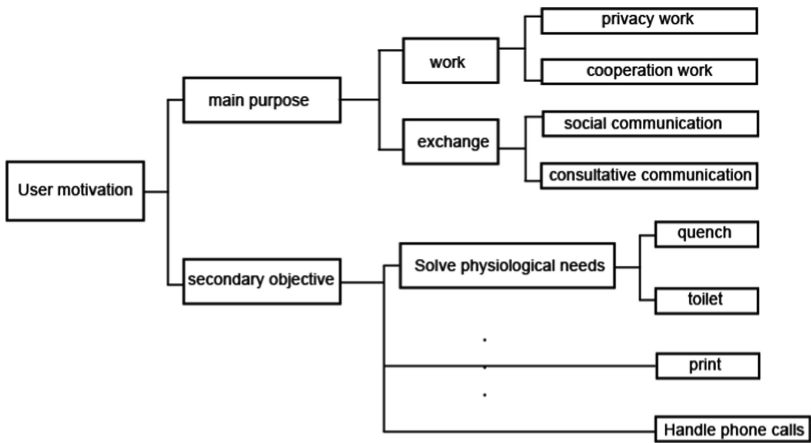


Fig. 1. User motivation

the behavior of the subject. Tools are the medium through which the subject achieves its goals. The essence of the tool could only be clarified by means of operational tool research based on the understanding of the subject and user goals [6].

2.4 Task Flow Determination

The logic of behavioral theory make it clear that “behavior” is the object of interaction design, and point out that designers should reasonably plan users’ behaviors according to their purposes, actions and habits, then carries out interaction design. Users will form specific behavior habits and operation modes in the process of learning and using products, while interactive products contain the operation paths and task flows preset by designers. According to the acquired user behavior motivation, the user behavior logic was analyzed, and then the main interactive task graph was drawn. The behavior process could be divided into basic behavior and subsidiary behavior according to the user’s behavior goal. The basic behavior acted as the mainline task to support the subsidiary behavior. Work behavior and communication behavior were distinguished by two office goals: “work” and “communication”. And the relevant behavior logic diagram and interaction task diagram were obtained as follows.

The user behavior was divided into two general behavior processes according to the main goal: general work process and general communication process. At the same time, due to other conditions, the user might have other purposes in the office process, which

might lead to the generation of other behaviors in continuous work or continuous communication. Due to the diversity of user needs, user behaviors would be changed or combined according to individual psychology or environment, so resulting in a complex task process formed by interweaving and combining general workflow and general communication process (Figs. 1, 2, 3, 4 and 5).

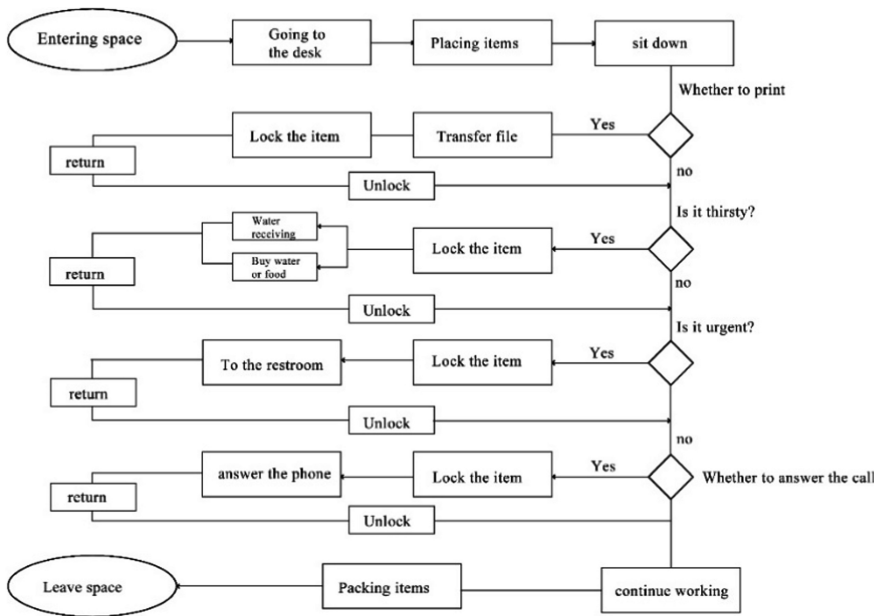


Fig. 2. Logic of behavior for general work behavior.

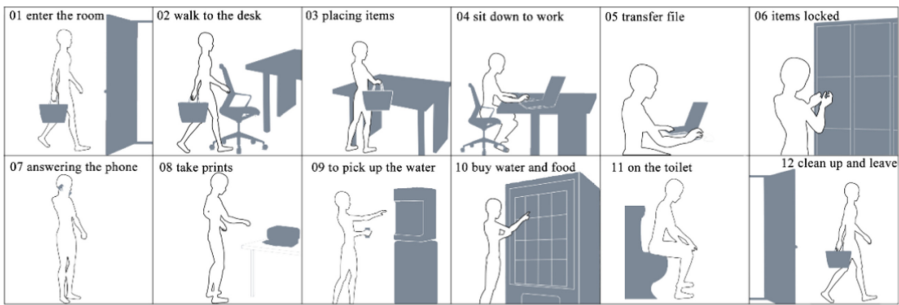
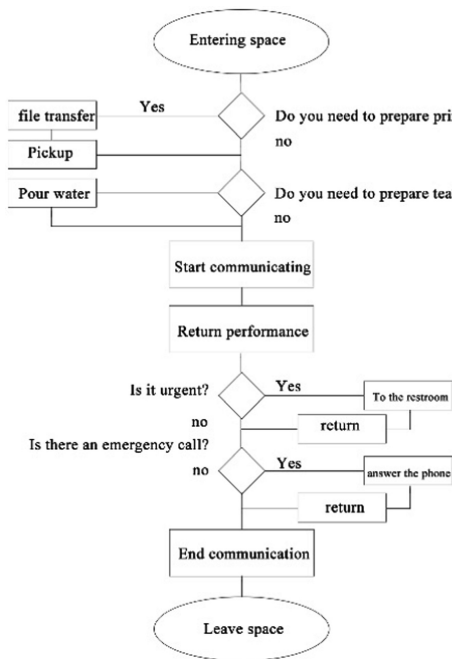
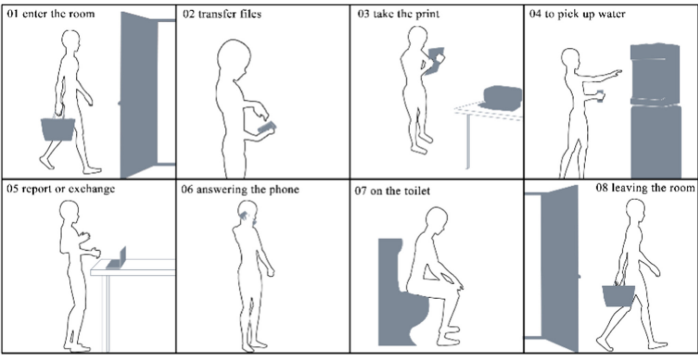


Fig. 3. Interactive task diagram for general work behavior.



**Fig. 4.** Logic of things for general work behavior.



**Fig. 5.** Interactive task diagram for general communication behavior.

### 3 Shared Office Space Design Model

#### 3.1 Environmental Psychology and Scene Theory

Environmental psychology is a subject that studies the relationship among people, the surrounding spiritual and material environment. It advocates the use of scientific means to solve the problems between the spirit and the material, and then explores the

relationship between psychology and the environment. It analyzes and studies the interaction between human thought and behavior. As for, it is a field that systematically explains the relationship between human and environment. Nowadays, the integration of environmental psychology into public space design was no longer confined to too rational space design, but in-depth study of the user's psychology. The use of environmental psychology in Shared office space was mainly in three aspects: personal space and sensory scale, human behavior in space and color environment. Since this paper mainly discussed the design layout of space, the factors of sensory scale and color environment were not considered here [7]:

- (1) Personal space: personal space refers to the limited space around oneself. It means that there should be an appropriate distance. Since inappropriate interpersonal distance will produce many negative effects, so appropriate interpersonal distance will give people more comfortable positive effects.
- (2) Behavioral characteristics of people in the environment: there are mainly unconscious behavioral habits of people like passing on the left, cutting corners, turning on the left, turning counterclockwise, and depending on others.

The “scenario theory” is an academic paradigm of the research for post-industrial city proposed by the new Chicago school. A new set of academic grammar system is proposed to analyze and evaluate the adsorption relationship between specific scenes and the emerging creative class. This system of academic grammar points out that to judge a scene, five elements need to be satisfied first: neighborhood or community, physical structure or infrastructure, diversity of people, such as diversity of race, class, gender and education, build cultural practice based on the fusion of the first three elements, cultural values conceived in the scene. The scene theory is not only applicable to the analysis of large areas or complex areas, but also to the analysis of small community space [8].

### 3.2 Shared Office Space Design Model

The model of shared office space design has been established. According to the logic of behavior, the user types and the behavioral motivations of relevant users were obtained. Then the user task flow was analyzed. Ultimately the device type was determined according to the behavior node, and the spatial layout was planned according to the behavior process combined with environmental psychology and the scenario theory (Fig. 6).

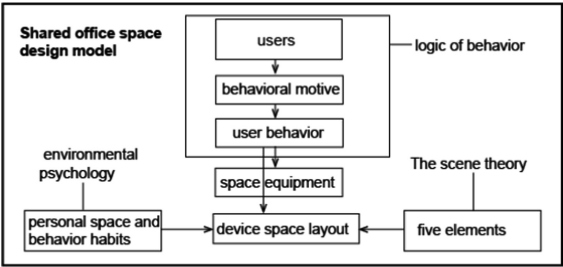


Fig. 6. Shared office space design model.

4 Shared Office Space Facility Layout

4.1 Space Equipment Determination and Optimization Design

The equipment in the Shared office space was the tool and medium for users to make behaviors in the space and achieve their goals. According to the obtained user task flow, the space infrastructure requirements could be obtained by extracting the important nodes (Table. 2).

Table 2. Space equipment.

Behavior node	Features	Device
Work	Privacy	Enclosed desk
	Cooperative	Open des
Exchange	Reporting	Switched projection, Whiteboard, Conference table
	Mode	The seat
Diet	-	Water fountains, Vending machines
WC	-	Toilet and sink
Print	-	The printer
Answer the phone	-	Soundproof booth

4.2 Equipment Space Layout Planning

**Shared Office Space Based on Logic of Things.** The spatial layout design of the existing Shared office space in China generally divided the space into functions, such as working space, activity space and leisure space, then arranged different Spaces in different regions. Only single-layer Shared space was discussed here, so the existing spatial distribution could be divided into centralized distribution and decentralized distribution according to the survey results. As shown in the Fig. 7, centralized spatial distribution referred to the relatively clear division of functional area communication space and work space. In the distributed spatial distribution, the working space and the communication space permeate each other and were distributed.

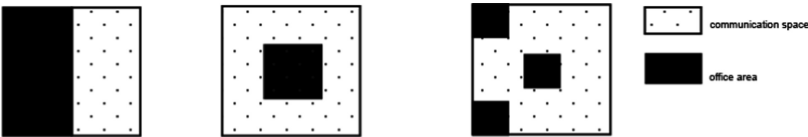


Fig. 7. Spatial distribution of existing shared office.

**Layout Planning of Shared Office Space Based on Logic of Behavior.** According to the diagram about user’s logic of behavior, the diversity of behavior combination lead to richer composition of office space and longer streamline. Due to the long working time, the places where all kinds of other demands were generated, such as toilets and

drinking water, were uncertain. And there were many possibilities of streamlines caused by various permutations and combinations. Some examples were shown in the Fig. 8. Shared space couldn't exist in isolation either in terms of usage behavior or streamline design. Only the organized combination between them could form an efficient and humanized space.

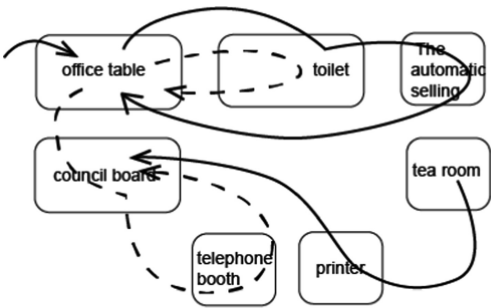


Fig. 8. Some examples for streamlines.

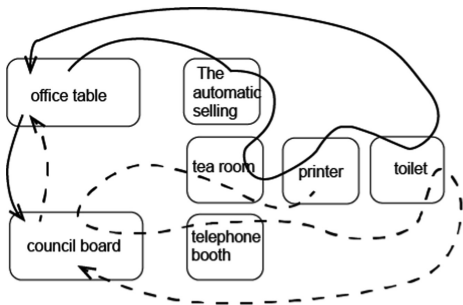


Fig. 9. The longest task flows

Due to the multiple possibilities of streamline, the longest task flow of general work behavior and general communication behavior was taken as the design reference in the spatial layout planning, and the obtained streamline is shown in the Fig. 9. According to the streamline of the task, the spatial layout of the equipment was carried out. According to the streamline, the first behavior of users entering the space was to walk to the desk, to the conference table, to print and to pour water. So, considered placing the functional devices of these three behavior nodes closer to the door. In the process of general work behavior, going to the toilet, printing, pouring water and buying were possible behaviors, and the frequency of occurrence for them shown a decreasing trend. So as to roughly determine the location of the relevant equipment and the location of the desk. In general communication behaviors, it was possible to go to the toilet and answer the phone with a small probability, so the location of relevant equipment should be taken into consideration. As was shown in Fig. 10.



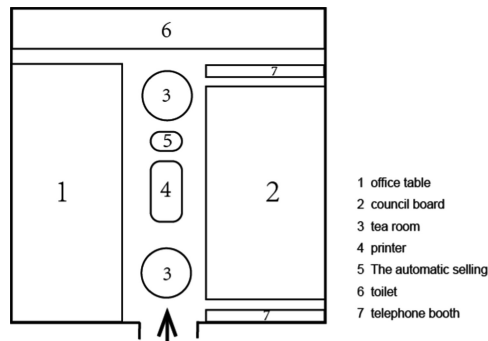


Fig. 10. Layout planning of shared office space based on logic of behavior.

5 Jack Evaluation

5.1 Establishment of Virtual Person and Device Model

According to the spatial layout obtained from the design, the spatial layout and the existing functional area were put into jack software for simulation evaluation. In the process of simulation, due to the randomness and diversity of human behavior streamline, it was considered to use a longest behavior flow as the evaluation path. Then, the longest behavior flow line should include all behaviors. The task flow is shown in Fig. 11, and the virtual person movement trajectory obtained from the task flow is shown in Fig. 12.

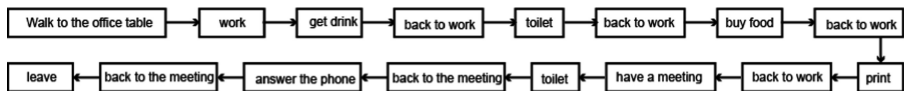


Fig. 11. The longest task flows.

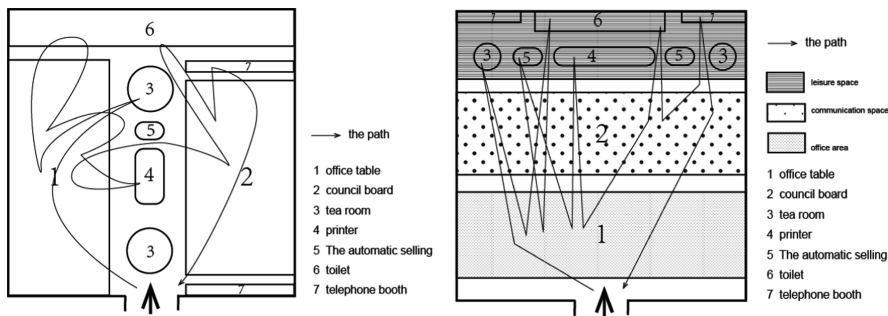
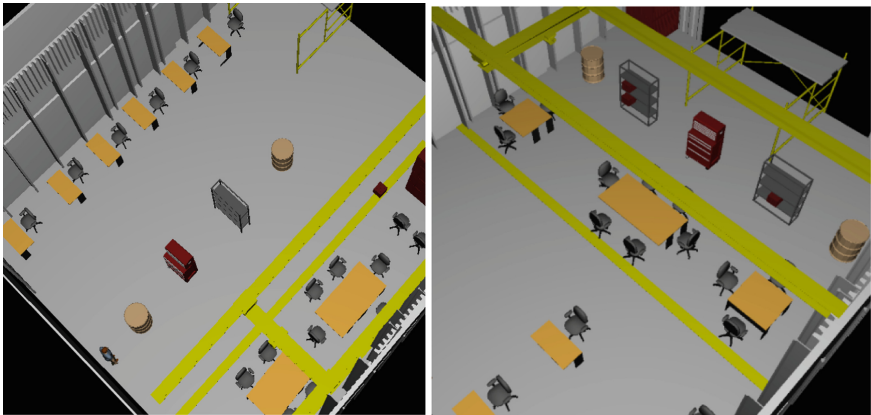


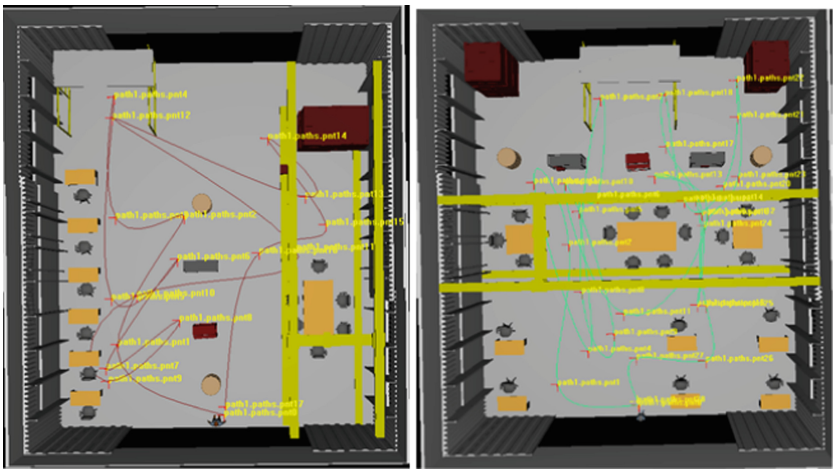
Fig. 12. Person movement trajectory in the space design based on the logic of behavior (left) and logic of things (right).

Next, Chinese human body data was used to build a digital human model in Jack simulation software, and the use scene was built according to the spatial layout to determine the behavior flow line (Fig. 13).

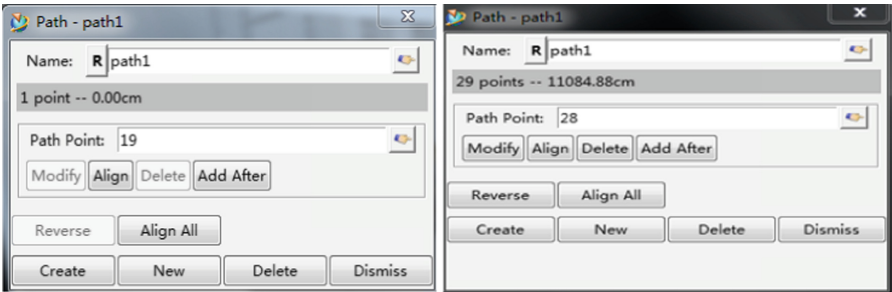


**Fig. 13.** The spatial layout in the space design based on the logic of behavior (left) and logic of things (right).

Firstly, the user streamline of the two Spaces was simulated, and it was found that there were 19 path points in the layout designed in this paper, while there were 28 path points in the traditional spatial layout. It could be seen that the spatial layout designed according to behavioral logic was better than that designed according to physical logic in terms of streamline convenience (Figs. 14, 15).

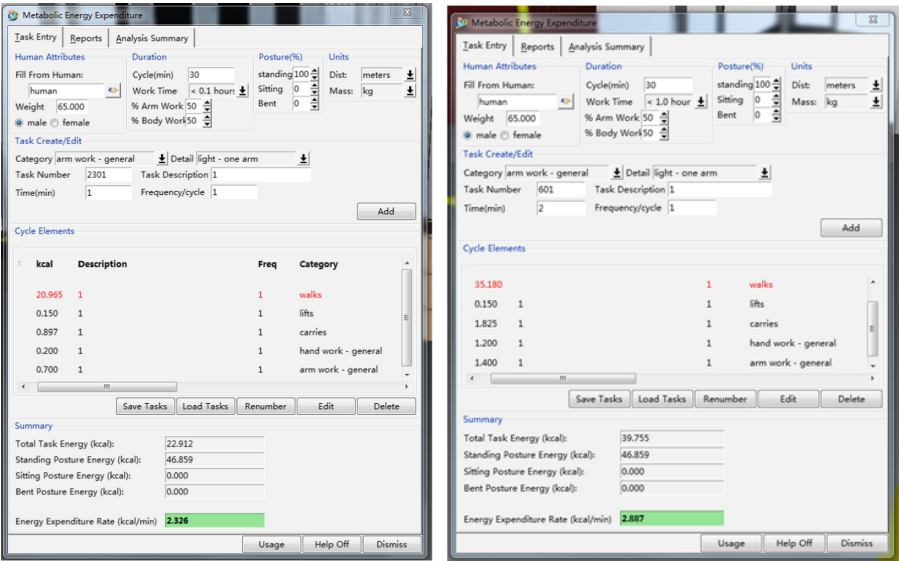


**Fig. 14.** The user streamline for the space design based on the logic of behavior (left) and logic of things (right).



**Fig. 15.** The path points of the space design based on the logic of behavior (left) and logic of things (right).

Secondly, interactive behaviors were added into the spatial task flow of digital people to analyze the energy consumption of simple walking paths and all interactive paths. The energy consumption rate of human body was an important indicator to reflect the fatigue degree of operators. In the MEE analysis tool of JACK software, the energy consumption of human body could be calculated by inputting task time, standing posture, sitting posture, bending posture and other data, as shown in the Fig. 16.



**Fig. 16.** The simulation result for the space design based on the logic of behavior (left) and logic of things (right).

## 5.2 Simulation and Comprehensive Evaluation

According to the results of Jack’s simulation output, the comparison of the two spatial layouts was shown in Table 3.

**Table 3.** Evaluation of contrast.

Layout	Path point	Path energy consumption (kcal)	Total task energy consumption (kcal)	Energy consumption rate (kcal/min)
Behavior based	19	93.954	22.912	2.326
Things based	28	145.116	39.755	2.887

It could be seen that compared with the common space layout design based on logic of things, the Shared office space design based on logic of behavior required fewer path points, consumed less energy through the path, and had a lower energy consumption rate of the total task. It could be seen that the design model of Shared office space based on behavior logic was feasible and effective.

## 6 Conclusion

This paper proposed a design model of Shared office space based on behavior logic, aimed at determining the interaction between users and space devices according to users’ needs from the perspective of users, and then designed the layout of space devices. The purpose was to make the layout of the space more user-friendly and practical. In the design process, the user’s behavior motivation should be fully considered, and the path of the space should fit with the user’s streamline to meet the user’s psychology, so as to make the final design result more efficient.

## References

1. Zhang, X.: Research on the Design of Local Joint Office Space –Taking the Mass Innovation Space Project of “Innovation Community” as an Example. China Central Academy of Fine Arts (2016)
2. Xin, X.: Interaction design: from logic of things to logic of behaviors. *Art Design* **1**, 58–62 (2015)
3. Liu, S.: *Psychology of Design Art*. Tsinghua University Press, Beijing (2006)
4. Tang, X.: Research on Collaborative Mode and Space Design of Co-working. Southeast University (2017)
5. Pan, Yu., Zhang, X., Dao, L., Wan, Y.: Research on consumer values in the context of chinese culture – scale development and comparison. *Manag. World*, 90–106 (2014)
6. Qiu, Z.: *The Research of Intelligent TV Interactive Design Based on User Behavior Oriented*. Jiangnan University (2017)
7. Lin, Y., Hu, Z.: *Environmental Psychology*. China Architecture & Building Press, Beijing (2000)
8. Gai, Q.: Construction of urban youth public cultural space from the perspective of scene theory - a case study of Beijing 706 youth space. *Dong Yue Tribune*, 72–80 (2017)



# The Italic Style: Understanding the Shape Through History

João Aranda Brandão<sup>(✉)</sup> and Catarina Machado Almeida

CIAUD Centro de Investigação em Arquitetura, Urbanismo e Design, Faculdade de Arquitetura da Universidade de Lisboa, Rua Sá Nogueira, Pólo Universitário, Alto da Ajuda, 1349-063 Lisbon, Portugal  
joao@b2design.pt, catarina.m.almeida@outlook.com

**Abstract.** The italic cursive calligraphic style originates, in general terms, from the simplification of the gesture of writing, since the inclination is a consequence of the speed and movement of the gesture. Italic fonts and the calligraphic style are easily recognizable in the Western world. However, contrary to what happens in typography studies, it is noted that the history of italics has not been adequately addressed in the scientific literature on the history of design, where the formal characteristics are not analyzed in a coherent way. Therefore, the objectives of this research are: to clarify the historical origins of italics, taking into account, in particular, the morphological evolution of the style from informal to formal writing and the adaptation of the shape of calligraphic characters to typography; to identify and analyze its characteristics, differentiating it from both regular and oblique variants; apply the study of movement and gesture to the drawing of the letter in italics (calligraphy) and evaluate its repercussions on typography; and finally, identify the main designers and engravers throughout their diachronic journey. This study is supported on qualitative methods of historical research and on the observation and critical analysis of the calligraphic practice. Through bibliographical research and literary review, a theoretical framework is created for the design of italic types, from which we intend to validate the hypothesis that the understanding of the calligraphic gesture is fundamental to the comprehension of the formal characteristics of italics, be it calligraphic or typographic. This article is based on the master's dissertation of C. Almeida titled "Origin and Evolution of Italic: from calligraphy to typography", presented in 2017 at the Lisbon School of Architecture of the University of Lisbon.

**Keywords:** Italic · Calligraphy · Typography · Humanistic writing · History of letters and writing

## 1 Introduction

This paper approaches the gestures required for writing in italic, with the purpose of clarifying the reasons that justify its shape morphologically. Here we continue the research from the previous paper on the historical evolution of the italic, that sought to understand and define italic, while analyzing and describing its detailed history, origin and evolution, entitled "The italic style, getting it straight" [2].

Here, we intended to explain that what defines the italic shape is the calligraphic gesture, whether it be hand written or typographic italic. The invention of this method of writing derives from the intention of writing the characters in an ergonomic, fast, efficient and readable way, adopted because of its space saving characteristics while maintaining its aesthetic quality without losing readability. Later italic was converted to typography.

For these reasons, we advanced the hypothesis that the origin of the form of the italic starts from the principle of the form associated with the abbreviated gesture.

The aim of this paper is also to validate the importance of this knowledge for designers and type designers. These need to know and interiorize the movement and the stroke required to handwrite italic, both to understand the morphology and the design of the characters, and to enable them to innovate and design new italic fonts.

Although this subject has been studied in the context of calligraphy and the history of writing (...), it has been little approached from the point of view of designers, where only Noordzij [17] studied the subject more consistently.

It's clear that both the typographic italic variant and the calligraphic style, is easily distinguishable by the Western population. On the other hand, most people, including graphic designers haven't studied its origins to understand its shape, even though they use it daily, and few are the scholars that study it. "Italic has become the most used and recognizable style. At the same time, it may be the least well understood" [23 p. 64].

Since the desktop publishing revolution, that the graphic designers have been given a huge and complicated choice of typefaces, as well as the tools to alter and manipulate them. It has never been so important for graphic designers to know the history of printing and typography [20 p. 27].

## 2 Historical Writing Systems and Styles

It is clear that two individuals would draw glyphs in entirely different ways, depending on whether they are using a paintbrush on a papyrus or a stylus on a clay tablet. And even if, instead of creating their own writing system, they were merely reproducing a known one, the result will still be quite different.

"Whichever form of writing is favored, the shapes of its symbols and the way in which it is written will be molded by the materials used and the purpose for which it is employed" [3, p. 50].

Scribes, for many centuries, used formal calligraphic styles to write books, because the letter forms were clearer and easier to be understood by others, while cursive and informal styles were used only for personal notes, because they were faster and the message was only meant to be readable by whoever wrote it.

The evolution of the characters of the Latin alphabet is linear for several centuries. It's clear that each style of writing was based on an earlier one. No innovating scribe dared to be radical because he knew he had to use the pre-existing styles of writing and used them as models. He could only modify them in order to answer the needs and values of his time (and place), thus creating something considered new in style.

Through out the history of the Latin alphabet, we can observe the constant evolution to simpler and readable formal styles. A style difficult to write in due to the high

number of strokes needed to create a letter or constant changes of the pen angle is usually replaced by a simpler style with fewer strokes and fewer angle variations.

### 3 The Italic Style, Understanding the Shape Through History

Broad-nibbed pen or edge pen began to be used during the Roman Empire. Before then, most documents were written with a sharp *calamus*. The Roman scribes began to use a wide-tipped *calamus*, which was eventually replaced by the cut quill (*penna*). The broad nib was the key to the natural production of the different thicknesses, thin and thick. Gradually, new styles were developed and the Roman alphabet took on new forms.

Edge pens automatically produce thick, thin, or graduated strokes that can be arranged in a fixed relationship to all letters of the alphabet. This is achieved by adjusting the angle and direction of the trim strokes. The action of this tool provides a logical structure to the rhythm of writing, but does not restrict the forms that can be produced, since there are a number of ways of manipulating the nib to change the character of the letters [13, p. 88].

Italic is known by paleographers as Humanistic cursive, and it was created in the fifteenth century during the Italian Renaissance. This period was characterized by a strong cultural and economic change, and by the awakening of interest in classical models. Writing was also influenced and humanists also reformed the writing styles by replacing the Gothic minuscule with a style influenced by the ancient Romans. This idea began with Francesco Petrarca, has highlighted in [19, p. 22]: “The first humanist who voiced his opposition to Gothic forms was Petrarch”.

Petrarch sought a pure and clear writing style, representative of the ideas that he defended, but he never went beyond creating semi-Gothic styles. However, it was only the next a generation of calligraphers, the group of humanists associated with the chancellor of Florence, Coluccio Salutati, who fought for Petrarch’s reform ideas.

After unremitting searches throughout Europe for forgotten works, they found the Caroline minuscule, an old script, elegant and more readable. Practically all the manuscripts of the classic writers they discovered were written in this script. Knowing little, perhaps, of the re-writing of all extant literature following Carl’s decree of 789, the humanists readily accepted this hand as the genuine writing style of the ancients. Based on this script, Poggio Bracciolini (disciple of Salutati) developed the *littera antiqua* or *littera humanistica*, to be initially used in Latin texts of classical antiquity, has highlighted in [19, p. 23]: “The invention of *littera antiqua* is attributed to the Florentine Giovanni Francesco Poggio Bracciolini”. This new style was encouraged by Niccolò Niccoli, preferred by the Medici and other book collectors, as well as sold and promoted by book merchants like Vespasiano of Bisticci. It was gradually perfected by scribes like Gherardo del Ciriagio, Antonio di Mario and Pierantonio Sallando. Quoting [21, p. 45]: “The Italian humanists did not take tradition as given but made up their own variations on it. They certainly respected the culture of classical antiquity but considered themselves superior to it”.

The Humanist minuscule is a direct descendant of the Caroline miniscule, and like this one, it was elegant and was better in small size [10, p. 91]. The Humanist

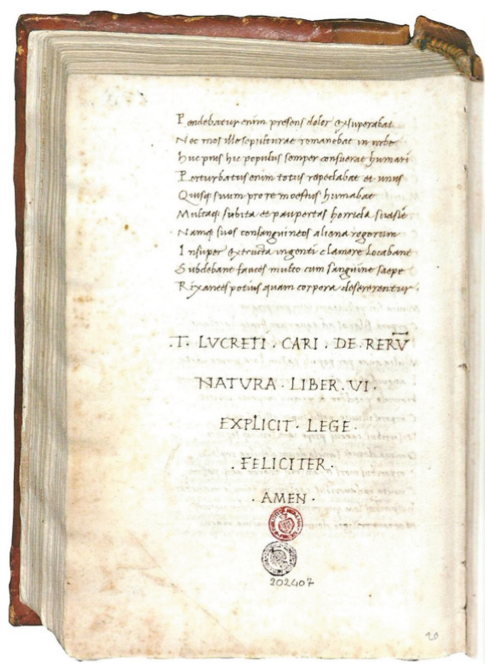


minuscule is more delicate, uniform and regular than the Caroline, with letters closer and less differentiated between thick and thin strokes [1 pp. 194–195]. All letters have a right aspect with clearly defined traits [10 pp. 90–91]. When printing was introduced in Italy, *littera humanistica* was the basis for the typographic font that we now call “Roman”. As a style of writing, it continued to be used until the sixteenth century, and was finally abandoned by the use of printing and Roman typeface [16 p. 69].

The first cursive variant (italic or Humanistic cursive), known as *littera antiqua corsiva*, was created by Niccolò Niccoli around 1420, and it was an informal hybrid hand that crossed the Italian gothic cursive with the *littera antiqua*. Niccoli, who was not a professional scribe, used it to copy books for his own use or to send as a loan [15 p. 208] so that others could copy them, in a formal style favored by society.

The manuscripts he used as the basis for his transcriptions were temporary, and often short-term loans. [15 p. 208] Therefore, he had to copy them quickly and without compromising the readability of the text.

The *littera antiqua corsiva* created by Niccoli was an extremely efficient writing style, because it was a rapid flowing script yet very clear and readable (Fig. 1).



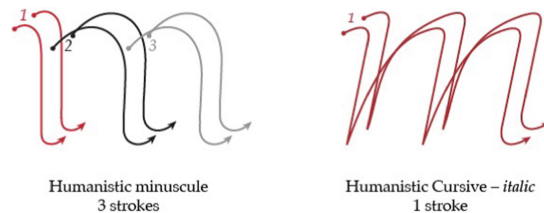
**Fig. 1.** Text by Lucrécio, handwritten by Niccolò Niccoli, top text in *littera antiqua corsiva*, bottom text in humanist capitals.

By writing quickly and with the least number of pen lifts (not to break the pace), Niccoli links the letters constantly (where it is convenient) as a non-professional writer



does naturally, using diagonal union traits (also a feature of Gothic italics). Letters have a slope to the right and are slightly compressed. This is especially noticeable in round letters that become oval. In addition, many letters are executed with a single stroke and with a continuous movement as is the case of “m” and “n”. Among the most notable letters (compared to Humanistic miniscule) is the “a”, with the same form of Gothic cursive. The “q” followed this shape, resembling an “a” with a tail (descending). Along with the lowercase letters, Niccoli used the uppercase Humanistic without inclination. The characteristics referred to have become representative of informal humanistic cursive.

The *littera antiqua corsiva* of Niccoli gradually gained popularity among the humanists, especially for margin notes (Fig. 2).



**Fig. 2.** Comparison of number of pen strokes between Humanistic miniscule and Humanistic cursive (italic).

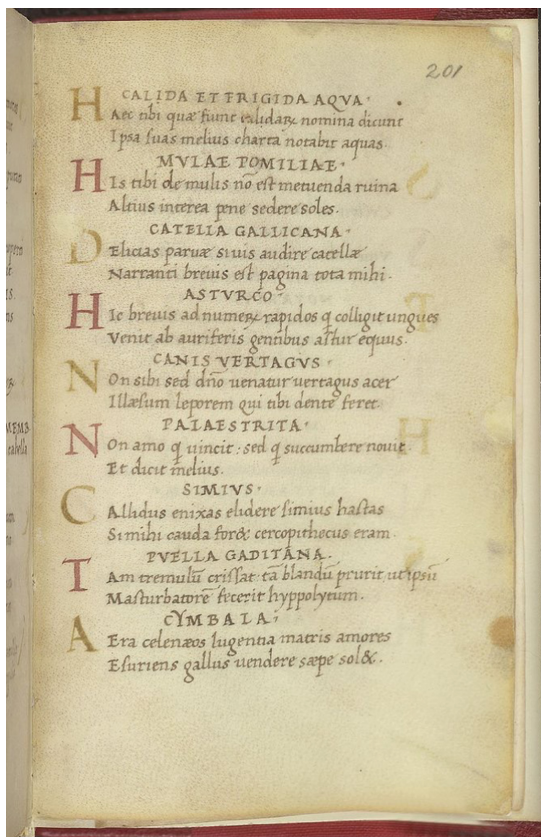
According to Wardrop [22], this style was initially modest and unpretentious, almost always small in scale, written with a narrower nib, with little differentiation between thick and thins. It could be more or less rounded or compressed, slanted or upright, depending on the writer.

Eventually, it started to get used in books, the less important ones, adopting the name of *littera humanistica cursiva libraria* (*libraria* is a word to describe scripts used in books).

Bartolomeo Sanvito was considered one of the best Renaissance scribes. In his youth, he learned gothic cursive and his first Humanistic cursive style dates back to the middle of 1454. Despite the fact that in the 1470s the printing press was crippling manuscript orders, Sanvito was able to overcome this adversity and wrote elaborate and exuberant books with which printed books could not compete. Almost all manuscripts of the Latin classics he wrote were in Humanistic cursive [4, pp. 104–106] (Fig. 3).

During the 1490s, he copied a series Cicero’s books, the first (dated December 1494) considered the first pocket manuscript. It was he who created this new small book format known as the octavo. Sanvito’s writing style gained acceptance, despite its imperfections. These were really part of its charm. His cursive was true to his nature: still informal [22].

By the end of the fifteenth century, the *littera humanistica cursiva libraria* had been perfected by professional scribes (like Pierantonio Sallando) and acquired a high degree of formalization.



**Fig. 3.** Page handwritten by Bartolomeo Sanvito. Image taken from f. 201 of Epigrams (index Epigrammatum).

Its clarity and convenience led to its use in both manuscript books and correspondence. [8 p. 16] This style saved time and money. Fewer materials (parchment or paper) were required and scribes could write faster without seeming rushed [14 p. 37].

The scribes of the Papal Chancery, in the mid-fifteenth century, developed a variant of the Humanistic cursive, which became known as *littera cancellaresca corsiva*.

The *cancellaresca corsiva* was the principal of many writing manuals for Italian master calligraphers, who usually worked in the papal chancellery or in municipal administrations.

The *cancellaresca corsiva* is a variant of the most perfected Humanistic cursive, a little narrower and more ornamented [23, 64]. It is a professional and virtuous style [16 p. 88]. Due to long ascending and descending lines (often curved or flowery or entwined), the lines are well spaced, the text is more legible, and has an elongated and elegant appearance. The angle of inclination can vary greatly depending on the writer.

According to Fairbank and Wolpe [7 pp. 37–38], the *cancellaresque* can be formal, precise and executed with a slower pace (*ductus*) for use in books, where elegance is as

important as function; it can be informal for current and daily use, and executed quickly; or, in the case of writing manuals, can be a model of education (*set cursive*), very detailed and precise. There are still other variants that do not fit into any of these style categories.

The *cancellaresca*, found in the writing handbooks, is a model of teaching, from which the person will inevitably move away from as they practice and speed increases [7 p. 37]. Thus, contrary to what one might think, the strict rules of execution in the manuals did not lead to an extreme formalization of this style of writing.

However, some of the freedom of humanistic cursive is lost when we come to the books of calligraphy masters, because we no longer have the original touch of the nib, but a translation into another medium (since writing was reproduced in wood), where writing is elaborated in a much more conscious and deliberate way [9]. To some extent, the engravers who produced the original blocks certainly left their mark [18 p IX].

The first manual of writing created for the general public (mainly non-professional writers) was *La Operina di Ludovico Vicentino, da imparare di scrivere littera Cancellarescha*, published in Rome in 1524 by Ludovico Vicentino degli Arrighi (Ludovicus Henricus Vicentinus), writer of Papal documents (*breves*). Arrighi's book is considered by many to be the most beautiful of all writing books, and was the first to illustrate and teach the *cancellaresca corsiva*. It is a modest but revolutionary book of thirty-two pages, where the public is invited to learn how to write the *cancellaresca* in just a few days. It displays simple, straightforward instructions for lowercase letters and some uppercase (which, unlike the lower case, had no slope and were slightly ornamented).

Ludovico degli Arrighi was one of the most successful scribes of his time.

His *cancellaresca* was simple, clear and fast. It was more uniform, had fewer ligatures and had less association with the forms of Gothic cursive. The lowercase letters are slightly inclined and compressed.

In the writing manuals of these calligraphy masters, capital letters (also called *majuscole cancellaresche*) do not have detailed rules, as opposed to the lower-case rules, and to a certain extent they are more relaxed in favor of personal expression. Scribes have generally taken this opportunity to show their individual abilities. Thus, we find a pleasant contrast between the readable regularity of the minuscule ones and the freedom in the flowery of the capital letters (Osley 2009). The ornate capital letters are the ancestor of the current "swash capitals" and the calligraphy masters never used them together to form words, they were always used in conjunction with the lowercase letters [16, p. 88].

The writing manual became an important book genre from the sixteenth century until the eighteenth century, mainly in Italy, Spain, Portugal, Holland, Belgium, France and England. The various variants of the *cancellaresca* have gained popularity because of their elegance and legibility and have resulted in more standardized writing styles throughout Europe.

Each scribe had a unique way of writing the *cancellaresca*, therefore scholars can usually identify the writer of unsigned copies by recognizing certain characteristics [23, pp. 76–77].

The typographic and handwritten *cancellaresca* quickly spread throughout Europe, and in the sixteenth century was well known in many countries as "Italian style" or

“italic”, derived from the name of the country of origin (Italy). The term “italic” (as a writing style) is currently used to describe any variant of Humanistic cursive.

Italic is one of the most variable writing styles; it can be fast and informal or slow and elegant. In general, it is thinner than other styles. It is characterized by having condensed characters (laterally) often with a slope to the right, an oval “o” and characters with asymmetric arcs (such as “n”).

One reason for this style to have several variants is that it is based on an oval “o”, and oval shapes may assume many structures but remain similar. The “o” is the key letter of this style, because it establishes the ductus, the curved features and the proportion of great part of the letters.

“The circle is linked to formality, but the ellipse tends more to informality and quick movements of the pen” [7, p. 22].

The purpose of informal italics was to achieve a balance between practicality and readability thus resulting in great efficiency. The gestures (*ductus*) should be as natural as possible, taking the easiest and quickest route. Acceleration of the hand tends to limit the number of pen lifts maintaining rhythm of writing constant. Because the pen nib is lifted as little as possible, ligatures (joining strokes) are consequential and necessary, and arches are produced by stem branching. The inclination of the nib is normally between 30° and 45° and the characters are usually inclined to the right.

In formal italics, the beauty of the characters is more important than speed. The calligraphic gestures can be as slow as needed to produce multiple individual strokes accurately. Most letters are comprised by a sequence of strokes which follows the order most commonly used in other formal styles. Even though many characters like “n” acquire an interrupted construction, their characteristic form still derives from the continuous construction of informal italics. The letters are usually slightly sloped forward about 10°, but some more elaborate cursives can reach the 15°.

There are variants of the Humanistic cursive that have formal and informal characteristics and can be classified as semi-formal.

According to Harris [10, p. 96], the extremities of the ascendants of the Humanistic cursive can be *formata*, in which they are horizontal or wedge-shaped and to the left, or *corsiva*, in which they are rounded and to the right. These also influence the ends of the descenders.

Unlike the *lettera antica formata*, the use of cursive variants for documents and handwritten books persisted long after printing was implemented in the main Italian cities [14, p. 39]. Possibly because the Humanistic cursive allows for the insertion of more words in a text page, due to their compressed letters. Thus, they save space and parchment so it makes the productions more economical.

Between the sixteenth and nineteenth centuries, the evolution of the italic, can be observed through the writing manuals created by master calligraphers or scribes. *Littera cancellaresca* was the basis from which italic evolved into several European styles, one of which known as copperplate. Characters are drawn continuously without lifting the pen forming words with connected letters. Over the years, these styles suffered alterations and their readability lost as more flowery ornamentation was applied. Nowadays, italic is still the ancestral base for the method of cursive taught in schools for the latin alphabet.

The early printed books known as incunables (from the latin *in cunabula*), used handwritten manuscripts as their base [3]. The handwritten scripts that were used in these books were the basis for early roman and italic typefaces (in the northern Europe Gothic script were favoured and the humanists inspired the roman and italic typefaces in Italy).

In 1501, in Venice, Aldo Manuzio published Virgil's *Opera*, the first of his *octavo* classics. For this Aldo Manuzio asked Francesco Griffo to convert the *littera humanistica cursiva libraria* to typography thus creating the first italic typographic font. Possibly based on a manuscript written by Bartolomeo Sanvito. The result was a typeface with good readability in a small size and, because it was narrower, it took up less horizontal space so it was possible to fit a greater number of words on a page, saving space, paper, and thus, money, both for the printer and the consumer. With a smaller number of pages there was still the advantage of the book being lighter.

"Venice was also the birthplace of the first italic typeface" [12, p. 27].

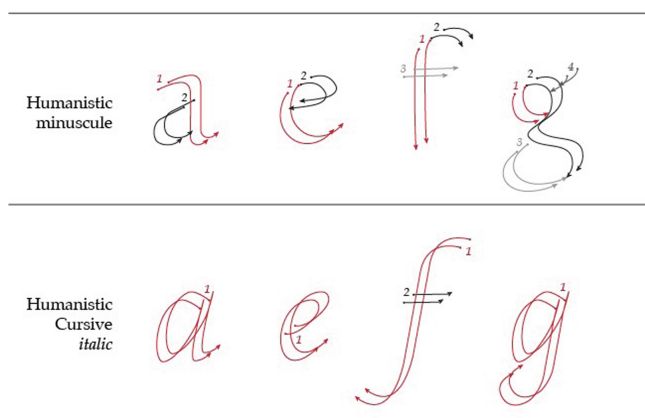
This was an innovation in Latin typography. It was technically challenging due to the high number of ligatures and abbreviations. This type maintained at least 65 ligatures, which compromised its functionality. As in the earliest manuscripts in Humanistic cursive, while the lower case is inclined, the upper case is vertical, the same as that used for the Roman type. The capitals inclined to accompany the lowercase italics were only adapted for typography about 30 years later.

Because of its advantages, italic fonts were quickly copied by other European typographers. One of the best exemplars of printed italic was the one created by the calligrapher Ludovico degli Arrighi based on his own *cancellaresca*.

The italic type and the *octavo* format become the main means of propagating classical literature in Europe [6, p. 60]. The pocketbooks (which Manuzio called *libelli portatiles*), which were cheaper and portable, were extremely successful and helped to stimulate the dissemination of knowledge. They were not intended for great intellectuals, but for a growing public who was educated and interested in humanistic thinking. According to Davies [5, p. 42], Manuzio published poetic texts in this format, and italics were used because they were less likely to tire the eyes, than long lines of prose created by other fonts.

Despite the more affordable price of printed pocketbooks (still considered expensive for most of the population), for a while it was still cheaper to order a small manuscript in Humanistic cursive written by a professional scribe [14 pp. 40–41].

Arrighi probably opened his press in 1522. However, his first printed book, is known to have been *Coryciana*, dating from 1524. This book is considered to be one of the finest printed copies of the Renaissance. In it he used an italic type, his first, which was based on his more formal *cancellaresca* and had long ascenders and descendants with curved ends. It was more elegant, readable, and lighter than Manuzio's.



The *cancellaresca corsiva* of Arrighi was a source of inspiration for many of the Italic fonts in the early twentieth century.

## 4 Conclusion

The knowledge of the italic style's shape can be understood through its History and evolution.

This information and know how is important for designers who use typography daily and especially for font designers. We personally recommend the practice of italic calligraphy.

This is aggravated by the fact most mainstream books on graphic design do not contain all the history on italics as it is known by paleographers.

With this research we want to clarify the origin of the Italic style and of its evolution over the ages since its invention as an efficient handwriting style *littera antiqua corsiva*, and its path from cursive writing to a formal book writing style until its conversion to typography.

It is very important to understand that the italic fonts are not merely skewed versions of their roman style fonts, both of these (roman and italics) were transformed into typographic shapes from historically different handwriting styles with different gestures, letter structures and characteristics. As a result, italic fonts have characters shaped clearly different from the design of roman characters of the same font. This is most noticeable on the lowercase “a” “a”, “e” “e”, “f” “f” and “g” “g”. Other characteristics are: inclination, lateral compression of letters, and cursive shape, but these are only secondary.

Although italic is recognized by most by its inclination, it should be mainly distinguished by the shape of its characters, similar to cursive style writing that is in its base. Today it is a part of many typographic families, harmonized with the round/Roman, but originally it was its “rival”.

Some fonts have oblique variants instead of a “true” italic. These are a sloping variant of the roman font. While the true italic shape is based on the calligraphic gesture of Italian cursive writing of the fifteenth and sixteenth centuries, the oblique shape is an inclined version of the round font of the same typeface.

This research intends to give a base for designers to why an italic to be true it must have characters different from those presented in the roman font, which demonstrate the influence from the calligraphic gesture of the Humanistic cursive writing style, and at least one of the secondary characteristics: slope, lateral compression or cursive details.

The first oblique (or “false” italic) appeared only for the first time in the nineteenth century. Of all the features of true italics, it had preserved only the secondary feature of the slope, but not its fundamental structure [11, p. 21].

We believe there are two valuable rules for designers, which should never be broken when it comes to italics:

The first is that one should not use only italic capitals in a word, phrase or text, because they were created only to complement the lowercase letters.

The second rule is to never artificially tilt a roman font by using software (digital composition programs) this is considered a typographical error by many typographers and designers.

In doing so, one inevitably distorts the shapes of the characters and makes them less readable and less pleasant.

Nowadays font families are structured in way italics are secondary typographic font and possibly for this reason people treat it as such. Perhaps because of this, or because of its complexity, few scholars have studied it. But, by not understanding correctly its shape, origin and its characteristics, some designers end up making unnecessary mistakes and using it incorrectly.

Currently, italics are the most elegant and clear option for differentiating individual words or whole parts of text, simply because of their structural difference with the round [11, pp. 20–21].

**Acknowledgments.** 1. CIAUD Centro de Investigação em Arquitetura, Urbanismo e Design, Faculdade de Arquitetura da Universidade de Lisboa. 2. FCT Fundação para a ciência e Tecnologia, Portugal. 3. Luso-American Development Foundation.

## References

1. Avrin, L.: *Scribes, Scripts & Books*. American Library Association, Chicago (1991)
2. Brandão, J.A., Almeida, C.M.: The italic style: getting it straight. In: Rebelo, F., Soares, M. (eds.) *Advances in Ergonomics in Design*. AHFE 2018. *Advances in Intelligent Systems and Computing*, vol. 777, pp. 453–461. Springer, Cham (2019)
3. Brown, M.P.: *The British Library Guide to Writing and Scripts*. The British Library, London (1998)
4. Clayton, E.: *The Golden Thread*. Atlantic Books, London (2013)
5. Davies, M.: *Aldus Manutius: Printer and Publisher of Renaissance Venice*. The British Library, London (1995)

6. Davies, M.: Humanism in script and print in the fifteenth century. In: Kraye, J. (ed.) *The Cambridge Companion to Renaissance Humanism*. Cambridge University Press, Cambridge (1996)
7. Fairbank, A., Wolpe, B.: *Renaissance Handwriting*. Faber and Faber, London (1960)
8. Fairbank, A.: *A Book of Scripts*. Pelican Books, London (1968)
9. Gray, N.: *Lettering as Drawing: The Moving Line*. Oxford University Press, London (1970)
10. Harris, D.: *The Art of Calligraphy*. Dorling Kindersley, London (1995)
11. Hochuli, J.: *Detail in Typography*. Hyphen Press, London (2009)
12. Loxley, S.: *Type: the Secret History of Letters*. I.B. Tauris & Co Ltd., London (2006)
13. Martin, J.: *The Complete Guide to Calligraphy*. Grange Books, London (1996)
14. Morison, S.: *Early Italian Writing-Books: Renaissance to Baroque*. David R. Godine, Bonton (1990)
15. Morison, S.: *Selected Essays on the History of Letter-forms in Manuscript and Print*. Cambridge University Press, Cambridge (2011)
16. Nesbitt, A.: *The History and Technique of Lettering*. Dover Publications, New York (1998)
17. Noordzij, G.: *The Stroke*. Hyphen Press, London (2005)
18. Ogg, O.: *Three Classics of Italian Calligraphy*. Dover Publications, New York (1953)
19. Pflughaupt, L.: *Letter by Letter*. Princeton Architectural Press, New York (2007)
20. Pipes, A.: *Production for Graphic Designers*. Laurence King Publishing, London (2009)
21. Smeijers, F.: *Counterpunch*. Hyphen Press, London (2011)
22. Wardrop, J.: *The Script of Humanism: Some Aspects of Humanistic Script*. Clarendon Press, Oxford (1963)
23. Waters, S.: *Foundations of Calligraphy*. John Neal Bookseller, Greensboro (2014)





# Graphic Design and Cinema: Portuguese Movie Posters from the Nouvelle Vague Period

Elisabete Rolo<sup>1</sup>(✉) and Maria do Carmo Kattau Lopes<sup>2</sup>

<sup>1</sup> CIAUD, Lisbon School of Architecture, Universidade de Lisboa,  
Rua Sá Nogueira, 1349-063 Lisbon, Portugal  
elisabeterolodesign@gmail.com

<sup>2</sup> Lisbon School of Architecture, Universidade de Lisboa,  
Rua Sá Nogueira, 1349-063 Lisbon, Portugal

**Abstract.** Graphic design and cinema are closely related, especially by the divulgation, in which the poster is a major vehicle. This article discusses the Portuguese poster history, focusing the movie poster in a specific period – the Portuguese Nouvelle Vague – 1962–1982. The choice of this period is related to its particularities, as it was a moment of great transformations, especially in Portugal – by this time living the dictatorship and the revolution that led to democracy (in 1974). It was also an important moment in graphic design, where the development of phototypesetting and offset printing led to the graphic “third revolution”. This research is based on bibliographical review, on the systematic collection of posters, interviews with designers and the detailed analysis of a sample of these posters. In this manner, we try to further study a pertinent topic that we consider important to introduce in the Portuguese graphic design history.

**Keywords:** Portuguese graphic design · Portuguese poster · Cinema · Portuguese Nouvelle Vague

## 1 Introduction

The choice of this article’s subject is due to the recognition that Portuguese Nouvelle Vague and, in particular, the posters that served to broadcast it, deserve a further detailed study, in order to enrich the (still under construction) Portuguese design history. This research has the fundamental purpose to preserve the posters’ visual memory and also to gather histories and paths of their design process. In order to do this, we need to better understand the context of the period 1962–1982, and the production of graphic objects at the time, particularly movie posters. This is not a clear and linear task, but it is made possible through literary research and through a visual analysis methodology.

## 2 *Nouvelle Vague Cinema*

From its very beginnings, Man has always wanted to portray life beyond his own existence, and we can consider that the genesis of cinema lies in the primitive caves, in the representations of animals in continuous and overlapping positions, which provide an illusion of movement.

The *Cinema* appeared in Paris on December 28, 1895, at the *Grand Café*, with the first public display of animated photographs, through the cinematograph invented by the Lumière brothers and we can say that the very first film was *The Exit of the Factory Workers*.

After about five decades of development and affirmation of the Cinema as an artistic discipline, around the 1950's, we witnessed the emergence of a movement that became known as "Nouvelle Vague Cinema". It was originated in France and was characterized by the youth of its authors, united by the common desire to disobey the norms of the commercial cinema. It was a type of cinema that originated more personal films (author's cinema), in which the authors demonstrated their creative autonomy, and portrayed their own personal and daily issues. It was characterized by cheap productions, with almost unknown actors, many street scenes (instead of studios), with plots that break with the traditional linear narrative, revealing great aesthetic freedom that allowed sudden cuts and several angles and positions of the cameras. It addresses everyday issues and taboos, often portraying marginal characters, such as criminals, adulterers or rebels. Nouvelle Vague Cinema flourished in several countries, especially in Italy, Germany, Brazil and France.

### 2.1 Portuguese Nouvelle Vague Cinema

In Portugal, moving pictures were introduced by Aurélio Paz dos Reis (1862–1931), who in 1896, installed in Porto a replica of the Lumière brothers Cinematograph.

With a timid course, Portuguese cinema would be strongly marked by the regime cinema, developed to express the ideals of the political propaganda of Estado Novo – the dictatorial regime that remained in Portugal from 1926 to 1974.

In our country, the Nouvelle Vague Cinema was especially influenced by French cinema, largely due to the young Portuguese who performed their artistic studies in France. As leading personalities in this movement, we can highlight the directors Paulo Rocha, António Macedo, Fernando Lopes, António Reis, João César Monteiro, among others. It became clear that the desire to make cinema without many resources created a wave of inter-help between filmmakers and, as a result, a movement with unique characteristics was created.

There is no consensus regarding the Portuguese Nouvelle Vague birth date, nor regarding the first Portuguese Nouvelle Vague movie. Jorge Leitão Ramos states that the first movie was the short film *As Pedras e o Tempo* (1961) by Fernando Lopes (Leitão Ramos, s.d.) [11]. Other authors, such as Eduardo Prado Coelho (1983) [12] and Alves Costa (1978) [1] point out *Dom Roberto*, by Ernesto de Sousa, as the first evidence of Portuguese Nouvelle Vague, in 1962.

However, in Portugal, *Nouvelle Vague Cinema* would not have the same acceptance as abroad. In the words of Leitão Ramos, “What would be the object of admiration and applause abroad, would be a real weakness in Portugal. This movement, for many, was not well accepted: it was considered a slow, too intellectualized and often hermetic cinema” (Leitão Ramos, J, s.d.) [11].

### 3 The Poster: Paths and Technologies

To talk about the history of the poster is to talk about the history of graphic design. However, although there are pieces of graphic design that can be considered as posters since the tenth century, this communication object only increased its visibility since the nineteenth century, in the industrial revolution period and as a consequence of the lithographic printing process development. Several plastic artists took advantage of this process, exploiting their expressive possibilities and applying it to the posters, often approaching them to the language of painting.

“If art is not primarily communication but creation, then posters, with their prescribed function of advertising and propaganda, would seem to be only a secondary art form. Yet posters, in the first hundred years of their existence, have also had a curious relationship with painting” [3].

Among the artists who first distinguished in the art of the poster, we can highlight Jules Chéret (1836–1932), Eugène Grasset (1845–1917), Henry de Toulouse Lautrec (1864–1901), Théophile Alexander (1859–1923), Alfons Maria Mucha (1860–1939), among others. All these artists were part of the Art Nouveau movement, following a Japanese inspired aesthetic in which large patches of flat colours prevailed. These graphics were easy to reproduce in the lithographic process.

In the continuity of the poster evolution path, we must mention other movements emerged after the industrial revolution, that sought to find new ways of designing the products without losing the quality that characterized the period prior to the mechanized production, trying to reach a union between fine arts and applied arts. In the field of graphic communication, essentially simple and geometric shapes characterized these movements. Among them are the Glasgow School – with the particular language of Charles Rennie Mackintosh – the Viennese Secession – where we can highlight Gustav Klimt – and the Deutsche Werkbund – with clear intentions to rationalize, where Peter Behrens stands out. All these movements would give rise to the Bauhaus, a school that would indelibly mark the design landscape and constitute the basis for the discipline development in the 20th century – notably through the New Typography, Swiss Style and New York School movements [13].

#### 3.1 The Poster in Portugal

In Portugal, the poster evolution occurred in the same way that it occurred in graphic design in general. Great work was done, but there was always some delay regarding the European pioneers.

According to Barbosa [2], the first posters did not provide a great exploration of the illustration and gave more importance to the text message. The application of the

lithography process can only be observed in commercial posters from 1880, when the technique was still germinal, being used together with typography.

In the first decade of the twentieth century, with the advent of the first advertising companies, modern advertising strategies began to be explored, and the poster gained great importance. Afterwards, the 1920s was characterized by a special graphic innovation, resulting from a greater openness of mind and culture, which was manifested in several advertising posters. The arrival of Fred Kradolfer (Swiss designer who immigrated to Portugal) in the late 1920s, attributed to the Portuguese poster a geometric and expressionist Germanic feeling [15]. In addition to this designer, the names of Jorge Barradas, Carlos Botelho, José Rocha, Roberto Nobre, Bernardo Marques, António Soares, among others, stand out in this decade.

The 1930s is pointed out by Rui Afonso dos Santos [15] as the period of the official arrival of modernity to Portugal. To this arrival, may have contributed the international exhibitions in which Portugal participated and where graphic quality (especially of the posters) was one of major concerns. In the 1940s, alongside to the Estado Novo propaganda, some authors stood out with posters presenting constant graphic novelties. Helena Barbosa highlights Manuel Lapa, Maria Keil, Emmerico Nunes and Fred Kradolfer [2].

In the 50's, posters developed in particular due to the successive use of photography, made possible by the introduction of offset printing and by the assembly through photolithography. In this decade, Sebastião Rodrigues, one of the main references in the Portuguese design panorama, and in particular in the realm of poster design, was beginning to stand out [13]. We also have to mention Sena da Silva, who introduced a remarkable visual language in Portuguese graphic design, through the posters resulting from his collaboration with Autosil (1952).

In the 1960s, Sebastião Rodrigues, Paulo Guiherme, Sena Silva, Carlos Rocha, Victor Palla, among others, were also prominent creating graphics marked by strong visual effects based on strong colours and pictorial and formal contrasts [2].

In the 70's, we must highlight the explosion of posters related to the April 25<sup>th</sup> revolution, usually with clear drawings, with a strong illustration component, and full of vivid and contrasting colours. Several designers stand out, such as João Abel Manta, Sebastião Rodrigues and Marcelino Vespeira.

It is in these decades (after the 60's) that the affirmation and emancipation of the graphic designer profession in Portugal occurs. Until then, it was carried out essentially by plastic artists and sometimes considered a "minor" area of their creations [13].

### 3.2 The Movie Poster

The Cinema and the poster were predestined to follow a parallel path. The Cinema emerged at a time when the poster arouse in the life of the cities as a privileged means of communication for the performing arts, such as circus, theatre, carnival parties, etc.

The poster was the main link between the film and the spectator. It was anxiously expected, because, beyond the function of stimulating the viewer to see the film, it had the function of elucidation regarding the plot. It was an essential dissemination object,

but, after the film came out, it was discarded. The fact of having a commercial function devalued it at the time, not being considered an object of further interest:

“They were never intended to be great art. Daily, then weekly, the posters sheets were discarded as theatre programs changed. Through the decades they were consumed in scrap paper drives or thrown away, much as yesterday’s newspapers” [16 p. 5].

Bernard Lancy (French illustrator) opposes this idea, pointing out that using in the film poster the same design process used in the (generalist) advertising poster and judging it according to the same criteria, is extremely reductive for the film poster, which the author considers a special communication vehicle [14].

In 1920s America, the movie poster had as its main function not only to sow interest in the movie history, but also to preserve and strengthen the star system. Only the names of the stars stood out over the headlines, and the presence of a renowned actor was an essential factor for success. In European posters, the major importance was attached to the impact of the images for the film’s dissemination, than to the words or slogans: “(...) posters without words were created so they could be used in several countries despite their different languages” [16, p. 10].

After 1945, the quality of posters was affected by the post-war period. With the advent of television, the film industry inevitably saw the number of spectators decline and this caused a general crisis. The companies started cutting at various costs and posters were no exception. There was also another factor that influenced the experience of the movie posters: in the film magazines, the traditional pastel illustrations were replaced by colour photography. The posters graphic aspect would soon change, and the illustrations would look more like photographs:

“The exaggerations of colour and proportion that had given many poster their charm began to disappear, and the drawings became as realistic as possible.” (...) “By 1950 even Fox had abandoned stone litho entirely and, through the decade, offset printing became over coarser” [16, p. 16].

In the 1950s, the studio system hegemony in film production in the United States of America was declining. A strong rivalry between producers and independent film-makers began to grow. The independents eagerly sought to stand out and one of the ways to determine the exclusivity of each one was the creation of graphic identities to identify and distinguish them.

Saul Bass was one of the first designers to flee from clichés in movie posters, with a different graphic language, innovative both in the formal and narrative ways. This led to significant changes in the movie posters, which have been inert for decades.

The designer started to give importance to the central theme of the movie, creating posters with an unprecedented design, which highlighted the metaphor of the film, brilliantly characterized in an abstract and unique way. The poster for *The Man With the Golden Arm* (1955) became iconic, and beyond the poster, Bass also made the credit sequences for the film, which was a huge novelty in the area, since until then, these elements were not graphically worked and often were not even visualized by the viewers.

“Many of their credit sequences have a poetic quality, that both serves and transcends their functionality. What makes Bass a master in his field is his ability to combine highly original designs with popular appeal [10, p. 20].

Bass was also the author of posters like *Psycho* (1960), *North by Northwest* (1959), *Anatomy of a Murder* (1959), *Exodus* (1960), *Advise & Consent* (1962), *The Cardinal* (1963), among others. With its fresh and modern style, Saul Bass would be an inspiration to many other designers and would constitute a turning point in the history of the movie poster.

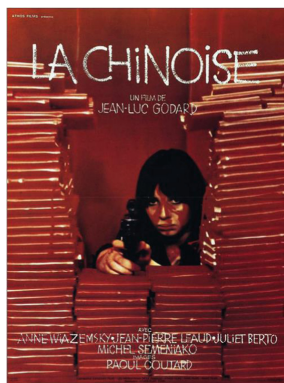
### 3.3 The Nouvelle Vague Movie Poster

In France, the transition from lithography to the offset printing system occurred in the late 1950s. As a consequence, drawing was replaced by photography, what caused a change in the design expression. But a new generation of poster designers was able to explore the technique of photography and create an innovative style, which would characterize the Nouvelle Vague movement.

In a general approach, there are some evident graphic aspects that make the Nouvelle Vague posters language cohesive and very unique. The use of picture collage is recurrent, – sometimes picking only details (face, torso, etc.) – and there is a great versatility in the typographic domain. The application of vibrant colors that somehow stands out (both in the text and in the background) is frequent. These posters have dynamic graphics and an intriguing expression that makes the posters and the film narrative more appealing (Figs. 1, 2, 3).



**Fig. 1.** *Muriel*, Alain Resnais, 1963. Source: <https://mubi.com/notebook/posts/movie-posters-of-the-week-the-films-of-alain-resnais>



**Fig. 2.** *La chinoise*, Jean-Luc Godard, 1967. Source: <https://mubi.com/pt/notebook/posts/movie-poster-of-the-week-jean-luc-godard-s-la-chinoise>



**Fig. 3.** *L'enfant sauvage*, Fran ois Truffaut, 1979. Source: <https://www.imdb.com/title/tt0064285/mediaviewer/rm4127064320>

### 3.4 The Portuguese Nouvelle Vague Poster

Portugal did not really develop a movie poster culture, although excellent designers and excellent posters existed. This fact could be related to facts like the cultural underdevelopment comparing to other countries, the Portuguese Cinema fragility and the lack of international visibility and with the producers' scepticism about the influence that a good poster could have on the success of a film.

Portuguese Nouvelle Vague films did not always have a poster, since budgets were very limited and some of these films only circulated among cinema clubs and private sessions and sometimes, as Jorge Silva Melo states in an interview, they even premiered years after being completed [17]. However, since there are no publications on this subject, we were able, through our investigation, to identify the main designers who conceived posters for Portuguese Nouvelle Vague Cinema and that, despite the idiosyncrasies of the period, developed quality work, which deserves to be studied and settled in the national design history. They are: Marcelino Vespiera (1925–2002), João Abel Manta (1928), Sebastião Rodrigues (1929–1997), João Câmara Leme (1930–1984), Armando Alves (1935), Edgar Valdez Marcelo (1939–1990), Judith Cília (n.1946), José Brandão (n.1944) and João Botelho (n.1949).

## 4 The New Cinema Poster in Portugal: Analysis and Characteristics

In our investigation we collected a set of 73 posters representative of the Portuguese Nouvelle Vague Cinema graphic design. In this collection we don't find a particular cohesion of language or elements to characterize these posters.

Judite Cília, author of most of these 73 posters, has a highly versatile graphic capacity, hampering to distinguish the posters designed by her from the ones designed by other authors. Most of other designers (or artists) of our collected posters, conceived only one piece, which also contributes to this "graphic dispersion". However, the intrinsic poetic factor of each poster is the characteristic that really distinguishes them and calls for some observation and reflection.

In order to better know and characterize our study object, we decided to select twelve posters to analyse. This choice was based on some criteria. In the first place, we chose different posters' authors and filmmakers, considering the graphic language diversity and formal aspects (photography, illustration, mixed technique). Secondly, we intend to represent several film categories: social, political and literary adaptation. Third, we tried to analyse objects that used various techniques (in order to understand their influence on the expressiveness of the poster).

In order to make the analysis of these graphical objects in a coherent and effective way, we conceived an analysis model – based on the one used by Elisabete Rolo in the Phd thesis "Olhar, jogo, espírito de serviço [look, play, spirit of service]: Sebastião Rodrigues and graphic design in Portugal" [13], also based on Laurent Gervereau analysis grid [9] – adapting it to the particularities of the cinema poster as a graphic object (Table 1).



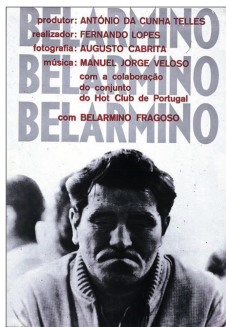
**Table 1.** Analysis model. *Source: The authors.*

Director's name
Poster's author
Poster dimensions
Date
Analysis of the whole composition – elements with higher visual weight.
Technique (illustration, photography, etc.).
Inventory of the elements represented and composition framing.
Interpretation – film narrative and relation with the element s/ symbology.
Information Hierarchy.
Headings Formal analysis and technical details / typeface.
Number of printing colours

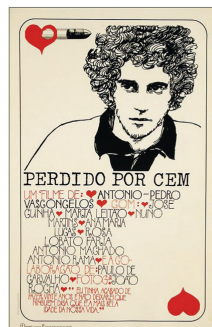
In Figs. 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 and 15, we can see the 12 posters chosen for analysis.



**Fig. 4.** *Dom Roberto*  
Director: Ernesto de  
Sousa | Author: Armando  
Alves | Dimensions:  
120 × 90 cm | 1962  
Source: Arquivo digital  
da Cinemateca



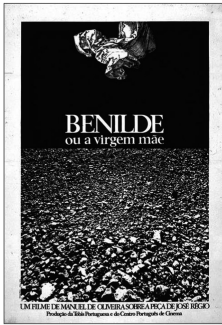
**Fig. 5.** *Belarmino*  
Director: Fernando  
Lopes | Author: Sebas-  
tião Rodrigues | Dimen-  
sions: 100 × 68 cm |  
1964 Source: Arquivo  
digital da Cinemateca



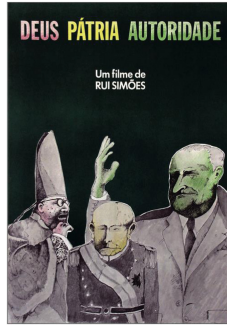
**Fig. 6.** *Perdido por Cem*  
 Director: António Pedro-  
 Vasconcelos | Author:  
 Guilherme Lopes Alves |  
 Dimensions: 87 × 56 cm |  
 1973. Source: Arquivo dig-  
 ital da Cinemateca

Despite the unique and distinct character of each collected poster, the analysis of these 12 copies showed several aspects. The posters show large, flat-colored backgrounds (except *Francisca* poster), and it is possible to observe that sober colors are prevalent. The use of sans-serif typefaces is more frequent than the serif type, and in general, the posters have a hierarchical structure that gives more emphasis to the headline, and then to the director. Only in the posters *Dom Roberto* and *Belarmino* the actors' names have more importance than the director's. Photography (applying the high contrast technique) and illustration are used, through a variety of materials.





**Fig. 7.** *Benilde ou Virgem Mãe* Director: Manoel de Oliveira | Author: João Abel Manta | Dimensions: 100 × 70 cm | 1975 Source: Arquivo digital da Cinemateca



**Fig. 8.** *Deus, Pátria, Autoridade* Director: Rui Simões | Author: José Brandão | Dimensions: 64 × 48 cm | 1976 Source: *Ceia, A (Coord.)*, 2014. José Brandão, Designer: cultura e prática do design gráfico. Fundação Calouste Gulbenkian, Lisboa [8].



**Fig. 9.** *Trás-os-Montes* Director: António Reis e Margarida Cordeiro | Author: João Câmara Leme | Dimensions: 98 × 68 cm | 1976. Source: *Ceia, A (Coord.)*, 2014. José Brandão, Designer: cultura e prática do design gráfico. Fundação Calouste Gulbenkian, Lisboa [8].



**Fig. 10.** *As ruínas no interior* Director: José de Sá Caetano | Author: João Abel Manta | Dimensions: 80 × 53 cm | 1977 Source: Arquivo digital da Cinemateca



**Fig. 11.** *Areia, lodo e mar* Director: Amílcar Lyra | Author: Judite Cília | Dimensions: 68 × 48 cm | 1978 Source: *Colecção digital de Judite Cília*



**Fig. 12.** *Nós por cá todos bem* Director: Fernando Lopes | Author: Marcelino Vespeira | Dimensions: 80 × 53 cm | 1978 Source: Arquivo digital da Cinemateca

From the 12 posters, only 4 are printed in 4 or more colors. The typography is little explored, except for *Dom Roberto*, *Belarmino* and *Perdido for Cem*. In the latter, the text is integrated with the rest of the composition, which doesn't happen in any other case.

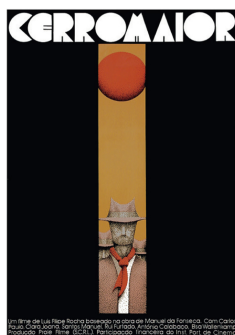
The details of the film narrative are not revealed in an obvious way, except for some posters, which are slightly more explicit (*Dom Roberto*, *Francisca* and *Deus, Pátria, Autoridade*). The characters do not convey any kind of positive emotion, except for *Dom Roberto* poster.

In the majority of the posters we can notice a strong light/shadow contrast, except in *Perdido por Cem*. Particular attention is paid to the symmetry and balance of composition and, in general, all of these posters convey poetic sensitivity.

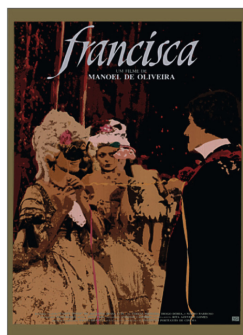
In order to understand if the Nouvelle Vague movement principles would have influenced the conception of the analysed posters, we have crossed some of its main characteristics in Table 2.

We can thus perceive that the inexpensive filmmaking mode is not accompanied by inexpensive printing modes in posters. It is known that in the cinema a great financial effort was necessary to produce films, and sometimes the productions were subsidized through the help among the filmmakers, as João Bénard da Costa states relatively to the *Dom Roberto* movie [4–6]. Opposed to this reality, we can observe the *Francisca* poster printed in silkscreen with more than 60 ink layers. This leads us to conclude that the modes of printing were not necessarily the cheapest ones.

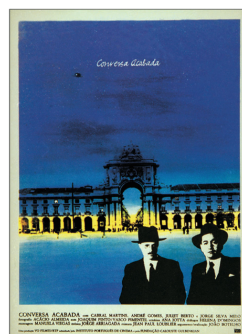
The French Nouvelle Vague influence present in Portuguese films is not evident in Portuguese posters. French Nouvelle Vague posters are marked by the photography exploitation, while the Portuguese ones, despite using photography, don't manipulate it in the same way. The poster for *Nós por cá todos bem* is, perhaps, the one that more approaches, using the mixed technique of illustration and photography. The designers' statements also support this conclusion, since they stated not having received this influence.



**Fig. 13.** *Cerromaior*  
Director: Luís Filipe Rocha | Author: Edgar Valdez Marcelo | Dimensions: 69 × 46 cm | 1980  
Source: Arquivo digital da Cinemateca



**Fig. 14.** *Francisca*  
Director: Manoel de Oliveira | Author: Judite Cília | Dimensions: 100,5 × 705 cm | 1981  
Source: Coleção digital de Judite Cília



**Fig. 15.** *Conversa Acabada*  
Director: João Botelho | Author: João Botelho | Dimensions: 100 × 70 cm | 1982  
Source: Arquivo digital da Cinemateca

**Table 2.** Portuguese Nouvelle Vague cinema and posters.

Portuguese Nouvelle vague cinema features	Portuguese Nouvelle Vague poster graphic characteristics	Common aspects
New filming mode	Especially innovative techniques	✓
Free and cheaper filming mode	Cheaper printing modes	×
It is not done “for” (it is not done to please the public, that is, for a purely commercial cinema)	The poster does not have as main objective to have commercial impact	✓
Poetic	Conveys poetic sensibility	✓
Breaks with the previous cinema	Break with the previous graphics	✓
Influenced by Nouvelle Vague	Influenced by the graphic design of the Nouvelle Vague posters	×

Source: The Authors.

Regarding the characteristics that the graphic and cinematographic areas have in common, we can say that there are especially innovative techniques in the Portuguese Nouvelle Vague Cinema posters. This is confirmed by the analysis of the twelve posters, which present a variety of textures and materials very different from the previous posters, which, in general, had very colorful and realistic illustrations.

Regarding the disruption of these posters with its predecessors, the interviewed designers were asked if there was any intention to break with the previous graphics. The answers mentioned that each poster should have its own approach and should serve the film, with no intention of breaking with the previous realism. Above all, it was imperative to see the movie and capture an idea that would define it.

We can assume that the Portuguese Nouvelle Vague Cinema posters corresponded to a desire to dignify the film, but were not the main advertising means and did not pursued commercial impact. The irrefutable beauty of some posters did not appear to have the intention to persuade the public, except in a few cases. As João Botelho states, “in the Portuguese Nouvelle Vague posters the ideas were much more abstract and there was not much appeal to easy things, to the *voyeurism* that some movies bring” [7].

## 5 Conclusion

With this brief research about the cinema and the cinema poster and the analysis of the selected posters, we can tell that there are no graphic stereotypes. Each poster had unique characteristics that differentiate it from all the others. However, this study allows us to observe in the posters some graphic characteristics identifying the cinematographic movement.

We are aware that the Portuguese cinema poster is very wide and is not yet explored and there are many aspects that deserve special attention. Thus, in future studies, it would be of great interest to approach the theme of the movie poster considering other temporal periods. And, in parallel and with the same kind of approach, it would be pertinent to study the poster in other areas of cultural activity, such as theater, ballet or music.

**Acknowledgments.** The authors gratefully acknowledge the support to this paper presentation by CIAUD, only possible by National Funds by FCT – Fundação para a Ciência e Tecnologia, Portugal.

## References

1. Alves Costa, H.: Breve história do cinema português: (1896–1962) [Brief history of Portuguese cinema: (1896–1962)]. ICLP, Lisboa (1978)
2. Barbosa, H.: Uma história do design do cartaz português do século XVII ao século XX. [A history of Portuguese poster design from the 17th to the 20th century]. Tese de Doutoramento, Universidade de Aveiro, Aveiro (2011)
3. Barnicoat, J.: A Concise History of Posters. Thames and Hudson, London (1975)
4. Bénard da Costa, J.: O Cinema Português nunca existiu. [Portuguese Cinema never existed]. CTT Correios, Lisboa (1996)
5. Bénard da Costa, J.: Cinema português: anos Gulbenkian. [Portuguese cinema: Gulbenkian years]. Fundação Calouste Gulbenkian, Lisboa (2007)
6. Bénard da Costa, J.: Manoel de Oliveira. Instituto Camões, Lisboa (2011)
7. Botelho, J.: Entrevista realizada pelas autoras [interview conducted by the authors] (2016)
8. Ceia, A (Coord.): José Brandão, Designer: cultura e prática do design gráfico. Fundação Calouste Gulbenkian, Lisboa (2014)
9. Gervereau, L.: Ver, Compreender, Analisar as Imagens [View, Understand, Analyze Images]. Edições 70, Lisboa (2007)
10. Horak, J.: Saul Bass: Anatomy of Film Design. The University Press of Kentucky, Kentucky (2014)
11. Leitão Ramos, J., et al.: As Revistas de Cinema [The Cinema Magazines] (s.d.)
12. Prado Coelho, E.: Vinte anos de cinema português: 1962–1982 [Twenty years of Portuguese cinema: 1962–1982]. Instituto de Cultura e Língua Portuguesa, Lisboa (1983)
13. Rolo, E.: Olhar | jogo | espírito de serviço: Sebastião Rodrigues e o Design Gráfico em Portugal [Look | play | spirit of service: Sebastião Rodrigues and Graphic Design in Portugal] [Tese de Doutoramento em design]. Faculdade de Arquitectura da Universidade de Lisboa, Lisboa (2015)
14. Rouch, J.: Catálogo da Exposição L’Affiche de Cinema de 1895–1946 [Catalog of the Exposition L’Affiche de Cinema 1895–1946]. Imprimerie Bedos & Cie., Paris (1946)
15. Santos, R.: O Design e a Decoração em Portugal: 1900–1994 [Design and Decoration in Portugal: 1900–1994]. História da Arte Portuguesa: Do Barroco à Contemporaneidade. Círculo de Leitores, Lisboa (1995)
16. Schapiro, S.: The Movie Poster Book. E.P. Dutton, Nova Iorque (1979)
17. Silva Melo, J.: Entrevista realizada pelas autoras (2016). [Interview conducted by the authors]



# At Hand, the Brain of Men

Luis Miguel Ginja<sup>(✉)</sup>

CIAUD – Centro de Investigação em Arquitectura,  
Urbanismo e Design, Faculdade de Arquitectura, Universidade de Lisboa,  
Rua Sá Nogueira, Pólo Universitário, Alto da Ajuda, 1349-055 Lisbon, Portugal  
lmg@fa.ulisboa.pt

**Abstract.** This paper intends to develop questions related to the creation and use of objects. We like to address the way the objects, can shape not only the world, but our self's in the process. Taking the dichotomy brain-hand as a starting point, we wish to inquire, the interactions of the hand as a construct of the brain. The intellectual proximity between the two creates a bound: the hand acts, the brain thinks, they both create. Tendentially the hand that shapes a material, arouses as an instrument, more or less virtuous, that follows bioelectrical impulses capable of altering that material. The brain would then be the master of these movements, orchestrating the whole. The hand and its manual labour appear as subaltern of the brain, the centre of intellectual work. However, another image seems to emerge from this process. The hands shape the objects, not just as subsidiary servants of brain impulses, but as main actors. To finish we would like to arise the question of emotions and feelings, as a part of the brain process, and try to understand the effect of the fact that the hand was transformed from a prime actor to a mere supporting role.

**Keywords:** Product design · Hand · Brain · Emotions · Feelings

## 1 Introduction

*“... and to see the centuries that continue to pass, swift and turbulent, generations overlapping the generations, some sad, like the Hebrews of the captivity, others joyful, like the debaucheries of Cômodo, and all of them punctual in the grave. I wanted to escape, but a mysterious force kept my feet; then he said to me: ‘Well, the centuries are passing, mine will come, and it will pass also, to the last that will give me the decipherment of eternity.’ And I fixed my eyes, and continued to see the ages, coming and going, then calm and resolute, don’t I know if cheerful. Maybe cheerful. Each century brought its share of shadow and light, apathy and combat, truth and error, and its courtship of systems, new ideas, new illusions; in each of greens a spring burst, and they yellowed afterwards, to start over later. While life had a calendar regularity, history and civilization were made, and man, naked and unarmed, armed and dressed, built the thugium and the palace, the rude village and the hundred-door Thebes, he created science, which he was examining, and the art he enveloped, became an orator, a mechanic, a philosopher, ran the face of the globe, descended into the womb of the*

*Earth, ascended to the sphere of clouds, thus collaborating in the mysterious work with which he entertained the need of life and the melancholy of helplessness.”* <sup>[TL]<sup>1</sup></sup> [1].

To begin is to first find a meaning. As a formal way of thinking, beginning is always toward a future, a cause effect. To begin something presupposes an action in the present time, which spreads in the immediate or distant future. We do not think actively, that present actions can change past facts, we can rather build a future action, based on past knowledge. We then speak of origins and destinies, possibly, and in a consensual way, the main concern of Human endeavour.

This concern for what’s to come, the notion of future, which we all increasingly, feel responsible for several reasons. Whether it is cultural, bioclimatic, technological or purely because we want better and better conditions for future generations to ensure our survival as a species. This legacy thought, of the world we are building, or what our children will inherit from us, is a reflection of the search for our eternal soul. We immortalize ourselves in what we project, obsessed in this construction that will necessarily guarantee us eternity, if not of the soul, at least of memory. We can all see this, even if it is far from scientific validations. We seek excellence in what we do and peer recognition, or the simple footnote in the annals of history on a professional or personal level. This is for now, however succinctly, our demand as a modern society.

Nevertheless, the information available in Modern society has not yet quenched another demand. A search that goes beyond simple curiosity, because of the power it has over us. We speak then of the strong desire to know who was constituted memory before us, or perhaps even more importantly, how that process occurred. In broad strokes, the pursuit of an origin, not only of a point, but as a construction. We yearn for the fundamental and powerful search of our sources, from the slow prehistoric rise to the construction of our present thinking. Important to note that we do not understand this, as only cumulative, would be detrimental to the investigation. It only makes sense in the dialectic of its construction, plunging into the past and looking at our future as a species, otherwise it merely masks, or replaces, religious myths with scientific facts. It would then be prudent, before even going too far, to understand the man who saw himself as Man.

## 2 The Hand, from Yesterday

To understand this quasi-palindrome, it is important to define what we understand as Man, that is, what are the fundamental criteria of humanity. In this almost human origin, we diverge from other animals in the sense that even today science can not specify. Thus, the current man is away from the primate over 70 million years, 200 thousand years of Homo Sapiens who gave us birth and just over 200 years of the first observations by John Frere (1740–1807), made over animal bones and use the of chipped flint [2]. It would take about 50 more years for this connection between primitive man and primate to be considered, which, though wrapped in discussion, by Charles Darwin (1809–1892). This discussion is in part due to Darwin being a

<sup>1</sup> Machado de Assis, *Memórias póstumas de Brás Cubas*, 34–35.

naturalist not an anthropologist, yet to him we forever owe the connection that man descends from the primate. This historical landmark of 1850 - Darwin publishes *The Origin of Species* in 1859 - will be marked as a point of no return in the obscurantism in which our evolution was immersed. The archaeological investigations that have taken place since then to this day increasingly clarify our origin and how we become who we are, from an evolutionary point of view. With the beginning of the twentieth century and the new scientific impetus, countless discoveries have been made that make the connection between men and primates increasingly clear. In order to accelerate events that were slow in their genesis, it is then necessary to identify what brings us closer together and why the evolutionary link between primates and men, or by what means the primate that become man. Looking back on history today, as Walter Benjamin (1892–1940) in the way he so cautiously advises us [3], we denoted that the difference was already been established at the first observation.

The use of chipped flint, that is, of utensils, implies the release of the hand thus differentiating us from the primates by the purpose of the technical activity, thus guessing that this release of the hand, allowed the locomotion in the vertical position.

The hand is by itself the great conductor in the epic that goes from the primate to the man. The hand allowed the man the transformation of the face, from a holding organ, as in other animals, to an organ of communication. In this same face the skull develops to accommodate a larger brain thus allowing the evolution of thought, and without any room for doubt the evolution of the technique. The totality of animal evolution is based on technique. The release of the aquatic environment by fishes, the elevation of the head from the soil as the reptiles, the release of the hand by the primates, the locution as hominids and finally the release of the brain, enabling the face [2] for the use of language as *Homo Sapiens*.

This evolutionism starts us in the epic of the hand, and we return to the shooting question of the proposed investigation, how did man become a man? Jean Brun (1919–1994) may point us into a less travelled path, quoting Oswald Spengler (1880–1936) in his book *La Main et l'esprit* (1963), however, we have narrowed down the framework we seek to address. We are then carried away by the direct comparison between the hand and the weapon - already here an object of use of the hand - unequalled combination in the world of free movement. To the predator's eye in which we have become, which we acquire with the technique, and which apprehends in theoretical terms, the world around us. The hand of the man who comes to dominate it in practical terms is added [4]. We denote the presence of theory and combined practice to shape the intellect. It is precisely here that Jean Brun instils in us the further examination of the technique of evolution, or how things have become things, not just as man became man, we are forced to face how things and men have become what we are. Evolution derives from the symbiosis of both. All the characteristics that we state as criteria of humanity, that is, the hand, the vertical position, the locomotion and the language, are crossed by the utensils that we use [4]. They, the objects, or things, have become an important part of what constituted us, and continues to constitute still today as men, through the hand from yesterday.



### 3 The Brain of Today

Roberto Esposito (n.1950) in *Le persone e le cose* (2016) remind us that our civilization is fundamentally marked by this chapter division, as if it were a pact between people and things. Things are distinguished by the fact that they are not people and in turn things are distinguished by the fact that they are not people [5]. So, the role of things is to serve people, in turn people are people because they have things. As stated by Esposito, we realize that much of this relation today is fundamentally substantiated in the echoes of ancient Roman law, where legal order is based, we are more interested in examining such implications in the field of the brain, or in the way they influence thought.

The clarity of the scientific method obliges us to make a short parenthesis about things. It is intended the use of the term thing to designate objects or utensils within the strict scope of this investigation. The philosophical character of the word is not used by us far from is broad spectrum. The thing itself is something unspeakable, for if we give it a linguistic code, which mediates our understanding of objects - and of people - facilitating communication, but we empty the thing of meaning by leaving only the void of the designation applied. As a conclusive conclusion for closing this side note, we only want to leave the suggestion that things are more than the mere characterization of objects, but to facilitate communication between people and things, we diminish the meaning of things by calling them objects. A book for example is in itself something superior to the linguistic code of the letters that compose it as word.

After the clarification of the ambivalence that the use of the term thing may have risen, and after the short excursion explanatory - deliberately excuses references that would lead us to a text unbearable to the spectrum that it is designated [6] - it is then time to return to the theme. We deduce, what we had already asked: whether the hand has given rise to the evolution of the brain in stride, and whether it has happened through the symbiosis between hand and object, or thing to report the utensil to its degree of immanence - to summon it in its absolute degree of purity and ideological decontextualization with which the present century has overloaded the objects - what is the importance of the objects in the construction of the brain?

In the practice of tracking these relationships, almost to the degree of absolute certainty, they have led us to construct the emotions and feelings that the objects can cause in us. The relation of the hand to objects, which we can call evolution today, instills in the brain the construction and refinement of thought. By this we mean that if the hand is part of the great construct of the brain, the brain in its opposite sense developed emotions and feelings on its own, towards the tools that gave it that knowledge. It will not be premature to say today that both hand and brain enjoy this knowledge, and both share and experience it. The body orchestrates an action program that serves as a trigger for emotions. From the hand in specific, as a part of the body, can voluntarily emerge an emotion through an action, the touch. The grasp of an object is associated with this behaviour, cerebral without a doubt, but always upstream of what we understand as feelings. Feelings are much more immanent in character, largely chemical processes that the brain makes in response to an emotion. That is, emotions as phenomena perceived by the brain of the actions of the body, the feelings on their side



are the mental, or cerebral, experience of that bodily action [7]. The feelings lead us to brain states that are originated by particular movements, for example the hand, to cite the example in question. The interaction of the hand with the objects we use is a form of knowledge of the world in general, that lead us, for instance, to emotions. Knowledge, in the double sense of the word. We discover the world through our sensory and empirical experience, in the same way that we are shaping the brain and building the mind-building from the reading of the world.

In this world, on which we interact, there are a multiplicity of connections, how many people there are. It is in the social totality that we understand the world today. Moving forward in an increasingly globalized world, it is composed not only of our close sphere of experience, but of a spectrum encompassing all human cultures. We derive in this way that the construction of our brain derives mainly from a social experience and from the interactivity we have with others and with the objects that consolidate our world. The design of objects, whether hand-scaled or body-wide, we speak here of buildings or cities, has a decisive influence on the construction of the brain of today.

## 4 The Man, Tomorrow

Neuroscience is certainly a branch of medicine that has advanced mainly in recent years and has rapidly become not only a form of knowledge for modern man but has mainly been a window that gradually opens onto the man of the past. How we have evolved, or what processes we have taken to constitute ourselves or how have become, is undoubtedly the great question which, if not the whole of humanity tries to uncover. Myths have always tried to appease these longings; they became a form of questioning since the classical formation of philosophy. This question is surely extending beyond modern philosophy, and we believe, will continue to constitute the imagery of the future man. How we came to be what we are.

Today, however, we are certain the history we know is singularly a *in media res* narration. We do not hold all the facts that can clarify what we are, where we came from and look forward even more wary about the path we are following. Is safe, however, to assume by the latest scientific advances that assure us, our brain structure has been developed by mechanisms of interconnection between hand and objects articulated by the technique. That is, as we have already mentioned, although it is a recent fact of our scientific evolution, this is somehow connected to the field of human emotions. Our brain was developed based on emotional attachments to the objects of use, tools or utensils. It was them who perhaps produced, the spark, which of divine will only have its character of inexplicability, but which lead us, still today to be who we are. The objects we use, draw or simply use without realizing that they exist, are the most reliable source of understanding our unconscious.

It will not take a degree of great scholarship to prove what we say, just a dedicated look at historical episodes. The scientific revolution from XVI to XVII would not be possible without the dynamic pairing of the brain and the human hand. Galileo did not impel science only with the narrative that what he claimed was contradictory to what existed as validity, earth as the center of the Universe. The claim he made would not be

welcomed for historical reasons well known and based only on the fictional disadvantage of the brain. But if we look more closely, we realize that only the harmony between the pair that we summoned, hand and brain, enabled a path of enlightenment to the true of facts. Galileo would eventually come in the end by withdrawing his claims, however, the legacy of this brain's observational and fictional ability, aided closely by the hand and the utensil, was what in the first instance allowed the earth to pass from the centre of the universe to be only a point more, in a vastness, of points still to this day, unfathomable.

We make clear the direction where the investigation led us. If, since prehistory, that human evolution is rooted in a construction of the intellect of man through processes of empirical nature, hand-brain, what is today the effect of this primordial relation? Do the objects we use continue to serve as a construct to our intellect?

Certain that we do not have in hand the answers to the hypothesis, is possible in the meanwhile make note and alert for the design of the problem in human production. Traversed increasingly by technological means, design processes are today a clear reflection of experience, which is reviewed in the intelligence of man. We must become aware that the objects, or things in their immanent sense, that we use today continue to have effect in a process that began thousands of years ago, and which is still as active today as it was then [8]. The technology has allowed the gear ratio multiplier in human production. If this same technology in its first instance, allowed only leveraging force and multiplication of the efforts of the hand, today, the hand, has become only a tool of interaction, not of action. Thus, we see that the rest of the hand has cut off the ancestral empirical flow between hand and brain, failing to feed our most precious resource, the intellect [9]. This cut has an effect that we believe even more nefarious if we put it in line with the emotions and the feelings. As we explained the emotions have their origin in the body and repercussions in the mind, thus triggering the feelings. If the hand, for example, misaligns its relationship with objects, thus preventing the triggering of emotions, can we live without feelings?

**Acknowledgments.** The Author gratefully acknowledges the support to this paper presentation by CIAUD, only possible by National Funds by FCT – Fundação para a Ciência e Tecnologia, Portugal.

## References

1. Machado de Assis. *Memórias póstumas de Brás Cubas*. Editora Guerra & Paz, Lisboa (2014)
2. Leroi - Gourhan, A.: *O Gesto e a Palavra - I - Técnica e Linguagem*, Edições 70, Lisboa (1985)
3. Benjamin, W.: *Sobre Arte, Técnica, Linguagem e Política*. Relógio d'Aqua, Lisboa (2012)
4. Brun, J.: *A Mão e o Espírito*. 1.a ed, Ed. 70, Lisboa (1991)
5. Esposito, R.: *As Pessoas e as Coisas*. 1.a ed, Rafael Copetti, São Paulo (2016)
6. Heidegger, M.: *Que é uma coisa? Doutrina de Kant dos princípios transcendentais*, Edições 70, Lisboa (2002)
7. Damásio, A.R.: *O erro de Descartes: emoção, razão e cérebro humano*. 9a. Reprint, Publicações Europa-América, Lisboa (1997)

8. Pallasmaa, J.: *The Eyes of the Skin: Architecture and the Senses*, 3rd edn. Wiley, Chichester (2012)
9. Ginja, L.M.: Form of the space in between objects. In: Bagnara, S., Tartaglia, R., Albolino, S., Alexander, T., Fujita, Y. (eds.) *Proceedings of the 20th Congress of the International Ergonomics Association, IEA 2018. Advances in Intelligent Systems and Computing*, vol. 824. Springer, Cham (2019)



# Exploring Design Requirements of Outdoor Fitness Equipment for Young People

Aylin Karadeniz<sup>(✉)</sup>, Melis Dursun, and Gülşen Töre-Yargın

METU/BILTIR-UTEST Product Usability Unit,  
Department of Industrial Design, Middle East Technical University,  
Dumlupınar Bulv. Üniversiteler Mah. No: 1, 06800 Ankara, Turkey  
{aylin.karadeniz,melis.dursun,tore}@metu.edu.tr

**Abstract.** Outdoor Fitness Equipment (OFE) can support public health by making physical activity available to all segments of the society. However, our knowledge is limited regarding how young people can adopt this equipment. Therefore, this study set out to explore (1) motivators of young people to do sports, (2) their perspective towards being physically active outside and (3) how to increase their outdoor physical activity level and OFE usage through design. Therefore, a cultural probes study and interviews were conducted with twelve participants aged between 20–30 years old, who do sports at home or gym. As a result, three types of needs were identified namely personal, social and practical needs. Moreover, design requirements are identified which are focusing on equipment, space, and service. As a result, this study provides brief guidance for designers and urban planners to meet young people's needs about doing sport outside.

**Keywords:** Physical activity · Outdoor Fitness Equipment (OFE) · Cultural probes · Product design

## 1 Introduction

Technology leads people to decrease the amount of physical activity in their daily lives [1]. Society has become such that everything is performed electronically and/or behind a desk, in a seated position. In addition, the preference for cars and other motorized transport has increased in recent decades. It is obvious that these developments have crucial impacts on reducing physical activity. Insufficient physical activity accounts for main health problems as it leads to rise in obesity and chronic diseases such as diabetes, heart disease and cancer [2, 3]. In addition, healthcare system has a great burden over recent few decades and it is known that deterring people from sedentary lifestyle reduce healthcare costs [4]. Moreover, it is clear that physical activity has many benefits to human health [5–9]. As such, adults and young people should weekly allocate certain time for intense physical activity [10]. However, it is not easy to change an inactive lifestyle and persuade people to exercise physically. Changing people's behavior in positive ways and motivating them with design interventions have been studied in the last decade [11–13]. Accordingly, there are technologies which are developed for persuading people to change their behavior towards more active life [14]

and number of outdoor fitness facilities and Outdoor Fitness Equipment (OFE) has been increasing day by day to convince people to do physical activity [15]. Currently, outdoor facilities are widely available for all segments of society and there are several studies which focus on enhancing and encouraging usage of outdoor fitness facilities and equipment [16, 17]. However, our knowledge is limited regarding the strategies for motivating young people to adopt this equipment and facilities. Therefore, the study aims to explore (1) motivators of young people to do sports, (2) their perspective towards being physically active outside and (3) how to increase their outdoor physical activity level and OFE usage through design. In order to explore these issues, a cultural probes study and interviews were conducted with twelve participants aged between 20–30 years old, who do sports at home or gym. In the following sections, first benefits and considerations related to outdoor physical activity and OFE are overviewed. Then, the methodology which involves cultural probes and interviews with young individuals is introduced. After that, the results of the study are presented by emphasizing the needs and expectations of young people regarding outdoor physical activity. Finally, the paper is concluded with our discussions and design suggestions related to OFE based on different activity levels.

## 2 Outdoor Physical Activity and Outdoor Fitness Equipment

Doing physical activities in outdoor environments have many benefits to human health both mentally and physically by helping people to reduce their stress and depression, gain self-confidence and increase their energy [18]. As such, people associate outdoor physical activities with positive emotions, satisfaction, spirituality and socialization [19]. To carry out such activities, public parks have been recognized as optimal settings by supporting public health through facilities such as OFE and outdoor group sessions [20]. Having these kinds of facilities, such as OFE, have also potentials to increase the usage of public parks [4, 21]. OFE involves workout tools with defined fitness aims or targeting a certain area of the body and they are usually inspired by the equipment designs available in indoor gyms and rehabilitation clinics [22]. Contemporary OFE provides free usage for public, thereby helping them to be physically active, improving their health and enabling social interactions, previously which were only available in indoor gyms [22, 23]. With the widespread availability of OFE, guidance on how to use them appropriately has been a critical issue [22]. For example, many cases for reckless usage of this equipment are identified, which may result in critical injuries [24]. Therefore, this topic has started to be investigated by fitness equipment and health promotion agencies. To illustrate, ‘A How to Use an Outdoor Gym Guide’ includes directions about effective and safe usage, which enables users to achieve proper health outcomes and prevents from injuries, getting bored and crowding in OFE zones [22, 25]. However, these kinds of sources are often not accessible by regular users of OFE unless they specifically search for them.

In a study about the impact of an outdoor gym installation on park users’ physical activity levels, it is shown that there is an increase in usage of parks by adults after installing outdoor gym facilities [26]. However, the literature is limited in terms of

young adults' point of view towards these parks with OFE. Factors such as lack of awareness regarding urban parks and outdoor facilities and lack of promotion strategies has negative impacts on participation to these outdoor activities [4, 27]. For increasing the number of visitors in outdoor gyms, events and free exercises organized in public parks are recommended as effective strategies [21, 26]. Moreover, it is also suggested that combining outdoor physical activities including walking, cycling or playground for children with OFE zone may also raise awareness towards physical activity, encourage use and attract inexperienced users [25, 26]. Nonetheless, these strategies are mostly focused on more generic services and approaches which can be applied and adopted by governmental bodies; however, design strategies to motivate young people to use OFE can be of great benefit while designing this equipment. In order to explore such strategies, our study examines the current motivators of youth for being active, their perceptions related to doing sport with OFE and their considerations related to design of OFE. In the following section, the methodology for achieving this aim is presented.

### 3 Methodology

In order to meet the aim of the study, we decided to focus on exploring young people's lifestyle and current experiences through ethnographic techniques [28]. Thus, cultural probes were prepared, and they were followed by semi-structured interviews conducted to understand users' habits, thoughts about being active and expectations for outdoor fitness equipment.

Cultural probes as a technique is specifically adapted for research activities that are investigating people's lifestyle and everyday habits when eliciting information is difficult with traditional methods such as observation and interviews. Probes are designed to gather detailed information from people about their lives while directing participants to collect data about themselves [29]. In order to figure out young people's sport activities, motivations, and values, we designed a collection of cultural probes tasks included in 'probe packs' (Fig. 1) and distributed them to 15 participants for a week. The tasks written on separate cards included three activities: *Task 1* involved a four-day Sport Diary aiming to understand the participants sport habits and needs. The diary included questions about the type of the activity, where, when, how long and with whom the activity was carried out and a timeline to record the process visually. *Task 2* included picture-taking tasks through five assignments in the form of 'hashtagged' statements: "#My sport motivation...", "#I feel best when...", "#I feel bad when...", "#My favorite equipment", and "#My favorite sport place". Participants were asked to take photos according to these hashtags in order to understand their opinions, values and motivations about being active. *Task 3* contains an assignment which asked the participant to do sport outside by visiting an outdoor public park and using OFE and take photos of the equipment they like or dislike. Through this task, we aimed to explore their perceptions about using OFE and its design.

Task 1: Sport Diary

Date:

when?

where?

which sport?

Duration?

with whom?

Home

Morning

Cardio

Yoga

15-40 min

Alone

Fitness Center

Evening

Fitness

Plates

60-90 min

Partner

Park

Night

Weight

Dance

90-120 min

Alone

Sport Process:

Write your own sports process by taking advantage of the attached sports process card. You can review the example below.

Start

Finish

Example: start aerobic weight walking break shower finish

Task 2: Hashtags

Photograph the following hashtags for your sports activities. You can use frames provided to you when photographing.

Hashtags:

#My sport motivation...

#I feel best when...

#I feel bad when...

#My favorite equipment

#My favorite sport place

Task 3: Exercise in Outdoor

Exercise for at least 15 minutes in a park with sports equipment near where you live.

Hashtags:

You can take a photo of the area where the sports equipment is located, or you can also record the video.

Take a photo of your favorite equipment. Explain why you like this tool briefly.

Take a photo of equipment you don't understand or you don't like. Briefly explain why you do not like that equipment.

Fig. 1. Cultural probes task cards

After eliciting information about participants’ habits and behaviors through cultural probes, we decided to conduct semi-structured interviews to understand participants’ opinions and concerns. Out of 15 participants, who received cultural probes kit, we interviewed with 12 participants, who returned their probe packs. Interview sessions took between 30 to 50 min and were conducted face to face or via Skype and audio recorded. The interview involved questions about their sport habits, such as how long they have been doing sport and their motivations for starting to do sport; their behaviors related to and opinions about exercising at home and outside. During the interviews, photos taken by participants for Task 2 and Task 3 were questioned together with their opinions about ideal OFE and outdoor sport area design.

To select the participants, we adopted purposive sampling approach [30]. Young people who are aged between 20 to 30 years old and do sports regularly at home or gym were selected, since we considered that willingness to being physically active is essential to our study. As a result, 6 female and 6 male participants were included in the study who are either full-time or part time grad students having another occupation and able to allocate time for physical activity despite their hectic schedule.

After collecting the data, audio recordings were transcribed verbatim and transcriptions were divided into chunks for exploring data through coding. Structural coding is used as a categorization technique for further data analysis [31]. After that, transcript sections were coded under four categories through a matrix display [32]. The categories include topics such as ‘habits’, ‘opinions’, ‘concerns’, ‘when, where and with whom they carried out physical activity’. Based on this analysis, a comparison table was created to divide participants into groups based on their level of activity and their concerns.

4 Results

Based on our analysis, in this section, we first describe the physical activity characteristics of participants by grouping them into different activity levels. After that, we outline young people’s personal, social and practical needs regarding outdoor physical activity based on our findings.

4.1 Activity Levels of Participants

Table 1 summarizes the findings related to participants’ habits of physical activity. According to these habits, such as the frequency of doing sport in a week and the types of sports, they were classified into three levels, namely, low, mid and high activity levels. Low activity level is characterized by soft sports like yoga and Pilates, which the participants prefer because they relax them. Mid activity level participants do sport 3 to 5 days in a week and they mostly focus on intense exercises like cardio. Also, practicing exercises such as bodybuilding 6 to 7 days per week was adopted by high activity level participants.

Table 1. Distribution of participants based their physical activity levels

Participants												
	P3	P6	P4	P5	P7	P8	P9	P1	P2	P10	P11	P12
Gender	Female	Female	Female	Male	Male	Female	Female	Male	Female	Male	Male	Male
Age	24	24	24	27	25	25	25	25	24	22	26	26
Occupation	Student / Designer	Student	Designer	Lawyer	Engineer	Designer	Student / Assistant	Assistant	Student	Student	Student	Personal Trainer
Where	Home-Outside	Studio-Home	Gym	Gym	Gym	Gym	Gym	University SF.	University SF.	Gym	Gym	Gym
When	Morning	Morning	Morning	Evening	Evening	Morning	Evening	Evening	Evening	Evening	Evening	Evening
Which sport	Fitness Yoga	Pilates Yoga	Fitness Cardio	Fitness Cardio	Body Building Cardio	Body Building Cardio	Yoga Spinning	Body Building	Body Building Dance	Body Building	Body Building	Body Building Swimming
With whom	Alone	Alone	Alone	Alone	Alone	Friend	Group Session	Sport Partner	Alone	Alone	Sport Partner	Friend
How often	2 days	2 days	5 days	3 days	5 days	3 days	4 days	6 days	6 days	6 days	7 days	6 days
How long	1 year	16 years	15 years	1 year	20 years	2 years	6 months	6 years	1 year	4 years	6 years	2 years
User Habits												
Demographics												
Activity Level Legend: <span>Low Activity Level</span> <span>Mid Activity Level</span> <span>High Activity Level</span>												

4.2 Young People’s Needs Regarding Outdoor Physical Activity

4.2.1 Personal Needs

In order to design OFE for young people, it is critical to understand what motivates them to do physical activity. According to the results of the study, participants have many personal motivations including, health concerns, gaining physical strength and their personal appearance and they need to know about personal development and progress regarding their physical activity levels.

First of all, for our participants, the primary reason for starting to do physical activity is *being healthy* and they are willing to do it to protect or improve their health. Moreover, gaining *physical strength* and feeling strong are other critical reasons to be physically active. Accordingly, they especially underlined that gaining strength makes them happy. Another significant motivation for starting to do sport is *personal appearance*. Especially, participants who are highly active agreed that positive comments on their appearance increase their motivations. On the other hand, if they receive a negative comment after a break from doing sports, their motivation decreases to minimum. To elevate motivation, they need to feel that they achieve *personal improvement* through learning how much *progress they made*.

“...When I saw my own development, I want to do sport more frequently. After all, it’s hard and it takes a lot of patience, but eventually you get the result” (P12).



For this purpose, they usually track their progress by using mobile applications and comparing their own performance by themselves or with others. As such, in the picture taking task, they associated ‘the moment they feel best’ with achieving the goal of the day and feeling of success (Fig. 2).



**Fig. 2.** Photos from participants related to the moment they feel best

In particular, low-level active participants expressed their best moment as the final period of their physical activity. In contrast, high-level active participants tend to see the results of their efforts immediately. Therefore, they use fitness equipment which enables them to achieve this desire. To sum up, their health conditions, their improvement on physical appearance and the feeling of success affect participants’ motivation to continue being active.

#### **4.2.2 Social Setting Needs**

Products do not exist in a vacuum; social context in which the product is present has impacts on design. Therefore, results related to young people’s needs about social context should be considered while designing OFE.

First of all, in the gym’s social context, participants tend to compare themselves with other physically active people and they believe that this situation creates a motivating social setting. For example, some participants prefer to do sports in crowded sport centers, since they may have chance to show off their appearance and strength.

“I’m skipping rope pretty well and everyone turns their head and looks at me when I’m skipping rope. They even come and ask how I can skip like that. Then, I feel so good. Because I like the fact that people see how I’m doing it really well” (P2).

Besides showing off their appearance, some participants prefer to observe others who are performing well and consider them as their role models. Especially, for high-level active participants, finding a role model is a common encouraging factor.

“There are all kinds of people in the gym, the types of people you can take as a role model. A man with a very good body or a woman, so you say, since they come here and do these movements, this means that you can be like them. In fact, this is one of the

greatest motivations. Then over time, you compare yourself with them [role models], that becomes a reference. But, you're alone in the park" (P1).

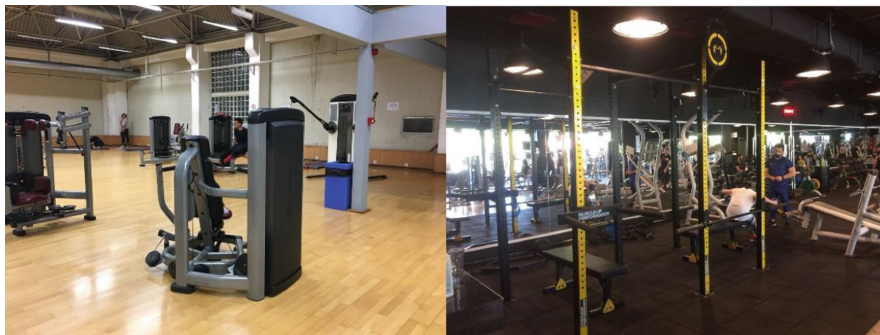
Apart from seeing role models in the context, seeing other people doing sports in the same context may make them feel more comfortable and encourage them to do sports together with them and satisfy their need for *socializing*. Moreover, gender is another factor which have effects on how participants perceive physical activity. For example, woman participants emphasized that they need to have privacy during their sport sessions and this is an important criterion for them to choose the right gym. Therefore, exercising at gym is vital criteria to choose a perfect gym for them. Furthermore, certain activities are identified as more gendered because of the dominance of a certain gender and this affects their preferences for activities.

"...There are group lessons such as Zumba, Pilates and etc., but they are for women. There are Spinning and crunch also. I can join them..." (P12).

#### 4.2.3 Practical Needs

According to the results of the study, certain practical needs are identified in terms of the environment that the physical activity is carried out, doing physical activity outside and the equipment design itself.

As it is indicated by participants, one of the most important criteria to choose a convenient place for doing sport is *closeness to home*. Most of the participants prefer sport centers in their neighborhood. Another critical factor that affects preference of the place is *cost*, such as membership fees. Additionally, participants especially from mid and high-level active groups prefer to exercise in sport centers to utilize different types of equipment. Therefore, *diversity in equipment* is one of the most significant factors that affect participants' preferences regarding the place they choose for doing sport (Fig. 3).



**Fig. 3.** Photos from participants related to diversity in equipment

Receiving right guidance and *working out correctly* is highly critical for all of the participants. They try to *avoid injuries* by warming up before exercising. In addition, *weather* is an important factor to decide to do sports in outside. Especially in winter, all the participants prefer to do sports in indoor sport centers.

Besides weather conditions, there are different practical needs and concerns regarding doing sports outside. Mid and high-level participants concerned that the equipment in outside areas may not be *suitable for their level*. Besides, location of the

OFE in terms of protecting *privacy* is highly critical while exercising outside especially for women participants. On the other hand, participants think that *availability of OFE throughout the day* is advantageous compared to sport centers.

In this study, we specifically asked participants to evaluate OFE through experiencing them with Task 3. As a result of this activity, most of the participants thought that current OFE resembles rehabilitation tools for elderly. They stated that they would use when they get older and added that it would be a better option than never being active. However, the current OFE is not suitable for their current sport practice and activity level, since for example there are no weights. They added that current OFE is not customizable as they do not have any adjustments for different weights, heights, genders or ages.

“The equipment there should be adjustable. Height, weight, etc. I mean it is made based on standard sizes, but I’m in the smaller percentage of that standard. Some can be longer or heavier. What can I do with such equipment that even my leg cannot reach anyway?” (P02).

Accordingly, people can injure themselves since current OFE does not fit their body requirements. Furthermore, participants who exercise at gym advised that there should be a *variety in equipment types* and number of each types of equipment should be increased, so that it can provide satisfactory experience for physically active users. Another problem regarding current OFE is that they *fall short to communicate their function*. For example, one participant pointed out that their colors are too vivid that they resemble playgrounds rather than a fitness area. Moreover, all participants complained that current OFE has many defects in terms of their *ergonomics* (Fig. 4).



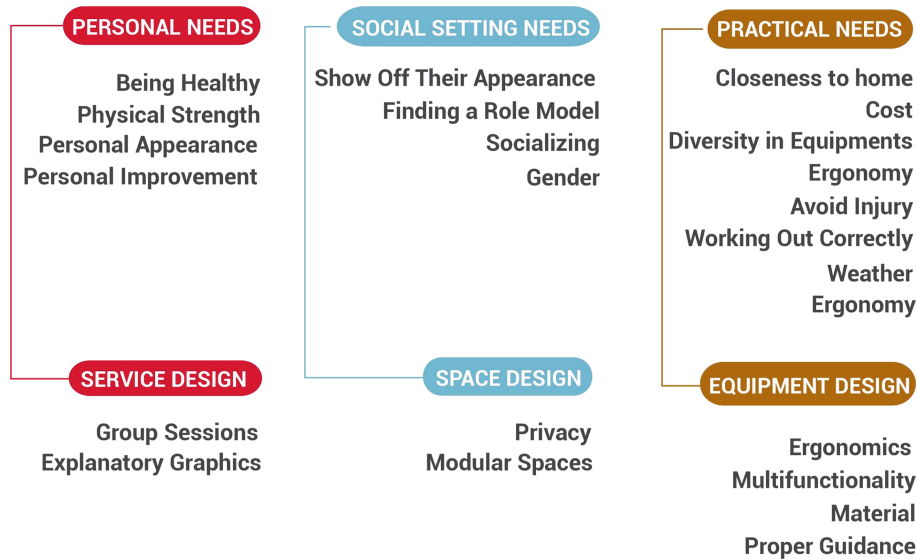
Fig. 4. Photos from participants related to outside equipment and its condition

## 5 Discussion

In this study, we identified several user needs based on young people’s habits, motivations and concerns regarding doing physical activity. Based on these personal, social and practical needs, we suggest certain design requirements in three different categories, namely, equipment, space and service related requirements. In this section, we first discuss these requirements, and then, we conclude the paper by reviewing limitations of the study and our suggestions for further studies.

Table 2 overviews the needs identified in this study and design requirements corresponding to the needs.

Table 2. Needs and design requirements



In terms of *service design*, literature findings suggest that promoting strategies such as group sessions to increase the usage of outdoor sport facilities. Likewise, our findings confirm this statement. All of the participants mentioned the importance of social context of being physically active such as by emphasizing having a sport partner regularly, going to gym with a friend or participating in group sessions. According to participants, the reason why they are motivated by such group sessions is that they see people who share the same purpose and ambitions for being active. Moreover, our findings suggest that some participants do not know whether they exercise correctly or not, thus they need a role model or a coach. To meet such needs, outdoor sport group sessions can be organized by city halls or sport facilities. These activities can encourage young people to be more active, as well as it can promote usage of OFE. Moreover, explanatory graphics and information to guide users of OFE can be placed in the outdoor sport facilities to prevent possible accidents and injuries and promote effective usage.

For *space design* where OFE is located, several space organization strategies can be considered. For each different types of activity, specific areas should be identified and these areas can be organized according to their orders in a sport program. Furthermore, these spaces can be isolated for creating a comfortable environment by maintaining the feeling of privacy. To meet this need, modular spaces can be considered and such a solution can also enable suitability to different weather conditions.

By considering the available literature and findings of this study, it can be concluded that current *equipment design* does not meet the needs of young users. In order to design OFE according to young users' needs, first of all, equipment's ergonomics should be considered by taking appropriate dimensions and material choice into account. In order to fit the body and preferred activity level of the user, the equipment should be adjustable and customizable. Variety in the type of exercises can be critical for different activity levels, therefore multifunctionality can be an option while designing such equipment. Working out correctly with proper guidance is highly important since it can cause injuries not only for young people but also for all users. Thus, foolproofing and proper guidance through affordances should be maintained with proper design.

These requirements and recommendations for OFE design aim to guide designers and urban planners for improving current OFE for young people's use and increasing their usage. However, this study has also some limitations such as its limited sample size and sampling frame. Future studies can be conducted with more people with diverse backgrounds as it can enable to identify different needs and requirements. Moreover, the requirements discussed in the paper solely depend on our observations regarding this study and literature sources. Applying these requirements to real-life cases on OFE design and testing the outcome with actual users would lead to more insightful conclusions and suggestions for future OFE design.

**Acknowledgments.** We would like to thank the participants of the study for their valuable contribution. This study was conducted as part of a graduate course ID531 Methods of User Research given at Middle East Technical University, Department of Industrial Design during 2017–2018 Spring Semester.

## References

1. Hallal, P.C., Andersen, L.B., Bull, F.C., Guthold, R., Haskell, W., Ekelund, U.: Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet* **380**(9838), 247–257 (2012)
2. Humphreys, B.R., Ruseski, J.E.: Participation in physical activity and government spending on parks and recreation. *Contemp. Econ. Policy* **25**(4), 538–552 (2007)
3. Babey, S.H., Wolstein, J., Krumholz, S., Robertson, B., Diamant, A.L.: Physical activity, park access and park use among California adolescents (2013)
4. Godbey, G., Mowen, A., Ashburn, V.A.: The Benefits of Physical Activity Provided by Park and Recreation Services: The Scientific Evidence. National Recreation and Park Association, Ashburn (2010)
5. Caspersen, C.J., Powell, K.E., Christenson, G.M.: Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep.* **100**(2), 126 (1985)
6. Hallal, P.C., Victora, C.G., Azevedo, M.R., Wells, J.C.: Adolescent physical activity and health. *Sport. Med.* **36**(12), 1019–1030 (2006)
7. Bouchard, C., Despres, J.P.: Physical activity and health: atherosclerotic, metabolic, and hypertensive diseases. *Res. Q. Exerc. Sport* **66**(4), 268–275 (1995)

8. Despres, J.P., Bouchard, C., Savard, R., Tremblay, A., Marcotte, M., Theriault, G.: The effect of a 20-week endurance training program on adipose-tissue morphology and lipolysis in men and women. *Metab. Clin. Exp.* **33**(3), 235–239 (1984)
9. Miles, L.: Physical activity and health. *Nutr. Bull.* **32**(4), 314–363 (2007)
10. Gales, G., Tsay, S.: Towards More Physical Activity in Cities: Transforming public spaces to promote physical activity. In: WHO European Region Report, pp. 4–5 (2017)
11. Fogg, B.J.: A behavior model for persuasive design. In: Proceedings of the 4th International Conference on Persuasive Technology, Claremont, California, ABD (2009)
12. Lilley, D.: Design for sustainable behaviour: strategies and perceptions. *Des. Stud.* **30**(6), 704–720 (2009)
13. Lockton, D., Harrison, D., Stanton, N.A.: The design with intent method: a design tool for influencing user behaviour. *Appl. Ergon.* **41**(3), 382–392 (2010)
14. Kuru, A.: Exploration of user experience of personal informatics systems. Unpublished Ph. D. thesis. METU, Ankara, Turkey (2013)
15. Outdoor Gyms Catching on in U.S. Parks. *Athletic Business*. <http://www.athleticbusiness.com/outdoor-gyms-catching-on-in-us-parks.html>
16. Cohen, D.A., McKenzie, T.L., Sehgal, A., Williamson, S., Golinelli, D., Lurie, N.: Contribution of public parks to physical activity. *Am. J. Public Health* **97**(3), 509–514 (2007)
17. Cohen, D.A., Golinelli, D., Williamson, S., Sehgal, A., Marsh, T., McKenzie, T.L.: Effects of park improvements on park use and physical activity: policy and programming implications. *Am. J. Prev. Med.* **37**(6), 475–480 (2009)
18. Thompson Coon, J., Boddy, K., Stein, K., Whear, R., Barton, J., Depledge, M.H.: Does participating in physical activity in outdoor natural environments have a greater effect on physical and mental wellbeing than physical activity indoors? A systematic review. *Environ. Sci. Technol.* **45**(5), 1761–1772 (2011)
19. Irvine, K.N., Warber, S.L., Devine-Wright, P., Gaston, K.J.: Understanding urban green space as a health resource: a qualitative comparison of visit motivation and derived effects among park users in Sheffield, UK. *Int. J. Environ. Res. Public Health* **10**(1), 417–442 (2013)
20. Bedimo-Rung, A.L., Mowen, A.J., Cohen, D.A.: The significance of parks to physical activity and public health: a conceptual model. *Am. J. Prev. Med.* **28**(2), 159–168 (2005)
21. Sibson, R., Scherrer, P., Ryan, M.M.: ‘I think it adds value, but I don’t use it’: use, perceptions and attitudes of outdoor exercise equipment in an urban public park. *Ann. Leis. Res.* **21**(1), 58–73 (2018)
22. Chow, H.W., Mowen, A.J., Wu, G.L.: Who is using outdoor fitness equipment and how? The case of Xihu Park. *Int. J. Environ. Res. Public Health* **14**(4), 448 (2017)
23. Chow, H.W.: Outdoor fitness equipment in parks: a qualitative study from older adults’ perceptions. *BMC Public Health* **13**(1), 1216 (2013)
24. Karahanoğlu, A., Öztoprak, A., Özdere, S.: UTAK Bildiri Kitabı: Egzersiz Parkları Kullanım Biçimlerinin İncelenmesi: Kavaklık Parki Örneği, pp. 57–65 (2016)
25. Scott, A., Stride, V., Neville, L., Hua, M.: Design and promotion of an outdoor gym for older adults: a collaborative project (2014)
26. Cranney, L., Phongsavan, P., Kariuki, M., Stride, V., Scott, A., Hua, M., Bauman, A.: Impact of an outdoor gym on park users’ physical activity: a natural experiment. *Health Place* **37**, 26–34 (2016)
27. Cohen, D.A., Marsh, T., Williamson, S., Golinelli, D., McKenzie, T.L.: Impact and cost-effectiveness of family fitness zones: a natural experiment in urban public parks. *Health Place* **18**(1), 39–45 (2012)

28. Beyer, H., Holtzblatt, K.: Contextual Design: Defining Customer-Centered Systems. Morgan Kaufmann, San Francisco (1998)
29. Gaver, B., Dunne, T., Pacenti, E.: Design: Cultural Probes. *Interactions* **6**(1), 21–29 (1999)
30. Robson, C., McCartan, K.: Real World Research. Wiley, Hoboken (2016)
31. Saldaña, J.: An introduction to codes and coding. In: *The Coding Manual for Qualitative Researchers*, vol. 3 (2009)
32. Morgan, D., Fellows, C., Guevara, H.: Emergent approaches to focus group research. In: *Handbook of Emergent Methods*, pp. 189–205 (2008)





# Design Ergonomics for Human Beings and Wild Animals in Densely Populated Cities: A Design Case in Hong Kong Country Parks

Kin Wai Michael Siu<sup>(✉)</sup>, Yi Lin Wong, and Chi Hang Lo

School of Design, The Hong Kong Polytechnic University,  
Hung Hom, Kowloon, Hong Kong  
{m.siu,yi-lin.wong,sdpaullo}@polyu.edu.hk

**Abstract.** Country parks in Hong Kong are often located close to residential areas. The waste produced by people living in village houses has affected park wildlife, and animals such as wild boars (*Sus scrofa*; feral pigs, wild swine, wild pigs) have attacked people for food. Wild boars have destroyed waste management and collection points. Using Hong Kong as a case study, this paper examines the interaction between wild animals and humans in a country park and aims to develop a waste management system for both. Country parks in which wild boars were settled were investigated. Cleaning contractor staff, village lot residents, and policy makers were invited for interviews. Design perimeters and primary physical designs were then generated for testing.

**Keywords:** Coexistence · Waste management system · Wild animals · Nature · Densely populated cities

## 1 Introduction

The world is undergoing rapid and accelerated urbanization [1]. Country parks have become crucial elements of urbanized cities and countries in which nature is reserved and protected. They are also essential public spaces in densely populated cities because they serve as relaxation sites and offer fresh air for busy people during holidays and at weekends. Despite rumors that parts of country parks in Hong Kong will be removed and more public housing estates built [2], country parks are still of great importance, as such proposals are hard to implement. However, despite their importance, country parks and the wild animals that inhabit them are currently challenged by urbanization and the perpetual modification of the natural landscape [3–5].

In densely populated cities such as Hong Kong, country parks are often located close to residential areas. Recess areas (i.e., areas between country parks and residential areas) are often occupied by residents who visit nature frequently. Recess areas are subject to considerable human activity, with humans disturbing nature and wild animal habitats. In other words, human life frequently and rapidly invades nature. For instance, in Hong Kong, some village lots and country parks are separated by no more than a street. The waste produced by people living in village houses affects wildlife, and some animals, such as wild boars (*Sus scrofa*; feral pigs, wild swine, wild pigs), attacked



people, as they may interpret bags carried by humans as containing food. Villages are occasionally subject to wildlife raids [6]. In the conflict between wildlife and human life, wildlife occasionally adapts to urban environments [7].

Other countries have developed policies to manage the wild boar population [8]. However, Hong Kong cannot do so for legal reasons. Investigation and research have attempted to solve the issue. Using Hong Kong as a case study, this study examines the interaction between wild animals and humans in a country park and aims to develop a waste management system for both. Country parks in which wild boars are settled are investigated. Cleaning contractor staff, village lot residents, and policy makers were invited for interviews. Design perimeters and primary physical designs were then generated for testing. This paper suggests that city planning should not only consider human life in the city, but also scrutinize how human life and nature can coexist. Humans use not only the city but also nature.

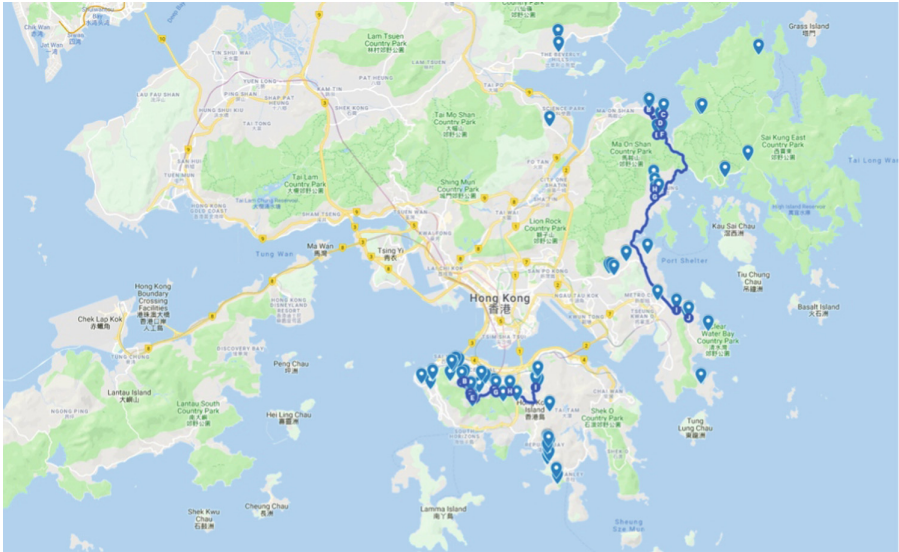
## 2 Method

### 2.1 Field Visits

Reports and complaints from villagers and other park users revealed the presence of wild boars in 56 country parks around Hong Kong. These wild boars moved in a group and had already found their dwelling places in these parks (Fig. 1. Wild boars in country parks). All of the parks were visited. Their locations are shown in Fig. 2.



**Fig. 1.** Wild boars in country parks.



**Fig. 2.** Country parks in Hong Kong where wild boars were found (extracted from Google Map).

**2.2 Interviews**

Semi-structured interviews were conducted with the villagers, the cleaning staff of the waste management facilities, and government officers from the Agriculture, Fisheries,



**Fig. 3.** Waste management facility and recyclable collection point where wildlife raids took place.

and Conservation Department (AFCD), the official department responsible for managing the country parks. The cleaning staff of the waste management facilities were interviewed because wildlife raids were often carried out at waste and recyclable collection points. The collection points were often located in the recess areas between the parks and village lots. In other words, it was easy for both villagers and wild animals to visit these areas. Figure 3 shows the state of a facility in one of the country parks.

The interviewees were asked questions related to their first-hand experience and observations of wildlife raids and the upkeep of the waste management facilities. All of the interviews were recorded and coded.

### 3 Findings

#### 3.1 Current Issues

Fifty-six country parks were visited. The facility design was inadequate to cater to the needs of villagers. The following issues were identified.

- Not all of the waste management facilities were in good locations. Some of them were located next to wildlife.
- The facilities were sometimes broken and did not function well.
- Some of the villages were larger, produced more waste, and lacked sufficient space to store it (Fig. 4). The villagers had to dispose of waste outside the villages next to the wildlife.
- Garbage bins for storing waste bags were kept open at all times. Although this made it easier for the villagers to dispose of their waste, it also made it easy for wild boars to find food (Fig. 5).

There was an apparent mismatch between the disposal habits of the villagers and the available facilities. This discrepancy encouraged wild boars to find food in the garbage bins and hence attack the villagers for more food. The management of the waste facilities was unsatisfactory.

#### 3.2 Interviews

Interviews were conducted to investigate the behavior of the villagers, the difficulties of the cleaning staff, and the factors considered by the policymakers. Table 1 summarizes their responses.

In view of the interview findings, apart from educating the villagers to develop a good habit of disposing waste using educational programs and notices, it was deemed necessary to redesign and develop the waste management facilities to change the villagers' behavior. Design can be used proactively to educate and reshape behavior. In this case, the design is required to prevent wild boars from finding food in garbage bins.





**Fig. 4.** Overloaded waste management facility with waste bags on the road.



**Fig. 5.** Waste management facilities were kept open at all times for people to dispose of waste easily. However, this also helped wild boars to find food.

**Table 1.** Findings from the interviews with the villagers, the cleaning staff at the waste and recyclable management facilities, and government officers from the AFCD.

Interviewees	Issues/considerations
Villagers	<ul style="list-style-type: none"><li>• Most of the household waste comprised food waste. Therefore, wild boars bit through the plastic bags that households threw out. When the boars saw people holding large plastic bags, they expected the bags to contain food and thus attacked the people to obtain it</li><li>• At broken facilities, some of the villagers threw their waste on the road carelessly. The wild boars bit through the plastic bags and made a mess</li><li>• Some elderly people fed the wild boars. Doing so was considered a charitable action and a virtue according to Chinese traditional values</li></ul>
Cleaning staff	<ul style="list-style-type: none"><li>• It was dangerous to clean due to the frequent appearance of the wild boars</li><li>• More workers were needed to clean the facilities and waste management areas because the wild boars messed up the areas after finding food</li><li>• In the past, the staff had managed to clean up five locations a day. However, due to their increased workload, the staff now managed to clean up only two locations a day. Their work became less efficient, and the hygiene situation worsened. Hence, the staff complained more often</li></ul>
AFCD officers	<ul style="list-style-type: none"><li>• The AFCD officers’ major concern was to balance the natural ecology</li><li>• Raids occurred between the natural (i.e., country park) and living areas. This was not easy for AFCD to manage. The officers had to negotiate with different government departments</li><li>• According to Hong Kong law, the AFCD could not kill the boars, only take preventative measures. They could play only a passive role. Therefore, they found it hard to control and manage the situation</li><li>• The AFCD ran many public education programs, such as educating the public not to feed the boars. However, Chinese traditional values made the outcomes unsatisfactory</li></ul>

3.3 Proposed Design Solution

Some design suggestions are listed below. These suggestions would help to prevent wild animals from finding food and reshape the behavior of garbage bin users.

1. A small opening should be installed to prevent oversized rubbish from being thrown into the garbage bins.
2. A dome-shaped, slippery opening would prevent rain from entering the bins and wild animals (wild boars and other animals) from climbing onto the bin roofs.
3. A foot pedal could be installed to open the bin. This would make it more difficult for the animals to open the bins.
4. A dual opening (one small and one large) could be installed for easier garbage disposal and removal.
5. A metal fence with the pavilion design of the bins should be installed to create a solid shield against wild boar attacks.
6. The edges of the bins could be made of cylindrical roller fencing to prevent wild animals from climbing onto the rubbish bins by grasping the edges.

7. Locks should be installed to prevent the bins from moving away from the fence and to help cleaners to move the bins.
8. All parts of the bins and fence should be easy to install and replace for maintenance.

All of these suggestions are meant to (1) prevent wild boars (and other wild animals) from getting food from the garbage bins, (2) help cleaners to use the bins more effectively, (3) allow users to use the bins easily so that waste can be disposed of properly, and (4) facilitate management and maintenance. The suggestions may be applied not in a single design but in several designs. In other words, designers may mix and match these suggestions according to the situation. A more useful and effective design may be generated to resolve any issues.

## 4 Conclusions

Based on the data collected from the field studies, wild animals, villagers, and facilities have subtle relationships. Although population management measures cannot be imposed on wild animals and educational programs for villagers have been unsuccessful, new designs of waste management facilities can be generated to address the problems.

In short, humans' misunderstanding causes the imbalance between wildlife and the urban living style. A new design should be generated and manufactured for pilot testing in different country parks in Hong Kong. Other animals, such as monkeys, cause different kinds of problems, such as stealing food and messing up garbage bins in country parks on mountains in Hong Kong. Similar measures have been adopted to improve the situation. Success has been achieved, and the new design for wild boars should represent a breakthrough in waste management systems.

City planning should not only consider human life in the city but also scrutinize how human life and wildlife can coexist. Both humans and wild animals use nature. Land planners, designers, and policy makers must consider both to achieve and maintain harmony and thereby conserve wildlife in an urban landscape [9].

**Acknowledgments.** The authors wish to acknowledge the support provided by the AFCD of Hong Kong for the data collection and preparation of the paper. The authors thank The Hong Kong Polytechnic University for its manpower support for the research. The Eric C. Yim Endowed Professorship provided financial support for the data analysis.

## References

1. Magle, S.B., Hunt, V.M., Vernon, M., Crooks, K.R.: Urban wildlife research: past, present, and future. *Biol. Conserv.* **155**, 23–32 (2012)
2. Citizen News (2018). <https://www.hkcnews.com/article/16527/明日大嶼-郊野公園-土地供應-16527/徵用部分郊野公園用地換取放棄「明日大嶼」計劃的妥協方案>
3. Birnie-Gauvin, K., Peiman, K.S., Gallagher, A.J., de Bruijn, R., Cooke, S.J.: Sublethal consequences of urban life for wild vertebrates. *Environ. Rev.* **24**, 416–425 (2016)

4. Jokimäki, J., Kaisanlahti-Jokimäki, M., Suhonen, J., Clergeau, P., Pautasso, M., Fernández-Juricic, E.F.: Merging wildlife community ecology with animal behavioral ecology for a better urban landscape planning. *Landsc. Urban Plan.* **100**, 383–385 (2011)
5. Lowry, H., Lill, A., Wong, B.B.M.: Behavioural responses of wildlife to urban environments. *Biol. Rev.* **88**, 537–549 (2013)
6. Citizen News (2019). <https://www.hk01.com/社會新聞/287882/豬年2019-餵飼成野豬滋擾主因-漁護署-為滿足感-好心做壞事>
7. Luniak, M.: Synurbization – adaptation of animal wildlife to urban development. In: *Proceedings of 4th International Urban Wildlife Symposium Urban Wildlife Conservation of Tucson*, pp. 50–55 (2004)
8. Flis, M.: Wild Boar Population Management vs. Damage Conditions in Economical and Social Grasps. *Ann. Wars. Univ. Life Sci. – SGGW Anim. Sci.* **20**, 43–50 (2011)
9. Soulé, M.E.: Land use planning and wildlife maintenance: guidelines for conserving wildlife in an urban landscape. *J. Am. Plan. Assoc.* **57**, 313–323 (1991)



# Research on Guiding Sign Ergonomic Setting Based on Visual Sensitivity in Long and Narrow Passageway

Ling Luo<sup>(✉)</sup>, Zhongting Wang, Linghua Ran, Chuanyu Zou,  
and Haimei Wu

SAMR Key Laboratory of Human Factors and Ergonomics,  
China National Institute of Standardization, Beijing, China  
{luoling, wangzht, ranlh, zouchy, wuhm}@cnis.gov.cn

**Abstract.** With the increase of building density in contemporary urban building space, the layout design of guiding signs has become a typical problem. There are few studies on the special characteristics of the building environment such as narrow passageways. Therefore, this paper studies the angle of clearly can be seen and the angle of comfortably can be seen based on visual sensitivity by experimental method, considering different eye heights and viewing distances so as to provide some references for the guided sign setting in narrow passageways and similar environment.

**Keywords:** Guiding sign · Setting · Ergonomics ·  
Long and narrow passageway

## 1 Introduction

With the increase of building density in contemporary urban building space, the layout design of guiding signs has become a typical problem. The Beijing subway signage system was studied with the relating factors in design such as feathers of passenger behavior, transit mode, information hierarchy and environmental factors so on [1]. The guiding sign system in High-speed railway station was studied based on the layout optimization design [2]. There are also many researches on the guiding sign with human characteristic too, such as visual field, range of visibility visual angle and visual colors [3–5]. But most of this literatures have studied the setting of guiding signs from a global perspective or base on the national standards, but there are few studies on the special characteristics of the building environment such as narrow passageways.

Most guiding signs are set erectly due to standard. In some environments, the erectly setting may cause a person raise his head hardly to see clearly especially in short distance (see Fig. 1). Fortunately, some designers have also concerned about the setting angle of guiding signs to make the watching more comfortable and easily (see Fig. 2).

So, this paper studies the angle of clearly can be seen and the angle of comfortably can be seen based on visual sensitivity by experimental method, considering different eye heights and viewing distances so as to provide some references for the guided sign setting in narrow passageways and similar environment.





Fig. 1. Guiding sign setting erectly



Fig. 2. Guiding sign setting with angles

## 2 Experiment

The  $3 \times 2$  factors within-subjects were designed, and the independent variables were the eye height and view distance. Two dependent visual sensitivity variables were studied in this paper: Clearly visible angle (the Chinese font strokes are clearly visible, no overlaps) and Comfortable angle (the Chinese font can be seen clearly, and people's head, neck and eyes are comfortable).

### 2.1 Experimental Material

To explore the suitable angle of guiding sign, a similar sign size (width 200 mm \* height 1500 mm) was made and set on a rotating device. The guide sign is shown in the following Pic1 (see Fig. 3).



Fig. 3. Guiding sign for experiment

2.2 Experimental Environment

In the experiment, a two-factor  $3 \times 2$  level of intra-subject design was adopted, and the independent variables were height (level 3) and distance (level 2).

A narrow and long channel was selected as the experimental site, with a width of 1.9 m and a height of 2.5 m. The basic illumination was 300lx–500lx. The test material drawing is printed with hard foam board and hung by tripod. The lowest edge of the sign is 2.2 m–2.3 m from the ground. Set a ruler on the floor of the straight corridor, measure the distance 2 m and 5 m from the sign, and mark it (see Fig. 4).

The view distance was two levels: 2 m and 5 m. Two dependent visual sensitivity variables were studied in this paper: Clearly visible angle (the Chinese font strokes are clearly visible, no overlaps) and Comfortable angle (the Chinese font can be seen clearly, and people’s head, neck and eyes are comfortable).

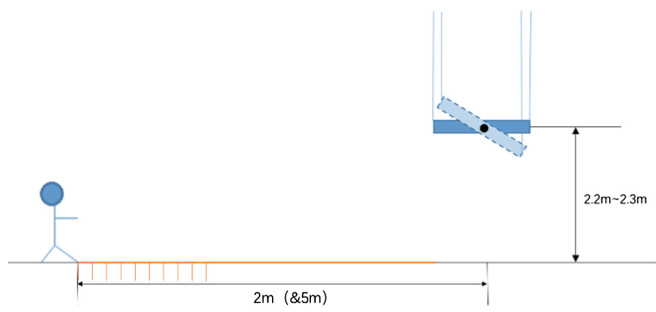


Fig. 4. The environment of the experiment

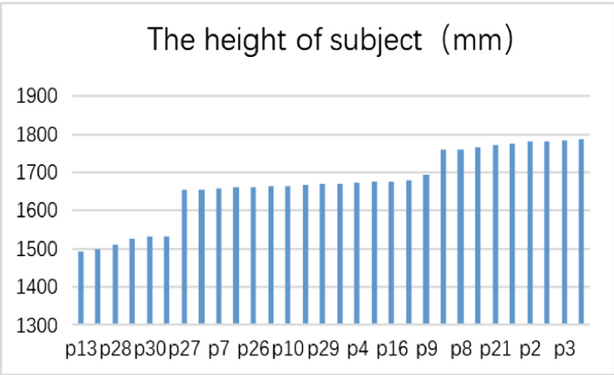
2.3 Participants

The eye height (3 levels, see Fig. 5) were selected from the GB 10000-88 standard “Human dimensions of Chinese adults”, including the eye height of 5 percentiles for adult women, 50 percentiles for adult men and 95 percentiles for adult men, see Table 1.

Thirty adults (13 males and 15 females), aged from 18 to 50 ( $32.3 \pm 10.9$  yrs.), with normal vision or corrected-to-normal vision, participated in this study. The specific conditions of the subjects are shown in Table 1, in which the height of the subjects is divided into three levels: G1(1550 mm and below); G2(1650 mm–1678 mm); G3(1760 mm–1780 mm).

Table 1. The dimension of the participants

	Height	Height of eye	Maximum head breath	Maximum head length
5% women	1484	1371	141	165
50% male	1678	1568	154	184
95% male	1775	1664	164	195



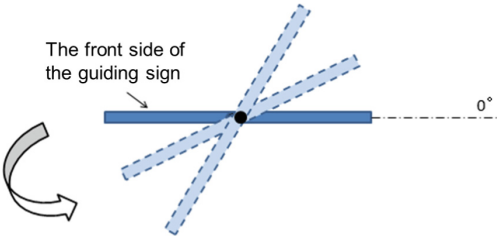
**Fig. 5.** The height of the participants

### 2.4 Procedures

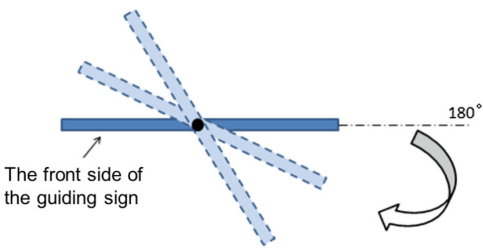
The test was conducted separately. After entering the laboratory, the participants were tested for visual acuity first. Those with normal visual acuity or corrected visual acuity could participate in the experiment and their height was measured at the same time. After the measurement, the participant was asked to stand at the mark line 5 m away from the guiding sign to start the test.

When the steering signs rotated slowly forward (see Fig. 6) and backward (see Fig. 7) respectively, the subjects were asked to report the angles of starting to see clearly, beginning to feel comfortable, beginning to feel uncomfortable and beginning to not see clearly. The whole process was measured three times. The results were statistically analyzed and the visual sensitivity variables were divided into four: Clearly visible angle<sub>lower</sub> and Clearly visible angle<sub>upper</sub>, Comfortable angle<sub>lower</sub> and Comfortable angle<sub>upper</sub>. The device was repeating the rotating three times totally.

When the line 5 m operation was finished, then the participant was asked to stand in front of the guiding sign 2 m away. And then the process of three time rotating backward and afterward was repeated, the four angles were recorded each time separately.



**Fig. 6.** Forward rotation of the Guiding Sign



**Fig. 7.** Backward rotation of the Guiding Sign

**2.5 Data Analysis**

In this research, each participant’s three times of clearly see and comfortable angles in each viewing distance will be averaged after outliers’ elimination. The two main factors human’s height and the viewing distance will be discussed separately following.

A repeated ANOVA were used for statistical analysis. SPSS (16.0 J, SPSS Inc.) was used for calculation.

**3 Results**

The following is the result of subjective and objective measurement we obtained in the experiment.

**3.1 The Result of the Impact of Height on Angle Value**

The height of subjects was divided into three groups: G1(1550 mm and below); G2 (1650 mm–1670 mm); G3(1760 mm–1780 mm). It can be inferred from the table that the average angle was various of different height groups.

Some obvious trends can be draw from the numbers that the Clearly visible angle no matter the lower or the upper will increases while the height becomes lower. The comfortable angle<sub>lower</sub> is the same trend, but the comfortable angle<sub>upper</sub> is the opposite trend decline with the height becomes lower. And the trends are the same in 2 m between 5 m, see Table 2.

The repeated measure ANOVA shows no significant main effects of different height groups on the Clearly visible angle and the Comfort angle( $P > 0.05$ ), see Table 3.

**Table 2.** Results of the angles in different groups of height

	2-m			5-m		
	G1	G2	G3	G1	G2	G3
Clearly visible angle <sub>lower</sub>	36.03	33.91	29.8	28.72	27.58	26.34
Clearly visible angle <sub>upper</sub>	178.28	171.61	170.87	165.31	165.08	163.09
Comfortable angle <sub>lower</sub>	77.47	71.94	67.96	68.19	67.52	66.68
Comfortable angle <sub>upper</sub>	123.53	126.13	130.56	121.81	124.86	128.30

**Table 3.** Results of ANOVA in different groups of height

Distance	Angle value	Df	F-value	Sig.
2 m	Clearly visible angle <sub>lower</sub>	Between Groups 2	1.165	0.327
	Clearly visible angle <sub>upper</sub>	Within Groups 27	0.745	0.484
	Clearly visible average-angle <sub>lower</sub>	Total 29	1.672	0.207
	Clearly visible average-angle <sub>upper</sub>		0.600	0.556
5 m	Clearly visible angle <sub>lower</sub>	Between Groups 2	1.165	0.327
	Clearly visible angle <sub>upper</sub>	Within Groups 27	0.745	0.484
	Clearly visible average-angle <sub>lower</sub>	Total 29	1.672	0.207
	Clearly visible average-angle <sub>upper</sub>		0.600	0.556

### 3.2 The Result of the Impact of Distance on Angle Value

The paired T-test was carried out for the Angle values at different distance levels. The results showed significant main effects of different distances on Clearly visible angle<sub>lower</sub>, Clearly visible angle<sub>upper</sub> and Comfortable angle<sub>lower</sub>. However, there is no significant difference in the Comfortable angle<sub>upper</sub> at the distance level.

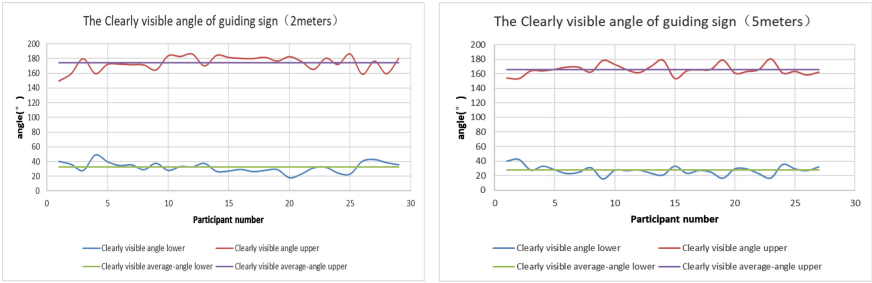
The paired T-test was performed separately, and the following results were obtained:

- (a)  $P_{\text{Clearly visible angle lower}} = 0.015 < 0.05$ , it shows significant difference, and the angle is bigger in 2 m.
- (b)  $P_{\text{Clearly visible angle upper}} = 0.000 < 0.05$ , it shows significant difference, and the angle is bigger in 2 m.
- (c)  $P_{\text{Comfortable angle lower}} = 0.003 < 0.05$ , it shows significant difference, and the angle is bigger in 2 m.
- (d)  $P_{\text{Comfortable angle upper}} = 0.323 > 0.05$ , it shows no significant difference.

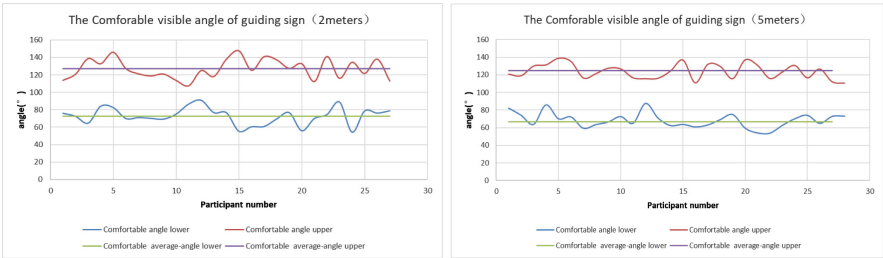
From the above analysis, it can be seen that the viewing distance is the main factor affected the subject visual sensitivity, and it has obvious influence on comfortable Angle range, but not the uncomfortable Angle range.

### 3.3 The Suitable View Angle of the Guiding Sign

Based on the results of this study, the following conclusions can be drawn: the angle can be clearly seen of guiding sign can be set between  $32.24^{\circ}$ – $174.16^{\circ}$ , but the comfortable angle can be set between  $72.68^{\circ}$ – $127.44^{\circ}$  when the guiding sign is to be seen in 2 m. the angle can be clearly seen of guiding sign can be set between  $27.46^{\circ}$ – $165.69^{\circ}$ , but the comfortable angle can be set between  $67.04^{\circ}$ – $123.83^{\circ}$  when the guiding sign is to be seen in 5 m (Fig. 8 and 9).



**Fig. 8.** The Clearly visible angle of guiding sign in 2 m and 5 m



**Fig. 9.** The Comfortable angle of guiding sign in 2 m and 5 m

## 4 Discussion and Conclusion

The present study was concerned with clearly visible and comfortable angle of the setting of guiding sign based on Ergonomics. The height of viewer and the viewing distance was considered to be the main factor to infect the setting angle. According to the standard GB-10000 of Human Dimension of Chinese Adults, 30 volunteers were recruited, and they could represent the wildly population of the physical characters in domestic. A guiding sign was set on a rotation device to rotate forward and backward to obtain the clearly visible and comfortable angle under 2 and 5 m.

The results from the experiment showed that there were no significant main effects of different heights of human but significant main effects of viewing distances on the angle. We guess it may due to the size of the guiding sign from the participants' interview after the test.

In conclusion, the guiding sign setting angle can be draw as  $72.68^{\circ}$ – $123.83^{\circ}$  reference to the comfortable angle.

Some factors haven't been concerned unfortunately due to various reasons, such as the sign's size. Different size of the sign will impact the setting angle of comfortable. In addition, the speed of people whose looking for the sign will do an important role to the setting angles too. Further study may focus on the more influence factors and conditions to acquire the reasonable angle of sign setting.

**Acknowledgments.** This work is supported by National Key R&D Program of China (2016YFF0201700).

## References

1. Peng, J.: The study of Beijing subway Signage System. Tongji University (2007)
2. He, H.: The Research on Evaluation of Guiding Sign in High-speed Railway Station. Southwest Jiaotong University, Xian (2014)
3. Chen, S.: A Sign Design Research on Based of Human Visual Characteristics. DongHua University (2014)
4. Ma, X.: The Design of Guide-Sign System in Underground Spaces. Tianjin University (2009)
5. Xu, L., Zhang, W., Tang, Z.: A virtue reality study of wayfinding and the sign layout in subway station. *Architectural J.* 1–4 (2010)



# The Application of Ergonomics of the Built Environment in Architectural Projects as a Benefit for the Hearing Impaired

Aline da Silva Oliveira<sup>1</sup>, Renata de Assunção Neves<sup>1</sup>,  
and Marcelo M. Soares<sup>2</sup>✉

<sup>1</sup> Center for Arts and Communication,  
Federal University of Pernambuco, Recife, Brazil  
linebelar@gmail.com, renatanevesdesign@gmail.com

<sup>2</sup> School of Design, Hunan University, Changsha, China  
soaresmm@gmail.com

**Abstract.** In design development, the architect must plan the space in a way that encompasses both physical and psychological comfort, taking into account the premises of universal design. The ergonomic intervention suffers some limitations due to the flawed design process, requiring a greater cost to adapt the space in specific cases. This study aims to demonstrate the importance of using universal design as a design guideline, to specify the restrictions experienced by people with hearing impairment that impede or hamper the process of social and cognitive interaction and to demonstrate how design solutions can bring solutions to these problems.

**Keywords:** Ergonomics · Built environment · Hearing impaired

## 1 Introduction

According to the 2010 Census of the Brazilian Institute of Geography and Statistics (IBGE) [1], in Brazil more than 45 million people have some deficiency. Within this context, it is understood that the built environment must be thought of in an accessible and inclusive way for any user profile, including in addition to this part of the population, the elderly, persons with temporary reduced mobility, pregnant women and children.

It can be said that the architecture thought of a “standard man” is flawed and not functional, since it cannot cover the various situations not included in the so-called “average man”, besides being in some aspects an exclusive and aggressive architecture. In addition, the use of space can occur in a conscious or unconscious way, influencing mood states and social appropriations. Therefore, the importance of environmental perception must be parallel to the aspects of thermal, acoustic and luminous comforts, as well as the distribution and physical structure of the place and aspects of accessibility. Villarouco [2] states that:

*The ergonomic adaptability of space includes attending to the user's wishes, not only in the aspects related to the development of work, but also in the reduction of suffering, that the segregation of the interpersonal relations provoked by the configuration of space can provoke.*



Given this context of environmental perception we can say that for people with hearing impairment this aspect becomes even more relevant, since the lack of hearing brings with it the need for a redoubled attention with the visual perception of the events in its circle of visual presence and in the organizational aspects of physical space. These aspects are essential both in relation to their own security and the integration of them with a sound world. An example of this need is observed in the meeting of deaf people, where first there is the reorganization of the furniture and a circle of conversation, for a clear vision of the participants, the adjustment of the lighting to avoid visual fatigue and other adaptations in the space as openings, mirrors and etc.

The Brazilian standard NBR 9050 [3] deals with aspects related to accessibility to buildings, spaces and equipment, but within what is dealt with in the standard there is very little reference on the need for accessibility of the space for the hearing impaired person, which demonstrates a lack of studies on this topic in Brazil. Keeping a space for deaf people with present hearing people can be a challenge for deaf and hard of hearing individuals. Providing a space for deaf users lies in focusing on the cultural values of deaf people and the unique visual needs that such people possess.

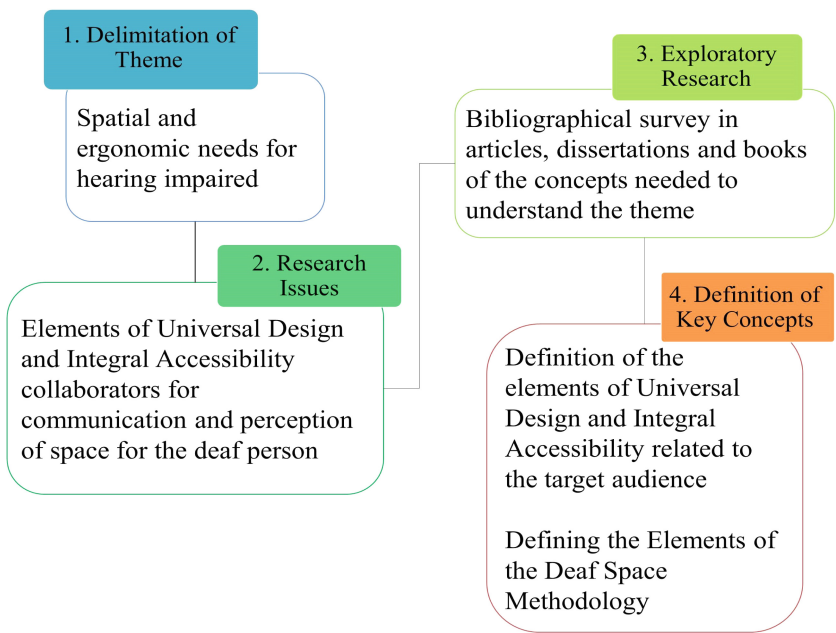
Many of the stressors experienced daily by the deaf are related to their interaction with the surrounding space, which is created for and by listening people. This is mainly the result of the architects' modern paradigm approach to architectural design, which does not take into account the visual communication and expression of the deaf. The modern paradigm focuses on the creation of a beautiful building and then takes the inhabitants into account [4, 5]. This creates a strong disconnect between the building and its inhabitants, which can lead deaf people to a sense of isolation and alienation because of the difficulty of interacting socially.

In view of this, it was tried to make a relation of the theme with the importance of the universal design in the project, the use of ergonomics interventions of the environment built in the space and the methodology of DeafSpace found in Bauman and Murray [6] in the elaboration of the Gallaudet University dormitory building in Washington DC.

## **2 Universal Design and Accessibility**

It is understood as accessibility of the built environment the possibility of participating in activities in an environment in an independent manner, with a minimum of comfort and understanding and participating in the organization and tasks developed in the environment by both disabled and non-disabled people. For this it is necessary to consider four components: 1. the information or understanding of the environment, being able to locate or move from information given from the environment itself; 2. the displacement, considering the free flow of the circulation areas, both vertical and horizontal; 3. the use, through participation in activities and use of equipment and furniture and 4. communication, through the easy interaction of users with the environment, integrating and including people and society and thought through furniture configurations and technologies. This work followed the steps shown in Fig. 1.

These four components are interrelated and are directly connected to the Universal Design, which proposes a space designed for different types of users so that regardless of the limitations that there may be egalitarian conditions in the use of space. Universal design follows seven principles that should guide the whole scope of the project: fair use, flexibility of use, intuitive use, perceivable information, error tolerance, low physical effort, and sufficient size and space for access and use. Following these principles creates a user autonomy independent of any restrictions. These principles were developed at the Center of Universal Design, North Carolina State University, which has conducted several studies and edited publications on Universal Design, from the ideology of Ron Mace.



**Fig. 1.** Steps of the methodology

Due to the range of possibilities for attending to physical, informative and social needs and the range of products (built environment, object, equipment, information system) several classes of study appeared within the accessibility theme.

For this to occur, the environment must be inclusive, with common forms of living, learning and working between disabled and non-disabled people, without stigma or segregation. Therefore, it is necessary to identify which elements make difficult or prevent the perception, circulation, understanding or appropriation of spaces and activities by the users and what social and/or psychological obstacles exist that impede their proper use.

### 3 Assessment Methods in Design of the Built Environment

At the outset, it should be borne in mind that a user-centered design takes into account all aspects of the human element that resides there, it is a design process that focuses on the needs and requirements of users. It is observed that a preventive posture is directly related to a later economy and a better adaptation of the user to the space.

In order to use an ergonomic action in the design process, the following aspects should be taken into account: environmental comfort, such as lighting, ventilation, noise, internal temperature, etc., the environmental perception of those who will use the suitability of the proposed coatings according to the function of the space, the cognitive aspects of the users and the aspects of the work accomplishment and their necessary dimensions.

Within this context, some fundamental factors are perceived so that there are no inadequate environments. In the process of elaboration of aspects related to environmental comfort, current standards that establish minimum standards related to noise, vibration, lighting, etc. are taken into account. But these minimum values should be carefully evaluated, because in various situations they become inadequate. Indirect illumination, for example, even before the recommended one, can be insufficient for a perfect interaction of the hearing impaired, since the visual aspect becomes paramount for a necessary understanding.

Aspects of environmental perception that do not take into account the experiential factors and feelings of the users have a great chance of becoming flawed, since they cannot be measured by norms or codes. Some users do not feel comfortable in environments where there is a large external exposure of the interior, and others do not have a good perception of very enclosed spaces.

Coating and finishing materials should take into account what kind of activities that space will perform. Materials with high reverb can make the environment uncomfortable and make it difficult for deaf users who use hearing aids and cochlear implants to understand.

Workstations that do not consider the activities that will be pursued tend to become flawed due to design errors, including poor sizing. It is necessary to know what kind of activity will be performed in the environment and how to make the space functional and comfortable for its users. It is necessary, then, to know the activities that will be carried out in the place and the context related to the diversity of individuals that can use the space.

In relation to the built environment a specific ergonomic methodology is necessary, in which both the physical environment and the aspects of environmental perception are taken into account.

In the area of perception, cognitive or mental maps can establish behavioral traits and visual preferences, important influencers in the psychological comfort of space. Through them one can identify the uses, the spatial arrangements or layouts, the flows and the spatial relations observed.

For this purpose we can use the Built Environment Analysis Method, and the Constellation of Attributes. The first method comprises four stages: the global analysis of the environment, the identification of the environmental configuration, the evaluation of the

environment in use in the performance of the activities and the analysis of the user's perception, the first three being related to the physical aspect of the environment and the latter the user's perception about the space used [2].

The Constellation of Attributes is related to a technique of extracting the user's perception about his environment through symbolic images generated from spontaneous associations of ideas of the environment and represents the individual experiences of the user. It is elaborated through graphics to understanding of users' needs on the site. Bringing the light of spatial perception a tool that helps the professionals connected to the area of design of constructed spaces, because it seeks the knowledge of the psychological conscience of users in relation to space. Oliveira, Mont'alvão and Rangel [7], citing Ekambi- Schmidt (1974) states that the Constellation of Attributes provides us with a clear separation of the stereotyped image of a space, of its subjective image.

## 4 A Deaf Space Methodology

The Deaf Space fundamentally takes into account the awareness of the sign language and the visual connectivity between people, as well as the feeling of safety and well-being and the clarity of the circulation and the paths. Circular geometry, width, reduction of "blind spots" and transparency. In architectural terms, the Deaf Space does not seek to ensure universal solutions, on the contrary, it seeks to promote particular socio-spatial situations that can sensibly and meaningfully connect individuals to each other and to what is around them [8], that is, provide friendly environments for the hearing impaired.

The design guidelines drawn are subdivided into: sensory range; space and proximity; mobility; light and color; acoustic and electromagnetic interference [9].

This methodology specifically follows five precepts. The first refers to the sensory range, which takes into account the spatial orientation and the awareness of the activities that develop in the environment as a way to bring a sense of well-being and safety. The deaf have a visual perception that gives them an ability to read the environment through characteristics that are sometimes not perceived by the listeners, such as the movement of shadows, vibrations and reading facial expressions of the other. The space in "360°" facilitates this orientation and the mobility of the user.

The second precept deals with space and mobility, since for the deaf person a specific distance is necessary so that one can clearly visualize both the visual expression of the other and their surroundings. The space between two deaf people tends to be larger than between the space required in a spoken conversation. Therefore, the layout of the furniture and the dimensions of the built space must take into account these factors in the design process.

The third precept refers to mobility and proximity, since for visual communication there is a need for a distance from the observer and ability to perceive the environment and ability to perceive danger and correct direction.

Light and color are a fundamental precept in this methodology, since some aspects of poor lighting interfere directly with visual communication, such as brightness, shadow patterns and backlighting that interfere with interaction and cause eye fatigue. Adequate artificial lighting is essential as well as architectural elements that control the

daylight so that there is always a soft and diffused light. The colors work as elements of contrast, as well as a tool to stimulate the psychological comfort of the place.

Acoustic and electromagnetic interference has a direct influence on deaf users of hearing aids and cochlear implants, since sound can be an element of distraction and distress. Some architectural elements and rigid furniture increase sound reverberation and bring discomfort. The whole environment should be thought of taking into account the reduction of background noise. In addition, elements of overlays that can bring acoustic insulation make it possible for deaf people who are in the process of hearing rehabilitation to make use of technological means with more comfort and understanding, such as watching television or listening to music.

These guidelines are essential for the development of an environment that is functional and comfortable for a deaf person and thus, through simple elements, to include this profile in the environment in a positive and accessible way.

Ergonomic evaluation methods of constructed space can and should be adapted so that there is an evaluation in a more visual aspect, through images, associations and concrete examples, thus having a greater chance of success in its purpose.

In this context, the Deaf Space is characterized as an attempt to create a “collective knowledge” about the construction of spaces adapted to the cognitive, linguistic and cultural sensibilities of deaf people, to be used as a guideline for the project. Its development began in 2005 at a workshop held at the University of Gallaudet aimed at establishing design principles for the construction of a new language communication center at Sorenson, Gallaudet Campus. The group sought to define a place that would reveal the connection of deaf people to one another, involving: a sense of community, a desire for openness and light, a feeling of well-being and a conscience of nature, a prioritization of vision and of tact as primary elements of spatial awareness and orientation [6].

## 5 Conclusion

It is concluded that it is of fundamental importance that there is an ergonomic method in the design process so that the space can be comfortable, aesthetic and functional. It is also observed that the visual perception of the user must be taken into account through evaluation methods that listen to the user or future user of the site and that there is a previous knowledge of the activities that will develop there.

In relation to the deaf user, a deeper study on the importance of awareness of the needs of this social group is necessary, so that they too can enjoy accessible and inclusive spaces.

## References

1. Instituto Brasileiro de Geografia e Estatística (IBGE): Censo Demográfico de 2010, Brasília (2012)
2. Villarouco, V.: O que é um ambiente ergonomicamente adequado? In: I Conferência Latino-Americana de Construção Sustentável, São Paulo (2004)

3. Associação Brasileira de Normas Técnicas: NBR 9050. <http://www.pessoacomdeficiencia.gov.br>
4. Bins Ely, V.H.M., Dischinger, M., Santos, A.P.R.T., Silva, L.C.: Acessibilidade e Orientabilidade no Campus da Univali – São José. Florianópolis: Relatório de Pesquisa Grupo PET/ARQ/UFSC/SESu (2004)
5. Dischinger, M.: Promovendo acessibilidade espacial nos edifícios públicos. Programa de Acessibilidade às Pessoas com Deficiência ou Mobilidade Reduzida nas Edificações de Espaço Público. Florianópolis: MPSC (2012)
6. Bauman, H., Murray, J.J.: Deaf Gain: Raising the Stakes for Human Diversity, Kindle Edition. University of Minnesota, London (2014)
7. Oliveira, R.G., Mont’alvão, C., Rangel, M.: Uma Visão Crítica Sobre as Metodologias Utilizadas nas Pesquisas de Ergonomia do Ambiente Construído – A Constelação de Atributos. In: 13º Congresso Internacional de Ergonomia e Usabilidades de Interfaces Humano, Ergodesign, Juiz de Fora-MG, UFJF (2013)
8. Tysimbal, K.A.: Deaf Space and the Visual World – Buildings that Speaks: An Elementary School for the Deaf. Thesis. School of Architecture Planning and Preservation. Faculty of the Graduate School of the University of Maryland, College Park, EUA (2010)
9. Hurley, A.K.: How Gallaudet University’s Architects are Redefining Deaf Space: The World’s Only Liberal Arts Institution for the Deaf Creates an Architectural Movement. Curbed, Longform (2016)

# **Design Applications**



# A Synthesis of Sociotechnical Principles for System Design

Amangul A. Imanghaliyeva<sup>1</sup>(✉), Pauline Thompson<sup>1</sup>, Paul Salmon<sup>2</sup>,  
and Neville A. Stanton<sup>3</sup>

<sup>1</sup> Institute for Infrastructure and Environment, Heriot-Watt University,  
Edinburgh EH14 4AS, UK

{ai2, p. thompson}@hw.ac.uk,  
amangul.imanghaliyeva@yahoo.com

<sup>2</sup> Centre for Human Factors and Sociotechnical Systems,  
University of the Sunshine Coast, Sippy Downs, QLD 4556, Australia  
psalmon@usc.edu.au

<sup>3</sup> Transportation Research Group, University of Southampton,  
Southampton SO17 1BJ, UK  
N.Stanton@soton.ac.uk

**Abstract.** A set of Sociotechnical System (STS) Principles that aims to optimise both the social and the technical aspects of the work system have been derived from many STS design efforts and experiences. In particular, the sets of principles have been developed by Trist and Bamforth [35], Cherns [9, 10], Davis [14], Berniker [5], Clegg [11], Walker et al. [41], Read et al. [30] and Waterson and Eason [45]. The current paper reviewed and compared the aforementioned seventy years of mainstream sociotechnical principles for system design. The principles were identified from a systematic review, grouped by similarity, and synthesised into an updated set of principles for researchers and organisations to use and discuss. In the tradition of all previous sociotechnical principles, they seek to provide criteria for designing organisational structures, group work, work processes, design processes, technology and individual tasks. They are also used as criteria to evaluate a set of existing ergonomics methods. The fortunes of sociotechnical theory have ebbed and flowed over the past seventy years, but the value of sociotechnical principles has remained. They are now increasingly relevant to a host of distinctly 21st century problems, all of which share a common imperative to effectively integrate people and technology. A synthesis of existing sociotechnical principles is overdue.

**Keywords:** Sociotechnical systems theory · Sociotechnical principles · System design · Design of work systems · Joint optimisation



# 1 Introduction<sup>1</sup>

## 1.1 Background and Context

Ever since the establishment of the London Tavistock Institute in 1946, Sociotechnical Systems (STS) theory has been developed and tested in order that its fundamental objective of joint optimisation can be attained. The notion of joint optimisation is shared with the field of ergonomics. It states that the social and technical aspects of a work system will produce better outcomes than if either is separately optimised [4, 35, 36].

STS design principles emerged as a novel approach for guiding the restructuring of work systems, or assessing the state of pre-existing systems, in terms of joint human and technical optimisation [28, 36]. This stems in part from action research, which is underpinned by a core idea about improving work situations in more human terms [25]. STS design principles provide guidance that analysts can translate and use on real systems [25], and this too is inspired by the same underpinnings. “Action research is intended to describe holistically what happens in naturally occurring settings, and to derive from these observations more broadly applicable principles or actionable knowledge” [2]. STS design principles show how STS theory can be converted into practical interventions. A STS design principle might state that “Design entails multiple task allocations between and amongst humans and machines” [11] or “the process of design must be compatible with its objective” [9]. Whilst not a detailed prescription of precisely what to do, they describe key STS outcomes that need to be achieved. There are several widely available STS design principles, in particular those by Trist and Bamforth [41], Chermans [9, 10], Davis [14], Berniker [5], Clegg [11], Walker et al. [41], Read et al. [30] and latterly Waterson and Eason [45]. Since 1951 they have been extended, updated and mapped across to new disciplines by subsequent researchers. Chermans’ 1976 principles, for example, were updated in 1987, extended and updated by Berniker in 1996 and Clegg in 2000. The latter’s principles were then mapped across to a new domain by Walker et al. in 2009, Read et al. in 2015 and again by Waterson and Eason in 2018. As it stands currently there are no fewer than 120 individual STS design principles by at least ten different authors spanning almost 70 years. The popularity of STS itself has ebbed and flowed over this period [see 44] but the attractiveness of practical and expedient STS design principles has remained. Indeed, today there is renewed interest in using it to envision work environments in new ways [19], applying it to the practical problem of workplace organisation [16, 21, 24, 37, 38], workplace safety [8, 31, 46], decision-making contexts [18], design of virtual research and development projects [26, 27], design of new governance systems [24] and addressing the numerous quality of care problems in healthcare domain [7, 17]. There is also a growing interest in what joint optimisation could do beyond ‘traditional’ organisational or work redesign, including everything from military command and control [40, 42] to modern debates about infrastructure resilience [43]. It is becoming apparent that joint

<sup>1</sup> **Practitioner summary.** The current paper has reviewed and compared 70 years of STS principles, identified the relationships between them, and synthesised them into the updated set of principles for researchers and organisations to use and discuss. It provides criteria for designing organisational structures, work processes, design processes, individual tasks, and methods.

social and technological systems are not the exclusive purview of ‘work systems’ but of ‘systems’ of all kinds [13]: from civil engineering systems through to the internet of things. Clearly, then, a lot has changed since 1946 when the first sociotechnical principles were developed, but the need for STS design principles remains. Indeed, with renewed interest comes an imperative to revisit them. In particular, a synthesis of all existing STS design principles will be of considerable benefit to researchers and practitioners going forward. This is the purpose of the current paper. In the sections that follow the wider background and context of sociotechnical theory is presented, along with a historical review of the development and foundations of STS design principles. This leads into a systematic identification of pre-existing sociotechnical principles (Table 1), a clustering and synthesis of those pre-existing principles (Table 2), culminating in a revised set of synthesised STS principles (Table 3) and a mapping onto systems ergonomics methods (Table 4).

## 2 Rationale for the Design of STS Principles

A principle is a proposition that serves as the foundation for a system of belief or behaviour or for a chain of reasoning. Good principles should be succinct and clear, and make it explicit what the desired outcome should be and who should action them. STS design principles are defined somewhat more loosely as “...guidelines to the ‘art of organization design” [5, 9]. In terms of desired outcomes, sociotechnical principles should enable organisations ‘to explore conflicts and complexity in the human, organisational, and technical aspects of change and to jointly optimise people and technology within a clear ethical principle’ [6, 12, 33]. Some principles do indeed describe an explicit outcome to be achieved (e.g. “design useful, meaningful, whole tasks” [42]); others take the form of a maxim or axiom (e.g. “values and mindsets are central to design”, [11]); others are more discursive (e.g. Cherns’ multifunctional principle). Perhaps the primary benefit of STS principles is to help embed a set of social values in systems that are typically viewed from a purely technological or mechanistic perspective [3, 23]. What principles ‘are not’ are prescriptions for action or a recipe to be enacted rigidly. Principles are “guides to critical evaluation of design alternatives making clear some of the differences between the sociotechnical systems approach and traditional job design” [5]. Principles “...are not intended as design rules for mechanistic application. Rather, they provide inputs to people working in different roles and from different disciplines who are engaged collaboratively in design. They offer ideas for debate, providing rhetorical devices through which detailed design discussions can be opened up and elaborated” [11]. In other words, sociotechnical principles are themselves ‘minimally critically specified’. The following sections describe the means by which existing STS principles were extracted from the wider literature, the method by which they were reviewed and integrated, and how the final set of synthesised principles was derived.

**Table 1.** Summary of the mainstream STS principles of Trist and Bamforth [35], Cherns [9, 10], Davis [14], Berniker [5], Clegg [11], Walker et al. [41], Read et al. [30] and Waterson and Eason [45]

Trist and Bamforth [35] 1951	Cherns [9, 10] 1976, 1987	Davis [14] 1977	Berniker [5] 1996	Clegg [11] 2000	Walker et al. [41] 2009	Read et al. [30] 2015	Waterson and Eason [45] 2018
1. Responsible Autonomy 2. Adaptability 3. Meaningfulness of Tasks	1. Compatibility 2. Minimal critical specification 3. Variance control 4. Boundary Location 5. Information flow 6. Power and authority 7. Multifunctionalism 8. Support congruence 9. Transitional organization 10. Incompletion	1. Systemic 2. Open system 3. Joint Optimization 4. Uniqueness 5. Philosophy 6. Quality of Working Life 7. Comprehensive Roles 8. Self-Maintaining Social Systems 9. Flat Structure 10. Participation 11. Minimum Status Differentials 12. Make Large Small 13. Design Process 14. Minimal Critical Specification 15. Action Research	1. Value clarification 2. Uncertainty 3. Choice 4. Motivated behavior 5. Participation 6. Open systems 7. Human values 8. Computability 9. Minimum critical specification 10. Constraint-free design 11. Self-regulating work groups 12. Responsible autonomy 13. Inducements to work 14. Boundary location 15. Boundary management 16. Joint optimization 17. Organizational uniqueness 18. Congruence 19. Variance control 20. Response variety 21. Information flow 22. Learning 23. Experimentation 24. Self-design	1. Design is systemic 2. Values and mindsets 3. Design choices 4. Design reflects needs 5. Design as social process 6. Design socially shaped 7. Design contingency 8. Process integration 9. Multiple task allocations 10. Congruence 11. Problem visibility 12. Problem control at source 13. Flexible specification 14. Design is a STS 15. Ownership 16. Evaluation 17. Multidisciplinary education 18. Resources and support 19. Political processes	1. Multidisciplinary input 2. Test implicit theories 3. Subsumption 4. Co-evolution 5. Design for adaptability 6. Whole tasks 7. Minimal critical specification 8. System DNA 9. Design is a STS 10. Users or 'prosumers'	1. Task allocation 2. Whole tasks 3. Boundary locations 4. Boundary management 5. Problem control 6. Incorporates needs 7. Intimate scale 8. Design context 9. Multifunctionalism 10. Congruence 11. Flexible specification 12. Allocation of authority 13. Flexible structures 14. Information linked to action needs 15. Agreed values and purposes 16. Resources and support 17. Appropriate design resources 18. Designing for transition 19. Choices constrain choices 20. User participation 21. Constraints questioned 22. Represent interconnectedness 23. Joint design 24. Multidisciplinary 25. Political debate 26. Avoid fads and fashions 27. Iteration and evaluation	1. Design is systemic, emergent and context-sensitive 2. Values, organizational culture and mindsets 3. Design choices and trade-offs 4. Business and user-centred design 5. Design socially shaped, contingent process 6. Core processes integrated and components congruent 7. Flexibly specified multiple task allocations 8. Simple systems which make problems visibility 9. Problems controlled at source 10. Design practice is a dynamic, evolutionary STS 11. Resources, support and evaluation 12. Political processes

\*The labels given above are abbreviations/shortened versions: full details are available in the source references.

**Table 2.** Synthesis of 120 existing STS principles leading to a revised set of 20 integrated principles. Shaded cells show groupings of existing principles based on similarity between them. Numbering inside the shaded cells cross refers to the specific principles listed in Table 1.

		Trist and Bamforth [35] 1951	Cherns [9, 10] 1976, 1987	Davis [14] 1977	Berniker [5] 1996	Clegg [11] 2000	Walker et al. [41] 2009	Read et al. [30] 2015	Waterson and Eason [45] 2018	Commonality
1	Multifunctionalism	2	7	7	20	9	5	1, 9	7	8/8
2	Congruence		8	5	13, 18	10, 18	1, 8	10	6, 11	7/8
3	Flexible specification		2	14	9	13	7	2, 11	7	7/8
4	Joint optimisation		1	3	16	1	1	23	1, 6	7/8
5	Participation		1	10, 11	5, 8	15	10	20	4	7/8
6	Designing design		2, 9	1, 2, 15	3, 6	1, 3, 14		17, 18, 19, 22, 27	3, 10	6/8
7	Experimentation		10	15	22, 23	16		5, 27	1	6/8
8	Flux		10		24	5, 14	5	18, 27	10	6/8
9	Responsibility	1	6	11	12	8		12		6/8
10	Values		8	6	1, 7, 13, 15	2		15	2	6/8
11	Boundaries		4	12	14, 15	8		3, 4		5/8
12	Constraints		2		10	6, 19		21, 25, 26	5, 12	5/8
13	Multidisciplinarity		10	13		17	1	24		5/8
14	Resource flows		5		21	8	9	14, 16		5/8
15	Uniqueness			4	17	7	3	8		5/8
16	Variance control		3		2, 19	12		5	9	5/8
17	Functional purposes				7	4	4	6, 15		4/8
18	Job characteristics	3			4		6	2		4/8
19	Simplicity and scale					11	2	7	8	4/8
20	Self-regulation			8, 9	11			13		3/8
	Total principles	3	9 (1976) 10 (1987)	15	24	19	10	27	12	

**Table 3.** Synthesised set of sociotechnical system design principles

	Principle	Proposition
1	Multifunctionalism	Human agents* should be skilled in more than one function
2	Congruence	System designers should ensure that support systems and sub-systems are congruent with the basic system design
3	Flexible specification	Human agents* should be provided with the outcome to be achieved but the means to achieve it minimally critically specified
4	Joint optimisation	System designers should give equal consideration to the role of humans and technology in systems
5	Participation	System designers should match democratic work structures with democratic design processes
6	Designing design	System designers should recognise that the design process for STS is itself an STS and can be treated as such
7	Experimentation	System designers should treat design iterations as ‘experiments’ and act on the results of those experiments
8	Flux	System designers need to recognise that systems are by their nature dynamic and never ‘complete’, and this requires continuous re-evaluation
9	Responsibility	Human agents* should be given responsible autonomy for carrying out tasks
10	Values	System designers should express the aspirations and needs of people within their design criteria
11	Boundaries	System designers should ensure that system boundaries do not interfere with the exchange of information and learning
12	Constraints	System designers should identify social, technical and political issues which constrain or enhance choices
13	Multidisciplinarity	System designers should draw from a diverse range of expertise, skills and perspectives
14	Resource flows	System designers need to ensure that information is provided at the point at which it required
15	Uniqueness	System designers should recognise that each system is different and these differences should not be neglected
16	Variance control	System designers should enable variances to be controlled from the point where they originate
17	Functional purposes	System designers should ensure it is designed to support the fundamental reason it exists; that fundamental reason needs to be made explicit
18	Job characteristics	System designers should design human roles within systems that involve a full, coherent and meaningful cycle of activities
19	Simplicity and scale	System designers should minimise complexity and maximise ease of use and understanding
20	Self-regulation	System designers should examine the conditions under which individuals or groups become self-regulating, and try to optimise those conditions

\*In the not too distant future it is conceivable this could apply equally to autonomous agents, AI, etc.

**Table 4.** Ergonomic methods aimed at the comprehensive analysis of STS assessed against the new synthesised STS principles. ‘XX’ denotes that a method addresses a given principle, ‘X’ denotes that it ‘partially addresses’ the principle, and a blank cell denotes that the method does not address a principle.

	Label	CWA	STAMP <sup>a</sup>	EAST	FRAM	ACCIMAP	HTA
1	Multifunctionalism	XX		XX	XX	XX	XX
2	Congruence	XX	X	XX	XX	XX	XX
3	Flexible specification	XX					XX
4	Joint optimisation	XX	X	X	XX	X	XX
5	Participation	XX	XX	XX	XX	XX	XX
6	Designing design	X	X	X			XX
7	Experimentation	XX	X	XX	XX		XX
8	Flux	XX	X	X	X	X	X
9	Responsibility	XX	XX	XX		XX	XX
10	Values	XX					
11	Boundaries	X	X	X	X	XX	X
12	Constraints	XX	X	X		X	X
13	Multidisciplinarity	XX	XX	XX	XX	XX	XX
14	Resource flows	X	XX	XX	XX	X	X
15	Uniqueness	XX	XX	XX	XX	XX	XX
16	Variance control	X	XX		XX	X	X
17	Functional purposes	XX		X			X
18	Job characteristics	X					XX
19	Simplicity and scale	X	X				XX
20	Self-regulation	X	X				X
	Totals	33	22	22	20	19	31

<sup>a</sup>With particular emphasis on the STPA aspect of STAMP

<sup>b</sup>Includes the numerous methods which make use of the outputs of HTA (i.e. not HTA alone)

### 3 Method

A large-scale literature search was undertaken to reveal all instances of STS principles extant in the publically available and peer-reviewed knowledge-base. The high-level search topics centred on four areas: (1) sociotechnical system design approaches, (2) sociotechnical system design in work systems, (3) principles of sociotechnical system design, (4) organisational behaviour.

General principles of design, or principles founded on different (and possibly incompatible) value-bases or domains except STS were excluded from the review. A mixed search strategy was employed, combining features of a systematic review with a more flexible and opportunistic approach. This ensured rigour on the one hand but also the flexibility to draw from cross - disciplinary literature in cases where search terms may not be present despite there being clearly relevant insights to draw from.

The following databases were accessed: Science Direct, Taylor and Francis, Google Scholar, Open Science Index, Semantic Scholar, BASE, OpenAIRE, WorldCAT, Sherpa/RoMEO, Zenedo.

This approach provides confidence that mainstream STS principles were harnessed, i.e. those that have enjoyed relatively widespread use and are available in the public domain. The authors acknowledge there may be STS principles of a more specialist and proprietary nature in existence. The completed review spanned the foundational work in STS principles dating from the field's inception in the 1940's and 50's and its precursors in scientific management approaches, though to the present day. In total 237 articles met the criteria above and were reviewed in depth. These articles included the prominent STS work of Trist and Bamforth [35], Cherns [9, 10], Davis [14], Berniker [5], Clegg [11], Walker et al. [41], Read et al. [30] and Waterson and Eason [45]. The review also shed light on the origins behind the principles, how they had been deployed in practice, and any subsequent revisions. This depth of knowledge was vital for the process of integrating and synthesising the principles.

#### 4 Synthesised Principles for Sociotechnical Systems Design

Table 1 provides a summary of the mainstream STS design principles currently extant in the literature. Two high-level findings emerged from the review. Firstly, the principles put forward by Trist et al., Cherns, Davis, Berniker, Clegg, Walker et al. and to a lesser extent Read et al. are quite persistent in the literature. They have tended to express the prevailing STS viewpoints of the day and been used in comparatively unmodified form. There are no other comprehensive sets of STS principles that have been widely published and used that diverge from these mainstream ones to a significant degree. Secondly, it is clear that comparatively little work has taken place synthesising these existing principles. To some extent the principles have grown from and built on previous versions as the underlying STS knowledge-base has itself grown, but apart from Read et al. [30] they have not been comprehensively integrated or synthesised into a common list. Table 2 goes on to present a matrix showing how the existing mainstream STS design principles can be grouped into a reduced number of themes based on their similarity. Table 2 also enables these groupings to be traced. The numbers in the cells show precisely which principles from Table 1 relate to which of the reduced themes in Table 2. These reduced themes then go on to form the synthesised list of STS principles elaborated and described in Table 3.

Many areas of commonality and distinctiveness are revealed in Table 2. The themes have been rank ordered to show which ones are more heavily loaded with pre-existing principles (e.g. multifunctionalism, congruence, joint optimisation, flexible specification etc.) or lightly loaded (e.g. simplicity and scale, self-regulation etc.). A mean of 5.6 out of 8 component principles load on to the reduced set of themes, reinforcing the point that the principles have more in common than they differ. It should also be added again that Tables 1 and 2 provide complete traceability, making it possible for the wider research community to scrutinise and, if necessary, revise these categorisations. For now, though, it is from this underlying structure that a fully up to date and synthesized list of 20 principles (see Table 3) can be derived.

An early use to which these principles can be put is in the assessment of existing ergonomics methods. Such an assessment is performed in Table 4. Here the principles are used to assess five contemporary systems ergonomics methods, all of which purport to support the analysis of STS. The methods are Cognitive Work Analysis (CWA) [29, 39, etc.], Systems-Theoretic Accident Model and Processes (STAMP) [22, 47, etc.], Event Analysis for Systemic Teamwork (EAST) [32, 34, etc.], Functional Resonance Analysis Method (FRAM) [20, etc.]. Also included is Hierarchical Task Analysis (HTA) [1, 32, etc.] a foundational method in ergonomics but one that drives a wide range of additional methods relevant to STS. This exercise is emphatically not about pitching one method against another in a form of competition, rather to flush out the different perspectives on STS each is able to provide. Clearly some methods are more comprehensive than others. CWA, for instance, provides a particularly wide ranging insight into relevant STS dimensions. Indeed, CWA seems to be one of the few that grants access to principles such as values (principle 10) and functional purposes (principle 17). It is interesting to note that HTA, when combined with the numerous methods that rely on its outputs, also provides comprehensive coverage of STS principles. As noted earlier, if there is a strategic need for the ergonomics discipline to become more engaged with high quality systems problems [e.g., 15] and for progress to be made in systematising STS practices and principles [e.g., 11] then ergonomic methods clearly have much to offer. Future research is being directed into a much more comprehensive STS methods review, using the new synthesised STS principles as evaluation criteria.

## 5 Conclusion

The current work has reviewed and compared 70 years of STS principles, identified the relationships between them, and synthesised them into updated set of principles for researchers and organisations to use and discuss. These principles, in the tradition of all previous STS principles, provide criteria for designing organisational structures, group work, work processes, design processes, technology, individual tasks, and methods. The principles are offered for use by anyone involved in organisational and system design, and should help to illustrate differences between traditional work design and the sociotechnical approach. The principles also provide direction to the system design process, providing a lens through which existing organisations and systems can be examined and new ones designed from scratch. The 70 year legacy of research which underpins these principles provides confidence that sociotechnical design principles will contribute to enhanced levels of performance, including operational measures such as productivity and effectiveness, but also psychological indicators concerned with well-being and attitudes. It is hard to deny that many organisations currently lack an integrated approach to organisational and technical change which, in the worst cases, results in a range of organisational pathologies right through to major system failures. As organisations become larger, more complex and more highly integrated, combined with dramatic changes in technology, the cost of such failures increases rapidly. Improving the existing set of sociotechnical principles provides a significant opportunity to cope with these emerging challenges in a more enlightened way. At the



simplest level it is possible to regard every single STS design principle as a possible risk, but at the same time they are also an opportunity.

**Acknowledgements.** This work was financed by the Republic of Kazakhstan's JSC 'Centre for International Programs' which operates under the Ministry of Education and Science of the Republic of Kazakhstan, and administers the Kazakhstan President's Bolashak Scholarship Program, that granted a Ph.D scholarship to Amangul Imanghaliyeva to support this study. The authors would like to thank the key researchers and practitioners of STS and organisation design area gathered in IWOT 19 2015 Festival of Connecting in Leuven, Belgium for providing valuable feedback on developing the work.

## References

1. Annett, J.: Hierarchical task analysis. In: *Handbook of Cognitive Task Design*, vol. 2, pp. 17–35 (2003)
2. Argyris, C.: Actionable knowledge: design causality in the service of consequential theory. *J. Appl. Behav. Sci.* **32**(4), 390–406 (1996)
3. Badham, R., Clegg, C., Wall, T.: Socio-technical theory. In: *Handbook of Ergonomics*, New York (2000)
4. Baxter, G., Sommerville, I.: Socio-technical systems: from design methods to systems engineering. *Interact. Comput.* **23**(1), 4–17 (2011)
5. Berniker, E.: Some principles of sociotechnical systems analysis and design. <http://www.plu.edu/~bernike/SocioTech/PRinciples%20of%20STS%20design.doc>. Accessed 18 Apr 1996
6. Bostrom, R., Heinen, S.: A socio-technical perspective; part 1: the causes. *MIS Q.: STS Perspect.* **1**(3), 17–24 (1977)
7. Carayon, P., Bass, E., Bellandi, T., Gurses, A., Hallbeck, M., Mollo, V.: Sociotechnical systems analysis in health care: a research agenda. *IIE Trans. Healthc. Syst. Eng.* **1**(3), 145–160 (2011)
8. Carayon, P., Hancock, P., Leveson, N., Noy, I., Sznclwar, L., Van Hootegeem, G.: Advancing a sociotechnical systems approach to workplace safety—developing the conceptual framework. *Ergonomics* **58**(4), 548–564 (2015)
9. Cherns, A.: The principles of sociotechnical design. *Hum. Relat.* **29**(8), 783–792 (1976)
10. Cherns, A.: Principles of sociotechnical design revisited. *Hum. Relat.* **40**(3), 153–161 (1987)
11. Clegg, C.: Sociotechnical principles for system design. *Appl. Ergon.* **31**(5), 463–477 (2000)
12. Coakes, E.: Knowledge management: a sociotechnical perspective. In: *Knowledge Management in the Sociotechnical World*, pp. 4–14. Springer, London (2002)
13. Davis, M., Challenger, R., Jayewardene, D., Clegg, C.: Advancing socio-technical systems thinking: a call for bravery. *Appl. Ergon.* **45**(2A), 171–180 (2014)
14. Davis, L.: Evolving alternative organization designs: their sociotechnical bases. *Hum. Relat.* **30**(3), 261–273 (1977)
15. Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W., van der Doelen, B.: A strategy for human factors/ergonomics: developing the discipline and profession. *Ergonomics* **55**(4), 377–395 (2012)
16. Eason, K., Harker, S., Olphert, W.: Representing socio-technical systems options in the development of new forms of work organization. *Eur. J. Work Organ. Psychol.* **5**(3), 399–420 (1996)
17. Eason, K.: Local sociotechnical system development in the NHS national programme for information technology. *J. Infor. Tech.* **22**(3), 257–264 (2007)

18. Flach, J., Carroll, J., Dainoff, M., Hamilton, W.: Striving for safety: communicating and deciding in sociotechnical systems. *Ergonomics* **58**(4), 615–634 (2015)
19. Hettinger, L., Kirlik, A., Goh, Y., Buckle, P.: Modelling and simulation of complex sociotechnical systems: envisioning and analysing work environments. *Ergonomics* **58**(4), 600–614 (2015)
20. Hollnagel, E.: *FRAM, The Functional Resonance Analysis Method: Modelling Complex Socio-technical Systems*. Ashgate Publishing, Ltd., Farnham (2012)
21. Hughes, H., Clegg, C., Bolton, L., Machon, L.: Systems scenarios: a tool for facilitating the socio-technical design of work systems. *Ergonomics* **60**, 1–17 (2017)
22. Leveson, N.: A new accident model for engineering safer systems. *Saf. Sci.* **42**(4), 237–270 (2004)
23. Majchrzak, A., Borys, B.: Generating testable socio-technical systems theory. *J. Eng. Tech. Manage.* **18**(3), 219–240 (2001)
24. Mohr, B., van Amelsvoort, P.: *Co-Creating Humane and Innovative Organizations: Evolutions in the Practice of Socio-technical System*. Global STS-D Network (2016)
25. Mumford, E.: The story of socio-technical design: reflections on its successes, failures and potential. *Inf. Syst. J.* **16**(4), 317–342 (2006)
26. Painter, B., Posey, P., Austrom, D., Tenkasi, R., Barrett, B., Merck, B.: Sociotechnical systems (STS) in coordination of virtual innovation work. In: *STPIS@ CAiSE*, pp. 40–55 (2015)
27. Painter, G., Posey, P., Austrom, D., Tenkasi, R., Barrett, B., Merck, B.: Sociotechnical systems design: coordination of virtual teamwork in innovation. *Team Perform. Manage.* **22** (7/8), 354–369 (2016)
28. Ramage, M., Shipp, K.: *Systems Thinkers*, pp. 267–277. Springer Science & Business Media (2009). Chapter 29
29. Rasmussen, J., Pejtersen, A., Schmidt, K.: *Taxonomy for cognitive work analysis* (1990)
30. Read, G., Salmon, P., Lenne, M., Stanton, N.: Designing sociotechnical systems with cognitive work analysis: putting theory back into practice. *Ergonomics* **58**(5), 822–851 (2015)
31. Robertson, M., Hettinger, L., Waterson, P., Ian Noy, Y., Dainoff, M., Leveson, N., Courtney, T.: Sociotechnical approaches to workplace safety: research needs and opportunities. *Ergonomics* **58**(4), 650–658 (2015)
32. Salmon, P., Lenne, M., Walker, G., Stanton, N., Filtress, A.: Using the Event Analysis of Systemic Teamwork (EAST) to explore conflicts between different road user groups when making right hand turns at urban intersections. *Ergonomics* **57**(11), 1628–1642 (2014)
33. Siau, J., Keng.: Social and technical aspects of systems analysis and design. In: *Systems Analysis and Design: People, Processes and Projects: Advances in Management information systems*, Vladimir Zwass (2011)
34. Stanton, N., Stewart, R., Harris, D., Houghton, R., Baber, C., McMaster, R., Linsell, M.: Distributed situation awareness in dynamic systems: theoretical development and application of an ergonomics methodology. *Ergonomics* **49**(12–13), 1288–1311 (2006)
35. Trist, E., Bamforth, K.: Some social and psychological consequences of the Longwall method of coal-getting: an examination of the psychological situation and defences of a work group in relation to the social structure and technological content of the work system. *Hum. Relat.* **4**(3), 3–38 (1951)
36. Trist, E.: *The Evolution of Socio-technical Systems: A Conceptual Framework and an Action Research Program*. Ontario Ministry of Labour, Ontario Quality of Working Life Centre (1981)

37. Van Amelsvoort, P., Van Hoogtem, G.: Towards a total workplace innovation concept based on sociotechnical systems design. In: *Workplace Innovation*, pp. 281–299. Springer, Cham (2017)
38. Vermeerbergen, L., Van Hoogtem, G., Benders, J.: Putting a band-aid on a wooden leg: a sociotechnical view on the success of decentralisation attempts to increase job autonomy. *Team Perform. Manage.* **22**(7/8), 383–398 (2016)
39. Vicente, K.: *Cognitive Work Analysis: Toward Safe, Productive, and Healthy Computer-Based Work*. CRC Press, Boca Raton (1999)
40. Walker, G., Stanton, N., Salmon, P., Jenkins, D.: A review of sociotechnical systems theory: a classic concept for new command and control paradigms. *Theor. Issues Ergon. Sci.* **9**(6), 479–499 (2008)
41. Walker, G., Stanton, N., Salmon, P., Jenkins, D.: *Command and Control: The Sociotechnical Perspective*. Ashgate, Aldershot (2009)
42. Walker, G., Stanton, N., Salmon, P., Jenkins, D., Rafferty, L.: Translating concepts of complexity to the field of ergonomics. *Ergonomics* **53**(10), 1175–1186 (2010)
43. Walker, G.: Evolution, co-evolution, and complexity: an anniversary systems journey through the grid. *J. Civ. Eng. Environ. Syst.* **30**(3–4), 249–262 (2013)
44. Walker, G.: Come back sociotechnical systems theory, all is forgiven. *J. Civ. Eng. Environ. Syst.* **32**(1–2), 170–179 (2015)
45. Waterson, P., Eason, K.: Revisiting the sociotechnical principles for system design (Clegg 2000). In: *Congress of the International Ergonomics Association*. Springer, Cham (2018)
46. Waterson, P., Robertson, M., Cooke, N.J., Militello, L., Roth, E., Stanton, N.: Defining the methodological challenges and opportunities for an effective science of sociotechnical systems and safety. *Ergonomics* **58**(4), 565–599 (2015)
47. Young, W., Leveson, N.G.: An integrated approach to safety and security based on systems theory. *Commun. ACM* **57**(2), 31–35 (2014)



# Cut Me Off: An Exploratory Study About How the User Perceives the Information of Clothes Textile Labels

Maria Aurileide Ferreira Alves<sup>1,2(✉)</sup> and Gonalo Falco<sup>1</sup>

<sup>1</sup> Faculdade de Arquitetura, CIAUD, Universidade de Lisboa, Rua S da, Nogueira, Polo Universitrio, Alto da Ajuda, 1349-055 Lisbon, Portugal  
mafa@campus.ul.pt, gfalcao@fa.ulisboa.pt

<sup>2</sup> Centro Universitrio Unifanor Wyden, Rua Antnio Gomes Guimares, 150, Fortaleza, CE 60191-195, Brazil

**Abstract.** Textile labels contain important data for consumers about the care and maintenance of clothing, but the knowledge regarding the information being passed on by them is relatively scarce. Existing literature describes how people behave before and after buying clothes but there is few information about the comprehensibility of the graphic symbols that allow consumers to take care of the products. Some studies focus on analyzing the consumer literacy of this information. In this paper, we introduce the results of a survey applied among Brazilian respondents. The inquiry helped to understand the attention paid to labels by the consumers, and their capacity to read the symbols and apply them to clothing care. Based on quantitative and qualitative research, we also try to know the context in which the clothing care is done and by who, emphasizing the importance of developing solutions to enhance people's understanding of this code.

**Keywords:** Human factors · Graphic symbols · Textile labels

## 1 Introduction

Be it for protection, distinction or belonging, clothing is an item present in the daily lives of all human beings. Its durability depends appropriate care and maintenance according to each type of product and according to the way textile, technology evolves, and new fibers are inserted in the market. It is in the textile labels that this information is organized and displayed so that the user may read and access it whenever necessary. Symbols were made, norms and laws regulate the procedure so that the manufacturers and federal and state institutes are able to supervise and guarantee the consistency and coherency in the information received by the consumer.

In 1963, in Paris, a consortium formed by three countries (Switzerland, France, Germany) after years of international symposiums, gave origin to the *Groupe ment Internationale d'Etiquetage pour l'Entretien des Textiles* - GINETEX. This organ created a system of graphic symbols supposed to be utilized in the textile network with the pretension to universalize the comprehension of the care and maintenance. The five

basic figures have become registered marks in many countries in which they appear invariable, independent of the language. Since its creation, these pictograms (as shown in Fig. 1) are reanalysed every five years, due to the technical development and ecological matters. Today there are 45 variations, encompassing a large range of products and situations involving the care and maintenance of pieces of clothing [1]. Each country linked to the Swiss institute, can organize its committees to manage the normalization, legislation and inspection of the labeling process. However, some countries continue to use their own graphic symbol system concomitantly with Ginetex's, which beckons the creation of more symbols. This is the complex scenario to the manufacturer and even more to the final user.



**Fig. 1.** GINETEX textile graphic symbols sequence from 2006 [1].

Many clothes become stained or faded after washing because the information on the care labels is incorrect. Colored clothing from various processes or excessive heat from the iron may cause irreversible damage [2]. During washing, dyes from clothes dyed by different techniques can be accidentally transferred from one item to another [3] and the use of bleach and abrasive products can also discolor clothes that have not been prepared to receive the action of these cleaning materials.

For the Brazilian consumer, clothing products have been regulated by law since 1973 [3, 4], obliging manufacturers to provide informative labels containing the origin, composition, size and conservation and use instructions affixed to the garment to ensure correct use without losing the original properties.

The Brazilian consumer of clothing products is accustomed to cutting the label and such behavior is encouraged by many companies [4] who already offer a cut line to facilitate the removal. However, this stimulus may serve only to reinforce the insignificance of the information contained therein, “since withdrawal prevents its use throughout the product’s useful life” [5].

The labels on the clothes are textile manuals [6]. A study carried out in Brazil in 2012, with 240 people, male and female, ages and professions varied, with the objective of verifying the behavior of the consumers in relation to the use of the information of the labels and related textile products indicated that 25% of respondents are unaware of the textile regulation and do not even know that there are standards for their presentation on clothing; 50% are partially aware or have heard of it. Regarding the respondents’ interest in knowing the information contained in the textile manuals, about 35% of the respondents said to look for information on the labels, however, the study did not verify that they are able to understand them. Finally, 50% of the respondents said that it confers the symbols of conservation of the product represented in the labels, but the research also did not intend to verify the degree of correctness in the interpretation of the information, mainly the symbolic ones. It is worth noting that the study does not address the comprehensibility of symbols [6].

Qualitative research [7] notes that consumers, even when they say that they want to make more environmentally friendly choices, do not even notice clothing labels, neglecting important aspects of garment care, such as environmental impact on disposal issues. Through interviews it was verified the existence of several types of labels that can be associated directly and indirectly with sustainability; it may still find that the consumer erroneously assumes that synthetic fibers are less sustainable than natural fibers. The study concludes that the selection of the washing procedures and maintenance of the piece by the consumers can directly interfere in the environmental impact of the clothes. A previous study in 2011 found that the correct maintenance can also potentially increase the life of the part, preserving the colors and avoiding the deformation (stretching or shrinking) of the fabric [8].

By analyzing the performance of Turkish consumers [9] regarding the understanding of the treatment and maintenance symbols on clothing labels, applying questionnaires to 120 participants from different cities, age, sex and education level submitted to eleven different types of symbols, verified It is believed that women had a better understanding of the symbols related to washing than men; even though of the five basic symbols, no individual was able to identify all, and that the bleach was the least recognized.

In India [10], a study of 1,200 participants, adult men and women separated into two groups: students (undergraduate and graduate) and couples with children showed that 48.17% of the participants always checked their labels and that 36, 58% only sometimes. 30.75% of users said to check information about textile composition before buying the piece, 20% of respondents never do and 6.5% did not understand what that means. Of all participants, 25.33% said they would read the label shortly for manufacturer's data (name, address), 19.75% would read if they had time and 26.50% never read it. Less than 47.25% of the total number of subjects reported taking care of their clothes according to the instructions on the labels, while 11.42% reported being unable to understand them and 9.08% stated that they never consulted the label before washing or ironing.

Considering the 26 symbols of the Latin alphabet and the clothing maintenance and the textile care system having 45 and, differently from the learning process of reading text or of the road symbols, for example, in this case there is not any informative effort by the countries side, the ones that use this code, to teach it to people. It's almost like a secret code. This essay has as objective verify some of the main consequences of ignorance regarding textile labels, not only of its symbols, but also – having in mind the fact that people don't know them – the label itself as an informative element. For such purpose, it aims to verify if the users are capable of attributing any importance to the labels, associating them to the care, maintenance and durability of their clothes.

## 2 Methodology

The data collection of this research, of exploratory character, occurred in October 2017 and had the voluntary participation of 100 consumers, all randomly invited through electronic means to answer a semi structured questionnaire with open and close ended questions about the habits of clothe washing, the labels and the care with the

maintenance and conservation of pieces of clothing. The objective was to verify the importance the user attributed to the labels and what major accidents occurred, usually, during the washing of the clothing.

The formulary was available for a period of 15 days after which it was closed to data treatment and recovery. Besides the socio demographic matters, like gender, age, profession and local of residence, the participants were inquired about their habits of clothe washing. The following questions were made: who washes your clothes? If you wash them at home, do you use a washing machine? If so, which information in the labels are useful to you? Have the labels' information ever helped you avoid accidents with the colour of the clothes? In order to investigate if the user had any personal pattern or ritual followed during the washing process the following question was inquired: Is there any special way, habit or procedure that you always use when you wash your clothes? If so, which one?

After the end of data collecting, the same we tabulated in a worksheet to that answers of quantitative or qualitative nature could be obtained.

### 3 Results and Discussion

Of the total of participants, all of them Brazilian, 61 women and 39 man; 41 were between 15 to 24 years old and the rest were between 25 and 64 years old; acting like students (26), professors (13), designers (10) and other professions with less than 10 occurrences (51).

Answering to the question of who washes their clothes, 57 said that they did it themselves, 35 some family member, 6 people said that a domestic maid, 1 said the diarist does it and 1 said that they sent it to a specialized laundry. Of this amount, women are the ones that wash their own clothing the most (45) and the men do not know exactly who is responsible, saying only that it is someone of their family (25). In addition, women are the one that sent the clothing pieces to the washhouse (1) or leave them to the diarist (1) or to the house cleaner/domestic maid (4). 86 of the respondents informed having a washing machine, against 9 that do not have the machine. 5 did not answer the question.

About the label questions. 75 of the respondents informed never verifying the clothes' labels and only 25 said to execute a reading of the mentioned, especially before the washing process.

And about the type of information that are most privileged on the labels, 21 of the respondents that wash their own clothing said they are interested in: knowing if the piece could be washed by hand, if it could be soaked, if it discolours during the washing, if it could be ironed, which is the composition of the fabric of the piece of clothing, if it could be washed in hot water, if the use of bleach is recommended, what type of soap or chemical products can be used, if the use of softener is allowed and if it can dry under sunlight. A user said that he considered only the labels that had written instructions in them, for the symbols were incomprehensible, according to himself. Others said to look for the labels only when the piece was expensive, when the fabric was delicate or unusual, but not in a daily basis.

Did the information on the labels helped avoiding accidents with the clothes' colours? Of the 25 that looked at the labels, 5 said that the information was not sufficient to help them in their task of washing and prevent accidents.

When asked about personal habits in the washing process, the answers were varied, but the majority said to only separate the clothes according to their colours before putting them in the machine and washing intimate or delicate clothing by hand, for fearing they might be damaged by the machine. Others said that they put delicate clothing pieces in a sack before washing them on the washing machine. Some reported the use of products available in the Brazilian market, to whiten the clothes, like coconut soap and even some unconventional products, like vinegar and salt. 2 people reported pre-washing manually the pieces that are dirtier or smellier (like children's or sports clothing) due to them thinking that the machine wasn't effective enough. At last, two respondents said they always use more soap than the indicated on the machines, for they thought the quantity was insufficient to clean the clothes with efficiency.

Regarding the reason why they didn't consult the labels, 49 of the answers revealed that the majority do not have the habit of consulting them for not thinking them to be necessary (31); due to the allergies to the materials they are made of, 2 people said they usually cut them and other 2 said that they cut them because they itched. Other people. Said that they found the information on the labels to be insufficient to guide the washing process, due to, for example, not warning about discolouring and torsion of the fabric. Others said that the symbols were of hard comprehension and that they thought every label was the same for any kind of clothing and because of that, they didn't contain any variation in the instructions.

At last, the users were asked if they had already had any type of clothing damaged during the washing process or ironing. 77 answered yes and 23 answered no.

## 4 Conclusion

Considering that Brazil is a country with continental dimensions and with an economic and social disparity that allows various scenarios to the study of clothes washing habits, it is convenient to mention what does the research emphasizes on, regarding, the use of the washing machine in Brazilian homes. Not all homes possess this kind of household appliance and, therefore, it is still commonplace to delegate the chore of washing the clothes to the diarist of the house cleaner/maid, or even to let them wash it in their own house.

Even though men are also doing the washing in their homes, it is the women, Brazilian, young ones and students that washes their own clothes the most and look at the labels on them. Nevertheless, it is also them that say that they don't think the existence of the labels is necessary, even when 77% of the inquired reported having already had some kind of accident or loss after a washing or ironing process. This answer seems to indicate the lack of comprehension of the importance of the label – as a manual of instruction- contributes to what could happen, being here a space for a possible educative action. On the other hand, when relating that they don't have interest in reading the label because they think the symbols to be complicated or difficult, the user is also relating a problem that can be avoided with a more efficient symbol design



that is able to communicate the washing functions of the textile pieces. If they cannot glimpse at the importance nor of a function, the only choice the user has is to cut the label out.

While on preliminary initiative, this essay, that integrates a more wide investigations, intends to contribute to make the focus shine upon these tiny informative objects, which its ubiquity makes them seem to be almost invisible (or only the fulfilment of an legal imperative), but that could contribute, efficiently, to the reduction of waste and, consequently to a better use of the natural resources. This essay proposes yet to expose this subject to the academic world so that other researches in this area may arise, enriching this little explored area of information design.

## References

1. Groupement Internationale d'Etiquetage pour l'Entretien des Textiles-GINETEX. <http://www.ginetex.com>
2. Testex: color fastness to wash of textile materials: fastness measurement-testex (2017). <http://www.testextextile.com/color-fastness-to-wash-of-textile-materials-fastness-measurement/>
3. Environmental Assurance Program: Color Fastness, Technical report, vol. 4, pp. 3–6 (2001)
4. Ministério do Desenvolvimento, Indústria e Comércio Exterior; Instituto Nacional de Metrologia-INMETRO: Procedimento de Fiscalização e Coleta de Amostras de Produtos Têxteis para a Avaliação da Fidedignidade das Informações. INMETRO (2011)
5. Associação Brasileira de Normas Técnicas–ABNT & SEBRAE: Normalização: Caminho da Qualidade na Confecção (2017). <http://portalmpe.abnt.org.br/bibliotecadearquivos/>
6. Nunes, E.L.S., de Trotta, T., Licheski, L.C.: Simbologia Têxtil: Aplicação e Compreensibilidade. *Revista Ação Ergonômica* **9**(1), 111–116 (2012)
7. Laitala, K., Klepp, I.G.: Environmental and ethical perceptions related to clothing labels among Norwegian consumers. *RJTA* **17**(February), 50–58 (2013). <https://doi.org/10.1108/RJTA-17-01-2013-B005>
8. Laitala, K., Boks, C., Klepp, I.G.: Potential for environmental improvements in laundering. *Int. J. Consum. Stud.* **35**(2), 254–264 (2011). <https://doi.org/10.1111/j.1470-6431.2010.00968.x>
9. Calisir, F., Gumussoy, C.A., Bozdurgut, N., Topalo, H., Bayraktaroglu, A.E.: Comprehension of care label symbols: effects of age, gender, and education level. In: *Proceedings of the World Congress on Engineering and Computer Science*, vol. 2, pp. 23–25 (2013)
10. Jain, M.: General practices of consumers during purchase and use of textile products: a survey report. *Int. J. Res. Commer. Manage.* **6**(05), 48–52 (2015)



# Ergonomic Research in Civil Aircraft External Service Design

Yu Chen<sup>(✉)</sup>

COMAC ShangHai Aircraft Design and Research Institute,  
No. 5188 Jinke Road, Pudong New District, Shanghai, China  
chenyu2@comac.cc

**Abstract.** Civil aircraft external service design has great impact on the maintainability and economy of civil aircraft. At the same time, it also has an important impact on the workload, operation pattern and accessibility of ground crew. Due to all above reasons, ergonomics research should be paid attention to in the design phase. This paper mainly discusses the ergonomic considerations in the layout and design of external service in the aircraft design phase, which provides some guidance for the civil aircraft external service design.

**Keywords:** External service · Accessibility · Civil aircraft · Ergonomic

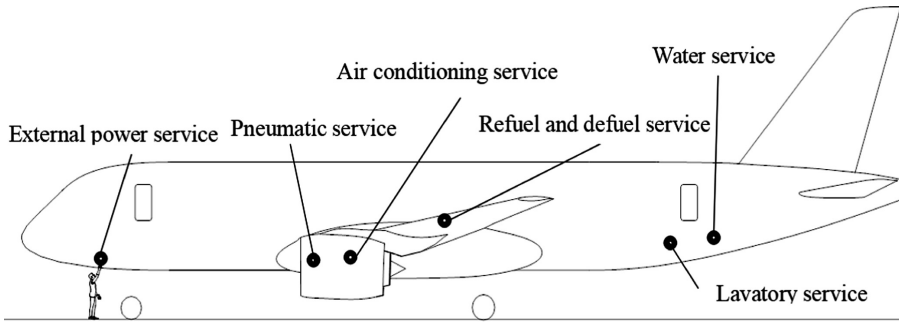
## 1 Review

With the development of aviation technology, the concept of civil aircraft design based on ergonomic has been paid more and more attention to. In the design and development of civil aircraft, human factors are quite important, such as in the cockpit design, where conception of ergonomic played an increasingly important role [1, 2].

Commercial airliners need to embark and disembark passengers, load and unload luggage and cargo, refuel and clean external surface before taking off, after arrival and between transit. Generally speaking, the design of external service interface (service hatch and service panel, etc.) mainly refers to the ground service and inspection before and after flight. Diagrammatic sketch of key service interfaces of civil aircraft are shown in Fig. 1. A reasonable layout design of service interfaces and service vehicles could effectively guarantee a well-arranged service routine work. Based on a reasonable layout design, the ground crew could work systematically, so operation would become more convenient.

## 2 General Layout and Ergonomic Design of External Service

Normally, all the external service interfaces require ground crew to carry out corresponding operations. So the layout design of these service interfaces shall take related human factors into consideration, such as psychological, physiological, cultural background, etc. The airplane and service work should be organically considered as a whole, workload of ground crew should be paid more attention to. With the combination of ergonomics, statistics and system engineering to fully optimize related



**Fig. 1.** Diagrammatic sketch of key service interfaces of civil aircraft

system's layout, a safe, efficient and accessible service interface can be designed. It can also reduce the ground crew's workload and the possibility of accident. Less downtime of ground service and high efficient maintenance means lower cost and higher profit for airlines. So that the aircraft design for the operation, maintenance and other processes is more reasonable.

Aircraft external service interfaces can be divided into the following categories: External power service interface, lavatory service interface, potable water service interface, pneumatic service interface, refuel and defuel service interface, etc. All these service interfaces are mostly determined by the layout of the internal system equipment, which also affects the layout of the internal system equipment to some extent.

The general layout design principles of external service interface are as follows:

- (1) The layout of external service interface shall be reasonable, which can facilitate the access of ground crew and service vehicles;
- (2) The location and form of external service interface shall be convenient for access;
- (3) External service interface should be located as far as possible away from the dangerous area around the aircraft engines;
- (4) The location of external service interface shall not affect other external critical system.

Based on the principles above, the preliminary layout scheme for external service interface can be defined.

The ergonomic design of external service interface will be discussed in following categories: accessibility design, error prevention design, operation safety evaluation and design, etc.

### 3 Accessibility Design

The accessibility of operation is an important factor of ergonomic design. Accessibility in operation includes three aspects: physical contact accessibility, operation accessibility and visual accessibility. Accessibility is the basis of all operation activities, and service tasks can only be carried out when accessibility meets the requirements.

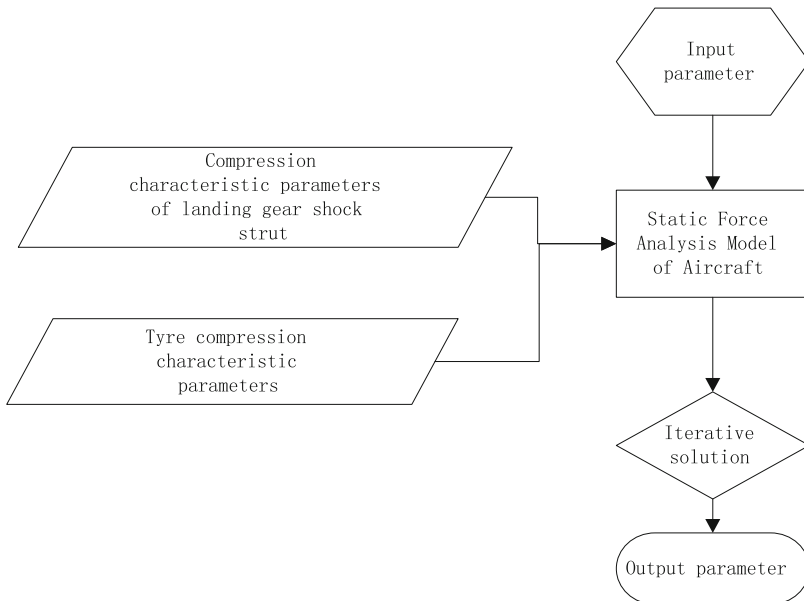
The following qualitative requirements are put forward for the accessibility of external service interfaces:

- (1) Reasonable layout design of service space, and sufficient accessibility for ground crew.
- (2) Visibility of the operation process. When perform service operation, sufficient operation space shall be guaranteed, certain space shall also be guaranteed to offer observation operation.
- (3) The target of operation is easy to be implemented without interference.

Based on the accessibility requirements above, it is meaningful to discuss the problem in the following aspect: height design of service interface, operation task accessibility design, visual accessibility design and operation convenience design.

### 3.1 Height Design of Service Interface

Ground clearance is the basis for the accessibility of external service interfaces. Since there is a great connection between the actual height of an aircraft and the weight/the center of gravity of the aircraft, generally speaking, the referred height is based on OEW (Operation Empty Weight), the height calculation method and process are shown in Fig. 2.



**Fig. 2.** Method and process of aircraft height calculation

In the early stage of aircraft development, in order to define the height of ground service interface, it is necessary to study the size of human body to provide effective

data for design and analysis. Human body size [3] is the size data measured by human body measuring instrument between specific measuring points, when the human body is in the specified measured state. It includes body size, feature points size, space between feature points and function size. The human body was divided into several percentile categories. The most commonly used data is 5th, 50th and 95th percentile.

In general statistics, instead of listing all percentile data, the mean  $\bar{x}$  and standard deviation  $S_D$  are presented, by which each percentile can be calculated. In general, human body size is considered as a normal distribution. Therefore, when the mean and standard deviation of a certain size data are known, the data at any percentile can be obtained, and the calculation formula is

$$x = \bar{x} \pm (S_D \times K). \quad (1)$$

Where,  $\bar{x}$  is the mean value;  $S_D$  is the standard deviation;  $K$  is the variation coefficient. When calculating the percentile data is less than 50%, take the negative sign; Take the positive sign when the percentile data is greater than 50%.

The percentile in the practical application should be selected according to the specific purpose. For example, when design for the extreme scale, select the 95% percentile data to ensure that the design meets the requirements for 95% of the population. In this paper, 95% percentile data can be selected for the evaluation for service operation.

According to this height, the height position of related service interfaces should be determined. Service interfaces with large service workload and high service frequency should be arranged in places where ground crew can access them without using ladders or workbenches, according to the actual height of related areas of the aircraft.

### 3.2 Operation Task Accessibility Design

The primary consideration in the design of service interface is whether the operation target is within the human body's reachable range. If the operation target were in the human body's reachable range, the human-machine ergonomics simulation analysis of the product shall be applied. If a workbench is needed, the design of workbench should be based on parameters of each human body posture, which would ensure a comfortable, convenient operation for ground crew.

The working space refers to the operator's close-in working space. The size of the close-in work space is limited by the length of the functional arm, that is, in order to maintain the balance of the body, the movement space of the upper body and arms must be limited. Standing posture close to the work space generally allows the operator to move the body to adjust the work posture, but the work space is also limited.

According to the analysis above, under different working posture, different working condition, the body work space is different. When the operation target is in a certain space range, for ground crew with different body size under different work posture, the service interface is accessible, and in operator's comfort posture range, then it is reasonable to consider the accessibility of this interface is good. For service interface within most operators' reach range, accessibility would be considered OK. For service interface near or beyond the extreme reachable range under a certain posture, then the accessibility would be considered poor or unreachable.

By using the human-machine engineering simulation software to get the accessible envelope of the upper limb of a virtual man, we can determine whether the referred service interface is within the accessible range of the human limb. Before the simulation, it is necessary to determine and adjust the posture of the ground crew, to ensure the ground crew would be in the best operation position, then adjust the posture of the virtual man, to determine the adopted posture, and then carry out contact and operation accessibility analysis.

### 3.3 Visual Accessibility Design

Visual accessibility analysis of operation refers to ground crew can see the operation target and the related objects under the operation condition. Visual accessibility directly affects the accuracy of operation.

The two main parameters of visual physiology are angle of view and field of vision. The Angle of view is the angle between two rays coming into the eye from the object, which starting points are the two end points of the object. So it's related to the distance between the two ends and the distance between the object and the eye.

Which can be presented by the equation below:

$$\alpha = 2 \arctan \frac{D}{2L}. \quad (2)$$

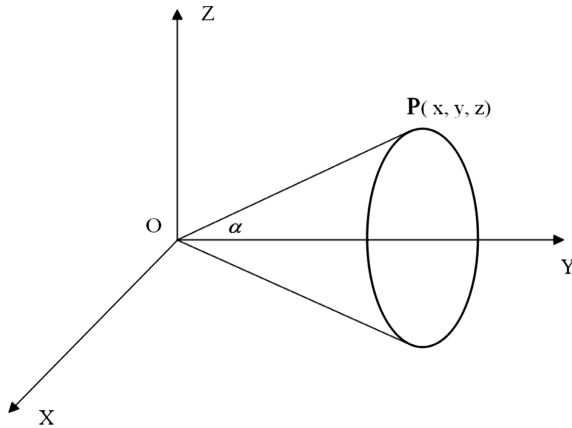
Where,  $\alpha$  is the angle of view;  $D$  is the straight-line distance between the two ends,  $L$  is the distance between the object and the eye.

Field of vision is defined as following. When the head and eye is fix, and faces forward, the area that eye can see is field of vision. Commonly use angle to measure it. The field of vision using one eye is defined as monocular vision. The area that can be seen by each eye when observed alone, namely the common area of monocular vision of left and right eyes, is called binocular vision. From the space perspective, the above field of vision is superposed to obtain the visual inner-cone of the field of vision. The vertex of the cone is at the intersection of the mid-line sagittal plane of the two eyes. If the service object is inside the cone, it is considered to satisfy the visual accessibility; if not, it is considered not visible.

The model of the inner-cone in the simulation is as follows: Select spatial coordinate system OXYZ, as shown in Fig. 3. The longitudinal axis of human body is defined as the X-axis, the lateral axis of human body is defined as the Y-axis, and the vertical axis of human body is defined as the Z-axis. The coordinate of the service object is set to  $P(x, y, z)$ .

$$\begin{cases} \frac{x^2}{a^2} + \frac{y^2}{a^2} - \frac{z^2}{c^2} = 0 \\ \tan \alpha = \frac{a}{c} \end{cases}. \quad (3)$$

Where,  $\alpha$  is cone apex angle,  $a$  is radius of the bottom face of the cone,  $c$  is the distance between two eyes.



**Fig. 3.** Coordinate system OXYZ

Simulation software can be used to build models and carry out related simulation to help evaluate visual accessibility of corresponding service operations. For example, some operation switches on the external service panel of the aircraft need to set related parameters, such as the refueling panel which needs to set the refueling quantity. For these ground service panels, the information needs to be checked and confirmed by the pilot or the ground crew before and after the flight, the angle of view and field of vision during the operation need to cover the related service objects.

### 3.4 Operation Convenience Design

Operational convenience means to be fully considered in the design process to reduce the physical and mental load of the ground crew in accordance with the operation procedures.

For the design of external service, it is necessary to mark the external fuselage near each service interface, mark the name of service interface, related service operation steps and important notes needing attention, and ensure that the operation objects and steps for ground crew won't make mistakes.

For a small service interface, set a separate service panel or hatch is unfavorable for the convenience of ground crew. In order to reduce the number of service interfaces and optimize system integration of the aircraft, the service interfaces in some area shall be integrated. The integration of service interfaces makes the service operation focus on several service hatch and panel, which could reduce ground crew's workload. For example, the aircraft's intercom jack can be integrated into other systems' panel as needed.

## 4 Error Prevention Design

Although the aircraft design level is continuously improving and error prevention ability is becoming greater and greater, due to technical and economic costs and other reasons, the current aircraft design level is far from enough to eliminate all the human errors in all the operation process.

Error prevention design is to take measures from the product design perspective, in order to ensure that critical service operations could be the correctly operated. Error prevention design includes three aspects. First is to take measures in product design, so that service operations cannot be wrong; Second, the design should ensure that operation matches the human habits, so they will not make mistakes; Third, the design has taken a certain fault tolerance technology which ensures even if operation error occurs, it would not cause serious consequences.

For the external service design, it is necessary to catch the errors that may occur in the operation process according to the ground crew, list out all the events that may occur, extract and summarize the design for preventing errors. Table 1 below lists the items that need to be checked for error prevention design in external service design.

**Table 1.** Error prevention design check list

No.	Check content
1	Whether the operation is within human's ability?
2	Does the hatch provided with an indication that it is properly locked?
3	Does the controls move in the same direction as the operator, the controlled object, or its implementation?
4	Are critical controls equipped with protection in case the operator accidentally touches them?
5	Are closely spaced controls distinguished in shape/color, etc.?

## 5 Operation Safety Evaluation and Design

In the of external service design process, it is necessary to evaluate the safety of external service operation and establish acceptable standards for operation risks.

When determining the evaluation index of operation safety, it is necessary to keep consistent with the industry standard, and determine the severity level and probability level of dangerous consequences according to similar empirical methods [4]. When determine the risk level of operation, the risk matrix method can be applied. In general, there is an inverse relationship between the severity level of consequence and the probability of occurrence.

Therefore, in order to determine the safety risk level of the aircraft, the risk matrix can be used. In the risk matrix, the horizontal axis corresponds to the severity level of consequences, and the vertical axis corresponds to the probability of occurrence. Risk matrix is shown in Table 2 below. The corresponding cell is indicated by signs (1A, 2B, 3C, etc.).



Risk level criteria are defined as follows:

- (a) Unacceptable risk  
If the risk is in one of the cells 3A, 2A, 1A, 3B, 2B, 1B, 2C, 1C and 1D, the risk is unacceptable and corrective/improvement measures to mitigate/control the risk will be taken. Until the risk is reduced to an acceptable level;
- (b) Tolerable risk  
If the risk is in one of cells 4A, 4B, 3C, 2D and 1E, the risk is tolerable, and corrective/improvement measures to mitigate/control the risk can be taken as appropriate. It is acceptable under specific mitigation conditions, but it requires continuous tracking and monitoring;
- (c) Acceptable risk:  
If the risk is in one of cells 5A, 4B, 5C, 5D, 5E, 4C, 4D, 4E, 3D, 3E and 2E, the risk is acceptable without any corrective/improvement measures to mitigate/control the risk; There is no need for active attention to this risk, but it must be documented.

Based on the above risk matrix, it can analyze the design scheme and the security of the service operation, which provide the basis for the gradual refinement and optimization of the external service interface scheme, and also give the conclusion of the security evaluation of the external service operation.

**Table 2.** Risk matrix evaluation table

Possibility \ Severity	Safely: 5	Slightly: 4	Significant: 3	Dangerous: 2	Disaster: 1
Frequent : A	✓ 5A	● 4A	■ 3A	■ 2A	■ 1A
Possible : B	✓ 5B	● 4B	■ 3B	■ 2B	■ 1B
Likely : C	✓ 5C	✓ 4C	● 3C	■ 2C	■ 1C
Nearly possibly : D	✓ 5D	✓ 4D	✓ 3D	● 2D	■ 1D
Highly unlikely: E	✓ 5E	✓ 4E	✓ 3E	✓ 2E	● 1E

## 6 Summarize

This paper generalizes and summarizes the critical points about the human-machine engineering for civil aircraft external service design, especially in accessibility design, which further expanded into height design of service interface, operation task accessibility design, visual accessibility design and operation convenience design, etc. At the same time, error prevention design should be conducted, and the evaluation index of

operation safety should be established to ensure that the external services design meet the requirements of operation safety. This paper conducts a preliminary study in ergonomics which provides guidance to external service interface design to satisfy customer's requirements.

## References

1. Wiegmann, D.A., Shappell, S.A.: A Human Error Approach to Aviation Accident Analysis: The Human Factors Analysis and Classification System. Ashgate Publishing, Vermont (2003)
2. John, W.: The autopilot challenge. *J. Air Transport World*. **6**, 16–18 (1995)
3. Ahlstrom, V., Longo, K.: Human Factors Design Standard (HFDS) For Acquisition of Commercial Off-The-Shelf Subsystems, Non-Developmental Items, and Developmental Systems. DOT/FAA/CT-03/05 (2003)
4. DEFSTAN 00-56/1-2012 Safety Management Requirements For Defence Systems



# Design for Children - Ergonomics in a Ceramic Tile's Project

Cristina Salvador<sup>(✉)</sup>

CIAUD, Lisbon's School of Architecture, Universidade de Lisboa,  
R. Sá Nogueira, 1349-055 Lisbon, Portugal  
cristinasalvador@fa.ulisboa.pt

**Abstract.** A ceramic tile's project, which is intended to stimulate the interaction of the child with his/her surroundings, was developed and prototyped. It focused on physical and emotional comfort through visual and tactile properties, targeting children but also parents as users and consumers. This project aims to create diversity by appropriation of the users, who may customize it using their imagination. The contribution of Human Factors and Ergonomics in a stage of evaluation of this design project had to be taken under account and applied as a useful tool in the design process. Besides literary review, this paper reports a study with primary school children with 9–12 years of age, based on interview and a quasi-experimental approach with drawing sessions, facing prototypes of the ceramic tiles' project. The results revealed much diversity and gave clues about their preferences, their interaction with indoor home environment, ceramic coatings and the child's imaginative universe in the context of the pre-teenage phase of their development. Also conclusive is the overall importance that HFE revealed once more in the development of a design project.

**Keywords:** Ergonomics and Human Factors · Product design · Design for children · Emotional and physical comfort · Ceramic coating

## 1 Introduction

Following a PhD Product Design research, which culminated in a children's furniture design project, a parallel ceramics project evolved, also targeting the child as a user. It is a ceramic tile's project, which intends to stimulate the interaction of the child with his/her surroundings. The project was created, developed and prototyped by the author of this study, using a manufactured plaster cast and white clay, going through 1200 °C temperatures in oven and a white glazing process.

Ceramic coatings have been manufactured and applied for thousands of years in architecture and home environment [1] and in Portugal, in particular, there is a Moorish tile heritage of ancient techniques and aesthetical influences [2], which have evolved through the centuries. Ceramic materials have had many applications [3] and its thermal, acoustic and structural characteristics have made them into valuable elements [4, 5] for humankind. Specifically, ceramic tiles were also applied in several contexts [6]. The study of the interaction of humans with ceramic coatings may be an added value when searching for physical and emotional comfort through visual and tactile properties in the

design of home interiors. The project targets children but also parents as users and consumers. This project intends to create diversity by appropriation of the users, who may customize it using their imagination, in a ceramic coating with a relatively abstract form. The form can be perceived visually and also by tact, thanks to its texture - a spiral and three hemispheres in high relief. Thanks to its glazing, it is possible to draw and/or write with markers for use on white boards (non permanent) and wipe it in seconds with a dry paper tissue or cloth. The tile may be placed in the wall permanently in several (chosen by the users) positions, rotating itself every 90°, starting from a 0° position or from a 45° position.

There is a force that drives children to explore their environments by using objects in new and different ways and it is identified as optimal stimulation. Its level varies between children and also depends on the child's temperament, background and environment [7]. Parents can help children discover their optimal level of stimulation, through exploration, trial and practice. To explore their world, children use their imagination and developmental capabilities. Children's surrounding environment may influence their development [8].

Several perspectives on child's development have been explored as biological, psychodynamic, sociocultural and Piaget's (1896–1980) cognitive-developmental. Cognitive-developmental theories are based on Piaget's belief that children have a scientific approach and actively construct meaning, when discovering how the world functions [9]. Four stages were identified in the child's development, being the third stage named concrete operational and occurring between 7 and 11 years of age [9–11]. Children in this stage, also referred as middle-childhood [7], have reached more maturity, have more autonomy and their communicational, social and representational skills are more developed. The children's fine and gross motor skills are on their way to full development [7, 12]. Communication skills, in particular, evolve between direct verbal and nonverbal interaction, being their reading and writing skills improved [7]. Although they can think logically, they cannot think abstractly, yet [9].

Middle school children were the age-group target chosen to evaluate the ceramic tile's project, as they have the prolific imagination of childhood but with already advanced skills and capabilities towards a pre-teenage phase of their development.

In the product design research project for children's furniture, the discipline of Human Factors and Ergonomics [13] were applied in a stage of evaluation of a high chair represented in the case study [14]. On this parallel design project, its contributions had to be taken under account and an ergonomic approach was applied once again as a useful tool in the design process, to attain first-hand information and evaluate the project's prototypes.

## 2 The Study

### 2.1 Method and Aim

This study was made with primary school children (9–12 years of age). It included observation, interview, tactile experience and drawing sessions in an empirical, mainly qualitative and quasi-experimental based research. The study was conducted in two

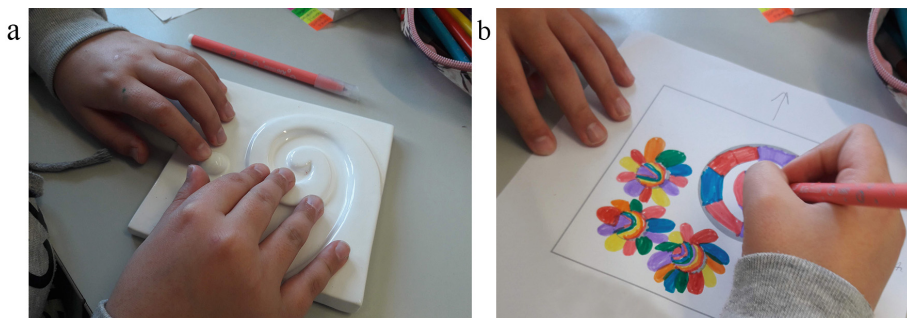
separate sessions on a public primary school with 47 children (boys and girls), distributed by 2 mixed classes (pre-existing groups). The school is located in the centre of a riverside town named Barreiro, in Lisbon's South Bay, in Portugal.

The focus of the research is on a domestic environment but a school setting was chosen given the nature of this study, which included drawing sessions and the need of their usual drawing materials. It was also a possibility to attain information from a large number of children in a limited period of space and time.

The aim was to search for information on:

- Past interaction: have they drawn in walls at home and what were their parents' reactions;
- Reactions to the project: prototyped product and its texture;
- Does the texture enable more interaction;
- Does the abstract shapes applied enable multiple ideas for a drawing;
- Shapes, figurative elements and colors used in their drawings.

Firstly, data about their names, gender and age was collected by questioning. Children were then asked to touch a ceramic tile's prototype and verbalize what they felt, if they liked the texture (Fig. 1a) and if they would prefer drawing in a textured tile rather than in a flat surfaced tile. They were asked to position a tile's representation in paper (front view) as they liked the most and imagine a drawing they would like to make, if they had it in their walls at home, illustrating it with their own drawing materials (markers, coloured pencils or crayons for use on paper), choosing shapes and colors (Fig. 1b). They were followed on the task and asked about what their drawings were meant to be.

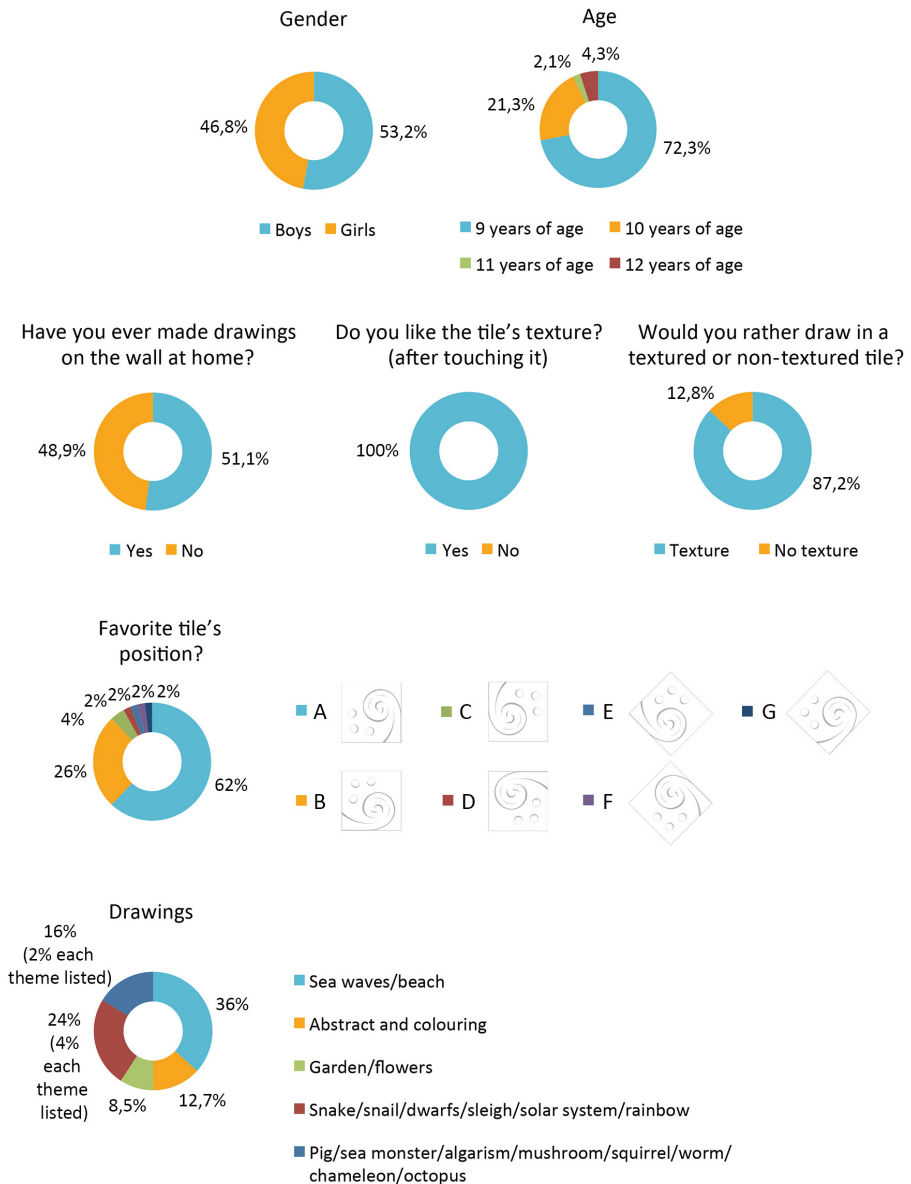


**Fig. 1.** a. Child having tactile experience with the ceramic tile; b. Child drawing flowers in an imaginary garden in the front view drawing of the ceramic tile, with markers (for use on paper). Photos: Cristina Salvador, Portugal.

## 2.2 Results

The results of the study were analyzed and represented in graphics, according to percentage rounded to the nearest tenth (Fig. 2). The sample was almost evenly divided in male (53,2%) and female (46,8%) gender and the majority of children were aged 9

years old (72,3%), being the 10 year-olds the second largest group with 21,3%. There were only 2,1% of 11 year-olds and 4,3% of 12 year-olds.



**Fig. 2.** Graphics with the results of the study about the interaction with a ceramic tiles' project with 47 primary school children, male and female, aged 9–12 years. Digital illustration: Cristina Salvador, Portugal.

When questioned if they had made drawings or sketches in their walls at home, whether remembering doing it or being told about it by their parents, 51,1% of the children answered “yes” and one third of them stated their parents got angry. 48,9% of the children answered “no”, but also one third of them stated they didn’t do it because they were afraid their parents would get angry.

Every child wanted to have a tactile experience with the tiles’ prototypes. The reactions were totally positive. Adjectives as smooth, soft and fresh were the most verbalized reactions. All of them felt good touching the tiles and some even considered the tile felt like yoghurt and smelled like strawberry yoghurt or something similar. Besides the ceramic tile’s prototypes (two units), children were shown a non-textured (flat surfaced) tile and asked which one they would rather interact with and the large majority preferred the textured tile (87,2%).

Children proceeded in positioning the representation of the tile (front view) on paper and the majority preferred position “A” (62%). Position “B” was chosen by 26% and position “C” was preferred by 4% of children. Positions “D”, “E”, “F” and “G” were chosen for only 2% of the children, each. The drawings made by children in the representation of the tile (front view) on paper were quite diverse. More than one third (36%) transformed the spiral into a sea wave, imagining a beach setting and using predominantly blue shades (Fig. 3b and e).

Only 12,7% of children chose not to draw figurative elements and simply colored the abstract shapes (Fig. 3c). A garden setting, with flowers, plants and bugs were drawn by 8,5% of the children (Fig. 3d and g). Green grass and orange, yellow and pink flowers were represented in these drawings and the spiral became a sprout or a grown plant.

The three hemispheres have the same dimension and are often used as the basis for the same figurative elements as bees (Fig. 3g), fishes (Fig. 3b and k), nuts (Fig. 3l) humanized drops of water (Fig. 3e) or apples (Fig. 3a). Depending of the tile’s position, the hemispheres were also used to draw faces of animals - in the cases displayed in Fig. 3f and j, a snail and a pig. There were drawings in which all of the tile’s representation was colored (Fig. 3f and k).

24% of the children who participated in the study chose to draw snakes (Fig. 3a), snails (Fig. 3f), dwarfs, sleighs (alluring to Santa Claus - Fig. 3i), solar system (Fig. 3h) and rainbows - 4% for each listed theme.

The remaining 16% of the children from the sample chose to draw several figurative elements or animals as a pig (Fig. 3j), a sea monster, the number “9”, mushrooms, a squirrel’s tale with nuts dropping (Fig. 3l), a worm, a chameleon’s tale and a giant octopus (Fig. 3k) under the sea. The choice of color was diverse as the choice of themes represented.

From the 47 children of the sample, only 3 children chose to write words in the tile’s representation, mainly to help describing the action they imagined would be taking place in their drawings (Fig. 3l).

The public primary school teaches several disciplines and the children are beginning to learn more about science and astronomy (which explains the interest in planets and the solar system). They have classes where they draw and express themselves. Expressing their imagination and speaking their minds is highly encouraged. They craved for outdoors and vacation, dreaming of beaches and gardens. Also they’re



**Fig. 3.** Some results from the drawing sessions with children, using front view representations on paper, of the ceramic tiles. Photos: Cristina Salvador, Portugal.

beginning to understand more about finances. When we were talking about what they were drawing and about the tile's project, a lot of children were asking if they could buy some tiles for their home. A 9 year-old boy offered to buy the project, so he could sell his colleagues some tiles, amusing the entire class.

The overall reactions from the two classes were overwhelmingly positive. Although more quiet when it comes to verbalize their thoughts, the first class to participate in the study, expressed more creatively in their drawings. With the second group a more enthusiastic reaction didn't result in more creative solutions. But even with different characteristics, children had in general, very positive reactions to the shape and texture of the ceramic tile's prototypes. They imagined an extensive variety of possibilities using drawing (and writing in much less extent) to interact with their surroundings, transforming it and identifying as their own.



### 3 Conclusions

Ceramic coatings are valuable assets in interior projects, due to its thermal, structural and acoustic characteristics, providing visual and tactile comfort. Due to the small extent of the sample, this study cannot be sure to generalize to a wider population, but the results revealed much diversity and provided clues about the children's interaction with indoor home environment.

The sample was almost evenly divided in feminine and masculine gender and mainly between 9 and 10 years of age, with a few exceptions. The project targets children and parents, as users and consumers. The sample was chosen by convenience, having under account the developmental characteristics, both physical as psychological, of the children from this age target.

More than half of the sample had drawn in their walls at home making one third of their parents angry. Also, one third of the children that didn't draw stated they wanted to do it, but they were scared their parents would react negatively. Therefore, most of the children drew or wanted to draw on their walls, interacting with the environment, attempting to customize their surroundings.

All of the 47 children felt good while touching the tile's prototypes and liked its texture and an overwhelming majority preferred to have texture instead of a non-textured solution to draw on. So, children reacted positively and texture may enable more interaction with the ceramic coating.

Although only two of the possible positions were chosen by a vast majority of the children, leaving small percentages to the remaining positions chosen, the drawings made in the representation of the tile on paper were quite diverse. Sea waves, gardens, planets, animals, objects and other figurative elements were represented with the help of their usual drawing materials. Only a small percentage decided to proceed with abstract drawing only adding color.

With this study it is possible to conclude the formal 3D solutions of the ceramic tile may enable a large number of interpretations and provide a basis for numerous 2D creations with simple (white board use) markers at home, given the child's imaginative universe in the context of the pre-teenage phase of their development. Also conclusive is the overall importance that Ergonomics and Human Factors revealed once more in the development of a design project.

**Acknowledgments.** Without the support of the University of Lisbon, Lisbon's School of Architecture, CIAUD - Research Centre in Architecture, Urbanism and Design and FCT - Foundation for Science and Technology, Portugal, this study wouldn't be possible. Special thanks to EB1/JI Prof. J. J. Rita Seixas school, Barreiro, Portugal, to its teachers and to the children who participated in the studies.

### References

1. Encyclopaedia Britannica. <https://www.britannica.com/technology/traditional-ceramics>
2. Museu do Azulejo-Cronologia do Azulejo em Portugal. <http://www.museudoazulejo.gov.pt/Data/Documents/Cronologia%20do%20Azulejo%20em%20Portugal.pdf>

3. Guo, J.-K., Li, J., Kou, H.-M.: Advanced ceramic materials. In: Xu, R., Xu, Y. (eds.) *Modern Inorganic Synthetic Chemistry*, 2nd edn, pp. 463–492. Elsevier, Amsterdam (2017)
4. Pelleg, J.: Mechanical properties of ceramics. In: *Solid Mechanics and its Applications*, vol. 213. Springer, Cham (2014)
5. Sōmiya, S., et al.: *Handbook of Advanced Ceramics*. Elsevier, Amsterdam (2003)
6. Berto, A.: Ceramic tiles: above and beyond traditional applications. *J. Eur. Ceram. Soc.* **27** (2–3), 1607–1613 (2007). Suvorov, D., Krzmann, M. (eds.)
7. Lueder, R., Rice, V.: *Ergonomics for Children—Designing Products and Spaces for Toddlers to Teens*, pp. 39–64. Taylor and Francis, New York (2008)
8. Evans, G.: Child development and the physical environment. *Ann. Rev. Psychol.* **2006**(57), 423–451 (2006)
9. Markopoulos, P., et al.: *Evaluating Children's Interactive Products—Principles and Practices for Interaction Designers*. Morgan Kaufmann/Elsevier, San Francisco (2008)
10. Piaget, J.: *The Child's Conception of the World*. Routledge, London (1929)
11. Kamii, C.: *A teoria de Piaget e a educação pré-escolar*. Instituto Piaget, Lisboa (2003)
12. World Health Organization-Child Growth Standards-Motor Development Milestones. [https://www.who.int/childgrowth/standards/motor\\_milestones/en/](https://www.who.int/childgrowth/standards/motor_milestones/en/)
13. Karwowski, W.: The discipline of human factors and ergonomics. In: Salvendy, G. (ed.) *Handbook of Human Factors and Ergonomics*. Wiley, Hoboken (2012)
14. Salvador, C., Vicente, J., Martins, J.P.: Ergonomics in children's furniture—emotional attachment. In: Abraham, T., Karwowski, W., Marek, T. (eds.) *Proceedings of the 5th International Conference AHFE 2014, Krakow*, pp. 5478–5485. CRC/Taylor and Francis (2014)



# Graphic-Semantic Expressions Map: A New Tool on Design Teaching

Cátia Rijo<sup>(✉)</sup>

CIAUD, Lisbon School of Architecture, Universidade de Lisboa,  
Rua Sá Nogueira, 1349-063 Lisbon, Portugal  
catia.rijo@gmail.com

**Abstract.** This paper aims to contribute to the discussion in design teaching and its consequent research context, considering participatory practices and methodologies. We propose a methodologic map, which will assist the process of synthesis expressive code and also boost the relationship between graphic expression and semantics in design practice. At the end, an attempt is made to evaluate if the association of semantic elements with graphic elements promote the convergence between the project goals and the synthesis of expressive codes, while facilitating the interpretation and creation of new graphic products.

**Keywords:** Design teaching · Teaching methodologies · Graphic design · Expression map

## 1 Introduction

Designed within a Polytechnic Higher Education institution, which is built on the affirmation, among others, that importance is given to experimentation and observation, knowledge, techniques and technologies. Considering the practices and methodologies normally used in the teaching of graphic design, the research was developed in search of alternative tools to those commonly used, contributing to research in design teaching methodology.

In teaching design is intended to recreate to the maximum with a real project works. Using the active methodologies, the student is the main agent of his/her learning. This method encourages criticism and reflection, which although accompanied by the teacher, the student is the center of this process. In this way it is possible to orient the learning in a more participative way, since the involvement of the student is that it brings the fluidity and the essence of the active methodology.

This method improves the student's individual autonomy, developing it as a whole, so that he is able to understand aspects within the various areas of knowledge. This methodology requires an active subject in the student role, in order to make it autonomous, responsible and capable of updating its potential, searching in a creative and inquiring way the knowledge in a reality that is changeable. Active methodology involves research, analysis, reflection and development of ideas individually or in pairs.

In fact, it is well-agreed that active learning is especially important for university education because it helps enhance higher order thinking and learning, such as the synthesized analysis and problem-solving skills.

There are a number of tools that apply in the classroom in order to be able to apply the active method, and the consequent observation is contacted that in some situations the students demonstrate some difficulty in understanding some of these instruments and in their applicability in the creation of a design project.

## 2 Problem

Dondis [1] states that the manipulation of visual language requires a knowledge of how formal, conceptual and relational structures are organized in a visual composition. The visual mode is a series of data that can be used to compose and understand messages at various levels. Such composition is constructed by grouped units that, in a network of mutual influences, provide meanings.

Many studies have been done in the field of visual language or formal language that have the purpose of providing references to the project, considering categories, relations and basic elements of form and visuality [6].

In the practice of teaching graphic design, the problem is systematic: the students have a lot of difficulty in the process of transposition of the design delimitation (this designation is the nomenclature used in the educational environment for the graphic composition of the various elements constituting a design basic element of visual communication) [5].

Such difficulty led to questioning and looking better at the methodological instruments that are currently used. If we look around only a few researches explore the application of semantic contours in graphic elements.

In the context of curricular units related to design and teaching experience, the problematic question arises: in the teaching of graphic design, what methodologies and instruments can we apply that associate's semantics with visual thinking? This problem led to the need to better evaluate the methodological instruments currently used and to perceive the feasibility of readapting them in order to overcome the difficulties experienced.

## 3 Design Process

All design projects start with the delivery of the briefing and delimitation of the problem and goes through several stages until the defense of the project. However, the order in which the different steps are taken are not watertight, according to Lawson [2], design thinking is marked by a cycle of advances, setbacks and changes of thought.

There are many authors that define the different design phases inherent to the development of a design project, but across all of them there are three major phases: analysis, synthesis and evaluation.

According to Jones [3], one mode of thought predominates in each of the phases and classifies the design stages in: divergence (includes the actions to expand the points of view on the problem, originates questions giving different perspectives on the same question); transformation (giving space to the structural exploration of the problem and the creation of creative concepts to establish connections in the search for a solution);

convergence (actions are channeled towards the definition of a solution, reducing uncertainties through evaluation strategies).

Transversal to all design development processes in design is the need to carry out a research and benchmarking of a concept for the project. This happens because project definitions are taken based on the knowledge of the project itself.

In a simplistic way we can define research as the way to look for answers to the questions raised. Preliminary research can be called exploratory research, that kind of research helps to better understand the context to be worked on the project. After this investigation it is essential to carry out the analysis and synthesis of the collected data and organize the information into a data visually so as to measure patterns that help the understanding of the whole.

After investigation of the problematic in question, the concept of the project should be checked, this concept will support the choices in the various stages inherent in the process. A concept is the idea behind design, it is the main idea of the project, what is meant to convey.

In order to define the concept, it is important to know what is intended to communicate, what the diagnosed need is and what are the final goal of the project.

In these early stages of a project - the research stage, definition of a problem and concept definition - students get a lot of visual information through images. For this reason, visual thinking is an essential tool because it helps to clarify ideas, i.e., the visualization of images that represent concepts help in the interpretation of the problem and trigger associations of ideas. In this way, the images are treated as information, so that from them, innovative ideas are created. In this context, concept maps are a widely-used tool in design teaching to help students visualize and communicate concepts.

## 4 Graphic-Semantic Expression Map

During the process of a design project it is necessary to articulate abstract or metaphorical concepts into images, in order to give visual meaning of concepts. The semantic panel provides a visual form capable of stimulating and inspiring the process of design projects. This is a technique that helps the active method, which aims to represent meanings through the visualization of images, i.e., is a technique that translates verbal language into visual signs.

Concept maps are means of visual or multi-sensory communication that can be useful in the construction of communication and design process. This tool relies on communication through visual metaphors and is usually built by collages with clippings of pictures, photographs or drawings.

This type of semantic panel offers a visual and sensorial channel of communication and inspiration for design research and development, which could be considered more logical and empathic within a context design than traditional verb-centric approaches.

Primarily, semantic panel provide a mechanism for students and practicing designers to respond to perceptions about the brief, the problem and facilitates the immersion of ideas. Through semantic panels it's possible to communicate in a more tangible way more abstracts concepts.

In the end through the construction of semantic panel it is possible to stimulate the perception and interpretation of more ephemeral phenomena such as color, texture, form, image and status [4], i.e. a semantic panel can extract references such as color, shape, textures, typography as well as subjective concepts, such as emotions.

Based on the traditional semantic panel, we create a graphic-semantic expressions map that intends to make the relationship between the various evaluable elements more understandable.

This map proposes to cross the collection made in the research phase, the design concept and the elements of inspiration with the typography, color and shape.

It's a methodological map, which will assist the process of synthesis expressive code and also boost the relationship between graphic expression and semantics in design practice (Fig. 1).

		INVESTIGATION	INSPIRATION	CONCEPT		
ANALYZE	TYPOGRAPHY					CONCEPTS
	COLOR					
	SHAPE (SYMBOL)					

Fig. 1. Structure of the graphic semantic-expression map proposed. Author’s image.

4.1 How It Works

To better understand how to fill the graphic semantic-expression map we give an example: imagine that we pretend to create a logo for a new coffee place.

i. Investigation/Research:

In this field we put all the images that we collect when we did the research, the set of images referring to the collection made within the scope of coffee brands. After the conjugation of these images in the form of a semantic panel, we analyze the typography, colors and shapes that stand out most (Fig. 2).

If we analyze the image we conclude that most of them are used fantasy or handwriting typography simultaneously with serif humanistic source with thicker stems. Doing the same analysis for the images it is noticed that shades of brown, orange and red are the most used colors. Now the form, the great majority uses circles, curved forms that present a little of movement.




INVESTIGATION	TYPOGRAPHY
	Red Doorcafe Cool Café WEST <b>CAF</b> <b>2COFFE</b> MoonCafe
	COLOR 
	SHAPE (SYMBOL) 

Fig. 2. Example of the analyses on the Investigation field. Author's image.

ii. Inspiration

Proceeding in the same way, the references of inspiration are analyzed. We can define inspiration as a process of being mentally stimulated to or feel something, especially to do something creative.

The inspiration can be originated by the most diverse sensorial elements: music, environments, spaces, patterns of clothes, among others. Therefore, we can say that inspiration can occur in any circumstance and by anything that surrounds us.

In this topic it is important to note that this inspiration is something very personal, because each one of us finds inspiration in different situations, in this way this field reflects the personal taste of each one.

In the following example the set of images that the author considered as her inspirational references for the proposed challenge is demonstrated (Fig. 3).

INSPIRATION	TYPOGRAPHY
	THE QUICK BROWN The quick brown fox The quick brown fox <b>Coffee</b> <b>MIGHTY</b> <b>T-FLO</b>
	COLOR 
	SHAPE (SYMBOL) 

Fig. 3. Example of the analyses on the Inspiration field. Author's image.

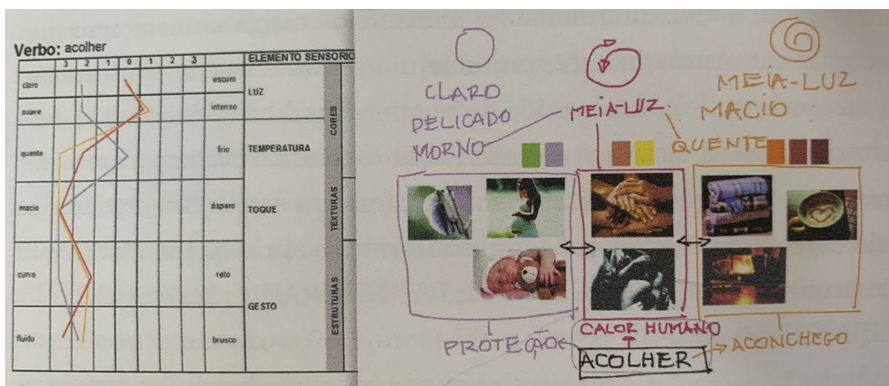
Similar with the analysis of the previous topic, it is analyzed the type of typography most used in the set of images selected, in this case it is visible the use of handwritten font and some examples of humanistic source without serif. In the set of colors were selected four more used: blue, pink, yellow and red. When analyzing the set of forms, we concluded that the main forms are organic and rounded.

### iii. Concept

Sanches [5] created a tool called Expressive Categories Map from a combination of techniques, including mood board, semantic differential scale, action verbs and mental map. With this tool it is possible to organize, gather and filter aesthetic-symbolic references, synthesizing a structure of connections for the visual statement of the projected artifact. This map was created to help students of fashion design in identifying symbolic codes that synthesize the intended concept.

To fill it up first identify a central verb and make a collection of images that better illustrate what is meant to convey. Participants of the project collect images that they consider representative of the action suggested by the verb.

Subsequently, the images are grouped with similar representations, discarding redundant information and identifying concepts derived from the initial verb (Fig. 4).



**Fig. 4.** Example of the Expressive Categories Map. The central verb demonstrate in this example is “to welcome”, and the three verbs after collect the images are: protection, human heat and warmth. Image of Sanches (2017).

To extract configurational elements of this map, a semantic differential scale is applied, analyzing the sensorial perceptions (light, temperature, touch and gesture) of each expressive category (Fig. 5).



	3	2	1	0	1	2	3		SENSITIVE ELEMENT / SYNTHETIC REFERENCES		
BRIGHTNESS								DARK	LIGTH	COLOR	
SOFTH								INTENSE			
WARM								COLD	TEMPERATURE		
SOFT								ROUGH	TOUCH	TYPE	
CURVED								STRAIGHT	GESTURE	SYMBOL / TYPE	
FLUID								BRUSCO			

**Fig. 5.** Expressive Categories Map propose by Sanches [5]. Adaptation of the author.

In the map of graphic-semantic expressions proposed, the map of expressive categories was adapted to help students of graphic design in the realization of the concept, since this often translates into an intangible concept and it is difficult to translate it into a more concrete representation and objective.

In this way, the sensorial perceptions of touch and gesture were replaced by Typography and Symbol, since they are the elements to be evaluated in graphic design, because color it's a transversal element on both areas (Fig. 6).

	3	2	1	0	1	2	3		SENSITIVE ELEMENT / SYNTHETIC REFERENCES		
BRIGHTNESS								DARK	LIGTH	COLOR	
SOFTH								INTENSE			
WARM								COLD	TEMPERATURE		
LIGHT								HEAVY	STRENG	TYPE	
CURVED								STRAIGHT	FORM	SYMBOL / TYPE	
DYNAMIC								STATIC			

**Fig. 6.** Adaptation of the Expressive Categories Map propose by Sanches [5] to Graphic Design teaching. Author's image.

Going back to the example in which we are working, for the creation of a logo to a coffee place and using the adaptation of Expressive Categories Map, it was verified as the main concept “Taste” originated three adjacent concepts: happiness, human warmth and pleasure (Fig. 6).





Fig. 7. Collection of images that better illustrate the intended concept and that originated three concepts: pleasure, human heat and happiness. Author’s image.

After completing the Expressive Categories Map we were able to extract guidelines at the level of color, typography and symbol shape to help in a more concrete representation of the concept of the project (Fig. 7).



Fig. 8. Expressive Categories Map applied to the concept “Taste”. Author’s image.

If we place the map of expressive categories and their conclusions in the map of semantic-graphic expressions, we complete the last missing field, referring to the concept (Fig. 8).

INSPIRATION	TYPOGRAPHY
	WHAM! VOLCANO ERUPTS FIERY LIQUID FF DIN <i>SIXTY ZIPPERS WERE QUICKLY</i>
TASTE = HAPPINESS + HUMAN HEAT + PLEASURE	COLOR
	
	SHAPE (SYMBOL)
	Round shapes // Movement

**Fig. 9.** Example of the analyses on the Inspiration field, after interpreted the results of the Expressive Categories Map. Author’s image.

After completing it, we conclude that for the representation of our concept we have as reference the cursive sources that demonstrate movement, at color level the three main colors are red, yellow and dark brown. With less expression comes the reference to blue and green. At the level of forms once again we have the predominance of rounded, organic forms with movement (Fig. 9).

iv. Triangulation of results

With all fields completed, it’s time to triangulate the results, this analysis is done from left to right within each field (Fig. 10).

		INVESTIGATION	INSPIRATION	CONCEPT	SUMMARY
ANALYZE					
	TYPOGRAPHY	Red Doorcafe Cool Cafe WEST	THE QUICK BROWN The quick brown fox The quick brown fox CRKEWA	WHAM! VOLCANO ERUPTS FIERY LIQUID FF DIN <i>SIXTY ZIPPERS WERE QUICKLY</i>	
	COLOR				
	SHAPE (SYMBOL)				

**Fig. 10.** Graphic semantic-expression map fill with the triangulation of results. Author’s image.

At the level of the main typography we concluded that the main type could be a handwritten source, it will be possible to use the italic as a way of demonstrating movement, for auxiliary typography it's one possibility the choice of humanistic font without serif, regular with fine stems.

For color the predominance is red, dark brown, yellow and blue, so it's a possibility a contrast between cold colors with warm colors.

In the form mostly are rounded, organic forms with some expression that demonstrates movement.

It is important to safeguarded that in design there are no recipes, the results are only guidelines that may help, in this case, to the creation of a logo. These guidelines are a sum of the different steps inherent in creation of a graphic design project.

With these guidelines the possibilities are endless, without compromising the creativity or the uniqueness of the project.

## 5 Conclusions

We propose research into active methodologies contributing to investigation, creative development and better results in the subjects related to graphic design.

By looking at our experience in the classroom and at school as an effective training tool, and the consequent observation of the student body, the creation of the proposed methodological map took place.

As mentioned earlier, on design teaching there are many exploratory tools that help students in the research phase and that help in achieving the various design phases.

In the early stages of a project - the research stage, definition of a problem, definition of a concept - students get a lot of visual information through images. For this reason, visual thinking is an essential tool because it helps to clarify ideas.

We proposed a graphic semantic-expression map to help students in the early stages of a projects to help them to concretize meaning and concepts into an objective graphic design product.

This map was tested and evaluated as an instrument to facilitate the creation and development of projects in the field of graphic design.

At the end, an attempt is made to evaluate whether the association of semantic elements with graphic elements promotes the convergence between the project goals and the synthesis of expressive codes, while facilitating the interpretation and creation of new graphic products.

To validate this proposal a series of workshops are being developed in several national and international higher education institutions for further analysis of results.

## References

1. Dondis, A.: *Sintaxe da linguagem visual*. Martins Fontes, São Paulo (1997)
2. Lawson, B.: *Como arquitetos e designers pensam*. Oficina de Textos, São Paulo (2011)
3. Jones, C.: *Design Methods*. Wiley, New York (1992)
4. Garner, S., McDonagh, D.: Problem interpretation and resolution via visual stimuli: the use of 'mood boards' in design education. *Int. J. Art Des. Educ.* **20**(1), 57–64 (2002)
5. Sanches, C.: *Moda e projeto, estratégias metodológicas em design*. Estação de Letras, São Paulo (2017)
6. Lessa, D.: Objetivos, desenvolvimento e síntese do projeto de design: a consciência do método. In: Westin, D., Coelho, L.A (orgs.) *Estudo e prática de metodologia em design nos cursos de pós-graduação*. Novas Ideias, Rio de Janeiro (2011)



# Research on Ergonomic Design and Evaluation of Office Backrest Curve

Yumeng Zhang<sup>1</sup>, Ling Luo<sup>2(✉)</sup>, Jie Wang<sup>1</sup>, Huimin Hu<sup>2</sup>,  
and Chaoyi Zhao<sup>2</sup>

<sup>1</sup> Capital University of Economics and Business, Beijing, China  
ml3520312497@163.com, wang.jie@cueb.edu.cn

<sup>2</sup> SAMR Key Laboratory of Human Factors and Ergonomics,  
China National Institute of Standardization, Beijing, China  
{luoling, huhm, zhaochy}@cnis.gov.cn

**Abstract.** The rationality of chair back design is an important index of comfort of an office chair. Sitting in a comfortable office chair can Improve work efficiency and prevent disease. Through the existing literature investigation and preliminary experiments, it can be found that the current defects and difficulties in the design of chair back mainly lie in the curve of chair back, which also attracts the researchers' interests recently. In this paper, we will study the curve of the back of the chair, measure the spine curve of the human body sitting posture with Qualisys, investigate the existing design problems of the back curve of the chair, and finally put forward suggestions and design basis for the back of the chair based on ergonomics.

**Keywords:** Office backrest curve · Spinal measurement · Ergonomics

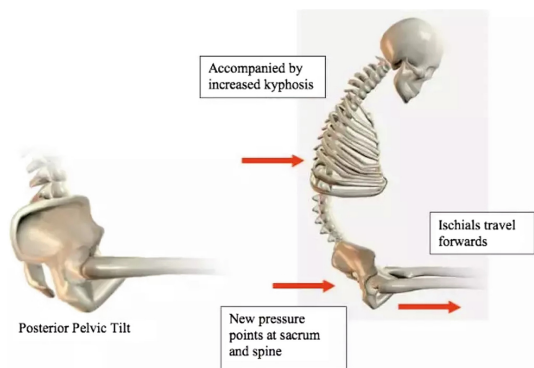
## 1 Introduction

Along with the improvement of modern living standard and strengthen of work pressure, office chairs need to be designed to arrive a higher level for satisfying the demands of a host of people. Office chairs play significant roles in contemporary work places since a host of mental workers use office chairs for up to 8 h. The reasonable design of chairs can help workers decrease the rate of several diseases such as cervical spondylosis and lumbar vertebrae disease and improve work efficiency by fulfilling sitting comfort. Office fatigue is the most common reason leading to decline working efficiency. It is the unreasonable sitting posture that constructing one of the reasons that lead to the sense of tiring to enhance.

Current studies have shown that the reduction of lumbar protrusion is one of the most likely causes of increased the incidence of low back pain [1], it is closely related to depth and height of waist supporting. When the human body sits in a posture, the pelvis tilts backward, so that the sacrum at the lower back is also tilted, so that the spine changes from S-shaped to arch (Fig. 1 shows that), which makes the intervertebral disc of the spine under great pressure and accelerates fatigue, leading to discomfort symptoms such as lumbar soreness. If the seat can give people's waist fully supported and make the waist restore to its natural state (see Fig. 2), then fatigue will be delayed.

And people will feel relaxed and comfortable. Experiments proved that if the curve of human body can fully coincide with the curve of seat back in natural relaxation, the evaluation of seat comfort will be better [2]. Thus it can be seen that it is of great necessity to design the backrest following the curve of human spine.

According to the survey data of internet business, more than 91% of office furniture merchants use the topic of “ergonomics” as a way to attract customers to buy. In order to get the current situation of seat back design, this study carried out a survey on the sitting posture, work health and the relationship between office chair and work health of 2000 office workers at first, and we found that there are still several problems in the design of office chairs in China. The back curve of office chair is still an important factor to affect the comfort of users, among which pillow, neck supporting, waist supporting, the back inclination angle and other parts, all of them play decisive roles. How to design the curve of the back of office chair to fit highly of the curve of human body to improve the comfort of users, and how to evaluate the design of the back of the chair are the problems will be discussed in this paper. The design and evaluation of seat back curve will be discussed in this paper by evaluate the compatibility between human spine curve and seat back curve. The conclusion can also provide some reference for the design and evaluation of the back curve of office chair.



**Fig. 1.** Change of spine without support



**Fig. 2.** Contrast of spine with backrest's support

## 2 Questionnaire

Before the survey began, some dimensions of office chairs were counted. The extreme dimensions of the first 12.5% and the last 12.5% were removed, and 75% size data were retained. Mainly for the more easily available data of human body sitting position height and head pillow height, which will help me to choose the subjects.

### 2.1 Subjects

Two thousand people, half of men and half of women, aged 20–60, were selected from working in front-line and second-line cities in China, including more than 6 kinds of occupations just like IT workers, technical professional, financial personnel, administrative stuff, people of scientific research institutes and civil servants. The height and weight of subjects were looked as normal distribution. Investigators were selected from every kinds of population as far as possible.

### 2.2 Question Setting

The questions about the design of the office chair backrest in the questionnaire are as follows:

1. Sitting posture most commonly used by employees in employees' minds
2. Which indicators of office chairs can cause discomfort?
3. What kinds of discomfort does office chair lead to?
4. Importance of office chair parts and the score of each part

### 2.3 The Result of the Investigation

#### 2.3.1 Discomfort Analysis

Questionnaire shown that 50.3% subjects consider the backrest is very important, 36.6% recognize backrests' importance and only 9.9% think general (Fig. 5 shows that). All of height, depth and hardness grade of waist supporting relating to the fitness of dorsal physiological curve and backrest and then the effective supporting making subjects more comfortable are the most important indicators of backrest (Figs. 2 and 6 show that). A backrest by reasonable designing enable to relieve the soreness of shoulder, waist and back which construct the most serious physical discomfort. Waist supporting, as a part of backrest, is most likely to cause 58.09% users having pain in the back. And neck supporting, as another part of backrest, is most likely to cause 57.23% users having pain in the neck. Their proportion is far higher than other indicators. (Figure 3 shows that) Fifty interviewees confirmed that low back pain was mainly caused by insufficient depth of support and inability to fit the physiological curve of the waist. When the back of the chair is hard and its inclination angle is not adjustable, the back of the user can not fit well with the back of the chair, so the backrest can not be supported by the seat, that will cause neck and shoulder pain eventually. Users' heads and necks leaning forward and can not get pillow's supporting, when they keep a prolonged relaxed sitting posture (Fig. 3 shows that), which are also reasons of neck and shoulder soreness (Fig. 4).



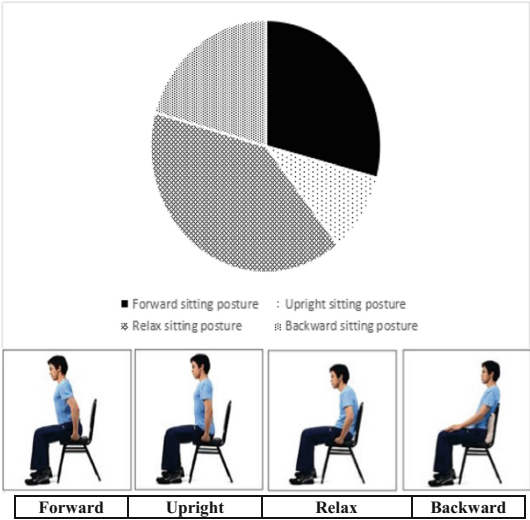


Fig. 3. Sitting posture most commonly used by employees

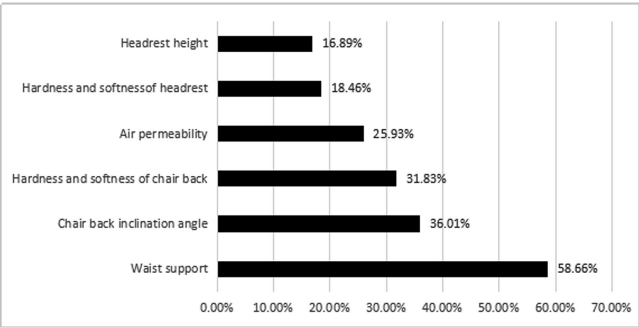


Fig. 4. The parts most likely to cause fatigue in users' mind

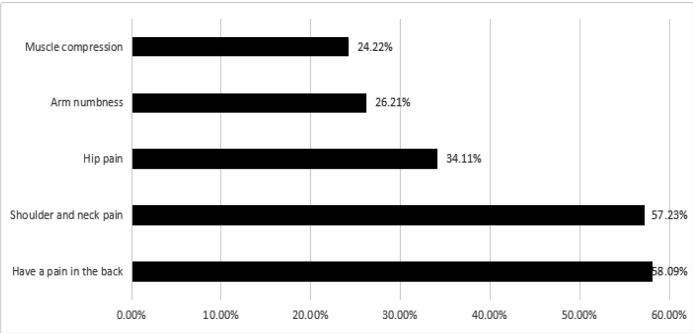


Fig. 5. Types of physical discomfort caused by fatigue

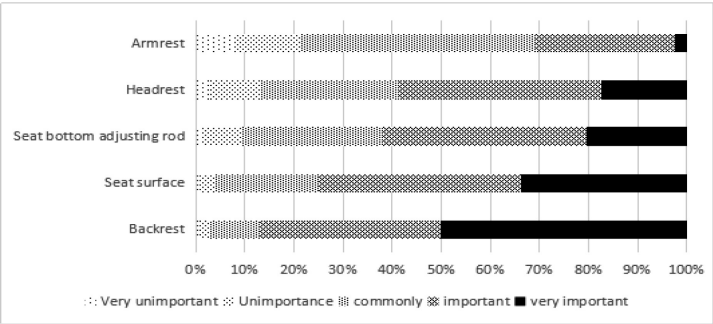


Fig. 6. Importance of office chair parts in employees’ minds

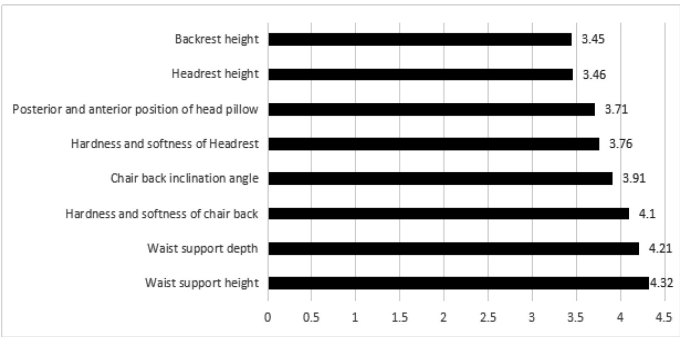


Fig. 7. Importance score of each part

2.3.2 Causes of Discomfort in Headrest Design

The headrest height of office chair is generally higher than that of P5 and P50 female users’ (as Table 1 shows), which means that most female users’ neck can not be effectively supported. When working in upright sitting position, the head pillow will reach the occipital part of female users, affecting the comfort of the head and neck. When the back is relaxed, the neck will be suspended, which will cause neck soreness after a period of time.

Table 1. Suitability of headrest height design

Index	Office chair headrest	P5 Female	P50 Female	P50 Male	P90 Male
Height	640–770	×	×	√	√

\*the unit of the headrest height is mm.

The headrest height of office chair is 870 mm, which higher than 714.9 mm, the cervical spine point height of P90 male in sitting posture; The headrest height of office chair is 560 mm, which lower than 581.3 mm, the cervical spine point height of P5

female in sitting posture. Both of male and female, their cervical neck can not be effectively supported (as Table 2 shows).

**Table 2.** Comparison of the maximum and minimum human height and headrest height

	Height	Office chair	Exciting problem
P90 Cervical Spot Height in Sitting Posture of Male	714.9	Maximum Headrest 870	Neck without support
P5 Cervical Spot Height in Sitting Posture of Female	581.3	Minimum Headrest 560	Neck without support

\*the unit of the headrest and human body height is mm.

### 3 Experiment

#### 3.1 Participants

To gain a comprehensive data, the sex ratio of all participants was 1:1 and with mean age of 30 years ranging from 18 to 35. All of those 10 participants were involved in the experiment. Selection of people's height were tried to base on height proportional distribution of human body database. Average height of them was 162.7 cm. Due the consideration of the difference between seat surface's subsidence and the set up base level, we regulated their BMI which was not exceeding 24.

#### 3.2 Equipment

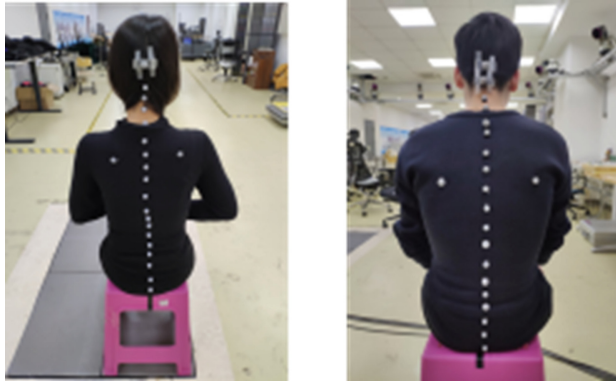
Qualisys motion capture system uses high-speed digital camera to accurately capture the motion of measurable objects with markers. This technology can transmit high quality data to users accurately, reliably and in real time. Now optical motion capture has been widely accepted and applied in everyday life around the world. Qualisys as an available facility was used to measure the curve of the subjects' spine in the upright sitting posture.

#### 3.3 Spinal Measurement

According to the results of the questionnaire survey, forward leaning and relaxation are the two most frequently working postures to be used. The inclination angle of upright sitting posture is between them. The use of waist and back is similar to relaxed sitting posture's, and the use of upper back is similar to forward leaning sitting posture's. In addition, sitting upright posture is more observable than relaxed posture, and it is easier to draw standardized conclusions. Therefore, we will only discuss the situation of upright sitting posture.

Specific methods were as follows: The subjects were sitting upright, sticking reflective spots on their occipital bone (the most prominent point of head), the deepest part of the neck during upright sitting, the Seventh cervical vertebra, the two scapulae

(the most prominent point of back) and the coccygeal spine. Then distributed the other 15 reflective spots evenly on the subjects' spine. (Figure 8 show that) After the capture, the data of X and Z coordinates are output.



**Fig. 8.** A female and a male subject who were being experimented

### 3.4 Office Chair Backrest Measurement

Four office chairs with different styles, which are ubiquitous in the market, were taken as research objects (the parameters are shown in Table 3). In the experiment, 15–20 points were averagely pasted on the central line of the back of the chair (as shown in the Fig. 9), and coordinate data were derived after the capture.

**Table 3.** Functional comparison of office chairs

Parameters	A	B	C	D	Ergonomic requirements for office chairs
Headrest height	630	686	654	684	628.3 mm–675.1 mm (This range ranges from P50 females to P50 males with high cervical spine point in sitting posture.)
Waist support height	134	110–180	227	145	$\geq 210$ mm
Waist support depth	144	100	134	154	20 mm–40 mm
Effective back width	490	473	148	492	$\geq 360$ mm
Seat back height	576	555	748	618	$\geq 460$ mm

\*the unit of the backrest size is mm.



**Fig. 9.** Office Chair A, B, C and D were being experimented

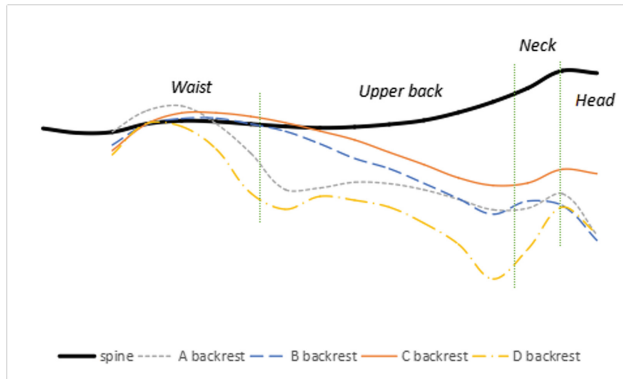
### 3.5 Data Analysis

In this research, the combination of user's objective evaluation methods and subjective experience evaluation were adopted. Statistical charts were used to analyze the subjective evaluation results of the questionnaire survey and draw conclusions intuitively. With the help of Qualisys, the coordinates of the back of the chair and the human spine were derived, and the curve were fitted in the coordinate axis. Finally, the objective conclusion of the fit between the backrest of the chair and the human spine was drawn.

#### 3.5.1 Fitting of Human Spine Curve and Office Chair Back

The height was determined by Z coordinate and the depth was determined by X coordinate. Finally, a curve, representing the shape of the spine of most people, was obtained. The back shapes of four office seats' curve representing the curvature of seat was fitted, and these four curve were compared with the curve of the human spine in same coordinates. We can clearly divide each picture into three parts: head and neck, back and waist.

It can be seen from Fig. 7 that the four chairs in the experiment do not conform to the curve of the spine when the human body is sitting upright. The head pillow and upper back are far from the users' back. The upper back of D is farthest away from the users' back, and the overall shape of D backrest does not conform to the shape of the human spine. The joints between waist and back and the part of neck are deeply sunken, even when the users are in the relaxation sitting position, they can't be supported in these parts. Four types of office chairs have waist support, but they are still not fully consistent with the human waist curve, only the B waist position is fit, the waist rest of others are larger or smaller. The waist protrusion degree is slightly large. (as shown in Fig. 10)



**Fig. 10.** Construct of spine and chair backrests (Head on the right)

To sum up, the design of office chair backrest in China is unsatisfactory at present, which does not conform to its claim of “ergonomics”:

- a. None of those 4 office chairs’ backrest can fit the shape of spine in an upright sitting position.
- b. The most serious difference is happened at head and neck, following is upper back.
- c. For the part of waist, only one of those chairs is same as spinal curve, the other three are far inconsistent.
- d. The design of waist supporting and head pillow should be modified to redirect the back curve of office chair.

## 4 Conclusion and Discussion

The main dimensions of office chairs are formulated according to the requirements of GB/T 3326. The comfort degree and function of office chairs are closely related to the structure and biomechanical characteristics of human body. The dimensions of office chairs should be designed according to anthropometric data. The parameters include seat height, seat depth, seat width, seat inclination, arm height, back characteristics, cushion elasticity, etc.

Based on ergonomics, the comfort of office chair backrest was studied in this paper. The seat back is divided into part of head and neck, part of back and part of waist. The results of subjective evaluation show that there are some problems in the existing office chairs, which also emphasizes the necessity of this study. In order to get the objective conclusion, we use Qualisys motion capture method to get the curve of human spines and seat backs. The uncomfortable parts of office chair back and the reasons were obtained by comparison. The objective evaluation is more reliable and intuitive, so the conclusion can be drawn from the objective evaluation.

In conclusion, the results of this study show that most of the existing office chair designs do not conform to the shape of the human spine in the office state. The main problems are the unreasonable depth of waist and the excessive distance between backrest and headrest and human body.

From the survey, it is also found that the chair backrest is mainly used for relaxation, and can not play an effective supporting role in the working. In the design of office chair, it is suggested to design the back of the chair according to the shape of the human spine, or to match the curve of the back of the chair with the shape of the spine in the sitting position, so as to support the human body as comprehensively as possible in the work.

**Acknowledgments.** This research is supported by 2017NQT project (2017YFF0206603) and Project of the President's Fund for China National Institute of Standardization for 2018 and 2019 (522018Y-5984; Study on ergonomic evaluation criteria of backpack products based on body pressure distribution and movement gait).

## References

1. Meng, X., Wang, W., Anderson, D.E., Bruno, A.G., Bo, C.: Study on the influence of waist support on driver's waist load. *Automob. Eng.* **38**(02), 206–210 (2016)
2. Yang, J.: *Human Comfort of Sofa Back*. Nanjing Forestry University (2008)
3. Chen, Y., Shen, L.: Discussion on the evaluation method of sofa comfort. *J. Northwest Forest. Coll.* **02**, 179–183 (2007)
4. Zhao, R.: Comfort of train seat. *Diesel Locomotive* **04**, 5–6+49 (2005)
5. Lu, J., Zhang, F., Shen, L.: Exploration of ergonomics in sitting posture and seat design. *Ergonomics* **04**, 44–46+49 (2005)
6. Shen, W.: Seat design and evaluation based on ergonomics. *Mech. Eng.* **10**, 72–73 (2005)



# Assessment of Portuguese Firefighters' Needs: Preliminary Results of a Pilot Study

Anna S. P. Moraes<sup>1</sup>(✉), Miguel A. F. Carvalho<sup>1</sup>, Rachel S. Boldt<sup>1</sup>,  
Fernando B. N. Ferreira<sup>1</sup>, Linsey Griffin<sup>2</sup>, and Susan P. Ashdown<sup>3</sup>

<sup>1</sup> Department of Textile Engineering, University of Minho, Guimarães, Portugal  
sophiapiacenza@gmail.com, rachelsagerb@gmail.com,  
{migcar, fnunes}@det.uminho.pt

<sup>2</sup> College of Design, University of Minnesota, Minnesota, USA  
lgriffin@umn.edu

<sup>3</sup> Department of Textiles and Apparel, Cornell University, Ithaca, USA  
spa4@cornell.edu

**Abstract.** Firefighter's job tasks require intensive physical work and involve a range of movements in a wide variety of hazardous environments and thermal conditions. It is thus critical that personal protective equipment allows firefighters to perform their duties with minimal limitations and maximum safety. However, many studies have shown concerns regarding turnout gear fit and comfort. This paper presents preliminary results of an in-progress study, for which the main goal is to develop design solutions to Portuguese firefighters' protective equipment. With the aim of identifying specific needs from this population, a pilot study was conducted in northern Portugal. Data were collected through an online survey and a semi-structured interview, which allowed a deeper understanding of issues encountered. Findings from this pilot study served as a guide to adjust the study and provided insights to recommend an ergonomic redesign of firefighters' gear.

**Keywords:** Human factors and ergonomics · Fit issues · Turnout ensemble

## 1 Introduction

Firefighting is necessary, critical, and challenging [1], and is considered one of the most dangerous, arduous [2], and physically demanding occupations [2, 3]. As stated by Coca *et al.* [4], firefighter's job tasks require intensive physical work and involve a range of movements in a wide variety of hazardous environments.

Firefighters' personal protective equipment (PPE) has been designed to provide protection against multiple hazards such as thermal threats (e.g. exposure to flame and excessive heat), toxic gas inhalation, and physical injuries (e.g. cuts, collisions, punctures, slips, falls, etc.) [5]. For this, firefighters are required to wear turnout gear<sup>1</sup> consisting of a protective coat and pants, and other equipment such as a hood, helmet, fire gloves, and bunker boots. Firefighters also carry a self-contained breathing apparatus (SCBA) that

<sup>1</sup> Also called bunker gear or turnout ensembles.



provides an external air supply to protect against toxic gases, hot steam, and debris [5, 6]. It is thus critical that personal protective equipment allows firefighters to perform their duties with minimal limitations and maximum safety [2].

Over the years, the nature of firefighting and the role of firefighters have shifted [6]. Firefighters' PPE has evolved [2, 6], but important trade-offs between protection and comfort remain.

As pointed out by Boorady *et al.* [2] and Park *et al.* [5], higher thermal protection, which combined with advances in material technology during the past decade, has greatly decreased burn injuries. Nonetheless, the efforts in improving thermal protection have inevitably increased the weight and bulkiness of the firefighters' protective gear, hence, significantly compromising firefighters' mobility and comfort [2, 5]. According to Smith *et al.* study, cited by Park and Hahn [6], the bulk and weight of the turnout ensemble increase physical exertion and the risk of heat stress, which, in the worst-case scenario, leads to heat stroke and cardiovascular malfunction.

The Occupational Safety and Health Administration (OSHA) reports that fit and comfort are important features to consider when selecting PPE [7]. Furthermore, Akbar-khanzadeh *et al.* [8] claimed that increased wearability and proper usage of the protective clothing system can be achieved only when human factors and user input are included in the design process. Exploring user input and perceptions of firefighters' protective gear is essential to identify areas for improvement [6].

### 1.1 Portuguese Firefighters' PPE Study

In Portugal, there are more than 466 fire brigades, comprising about 27,000 firefighters [9]. As in many other countries, Portuguese firefighters "are the first ones called to a variety of situations" [2], responsible for responding to many different circumstances and emergencies like structural fires, wildfires, chemical spills, extrication from vehicles, medical emergencies, and so on.

To understand if the Portuguese firefighters' protective personal equipment is adjusted to their anthropometrics and identify specific needs, a study designated as *SizeFF Portugal – Anthropometric Study of Firefighters* is being developed by 2C2T - Centre for Textile Science and Technology, in the Department of Textile Engineering at University of Minho, in partnership with an USA study, involving twelve Universities. The study's main goal is to assess and present design solutions to the PPE used by Portuguese firefighters, using 3D body scanning technologies. In order to validate the study methods and tools and to obtain the first insights from firefighters' experiences in wearing their turnout ensembles and other protective equipment, a pilot study was conducted in a Portuguese Fire Brigade. This paper presents the first qualitative results related to their turnout gear, in particular coats and pants.

## 2 Materials and Methods

The pilot study was conducted in a Fire Brigade located in the northern region of Portugal. After obtaining the permission of the Fire Brigade responsible, firefighters were invited to participate.

## 2.1 Data Collection

For data collection, an online survey was administered. Participants were requested to answer the questions based on their perceptions and experience of wearing their current equipment. Although the survey was administered online, a researcher was available throughout the process to clarify any issues or answer any questions participants may have. While administering the survey, researchers also conducted semi-structured interviews, allowing a deep understanding of issues encountered and better exploring their needs.

**Survey.** The online survey was comprised of 83 questions, divided into five parts, including questions about: sociodemographic information, turnout coat, turnout pants, fire boots, and fire gloves. Figures indicating specific areas of the turnout ensemble, gloves, and boots were presented to the participants, followed by questions containing common fit issues related to the respective body areas.

**Interview.** The interview questions were initially formulated based on results from similar studies [2, 6]. Throughout the pilot study, additional questions were included in the interview, as the participants mentioned some other specific items, not previously included in the survey. In addition, while applying the survey, researchers followed up with additional questions when responses required further information or clarification, assuring a more natural and relaxed conversation.

After obtaining participants' consent, interviews were audio recorded to ensure all comments were captured. Further, each interview recording was transcribed for accuracy in data analysis. Data were collected in December 2018 and January 2019, and each interview/survey took approximately 40 min.

## 2.2 Data Analysis

Data obtained in the interviews were coded and analyzed using an interpretive thematic analysis method, while responses from the online survey were statistically analyzed. Data were organized by classifying the most common problems and areas needing improvement identified by the participants.

# 3 Results

## 3.1 Demographic Information

The Fire Brigade is comprised of 38 firefighters, including both career and volunteer personnel<sup>2</sup> and only volunteer personnel. The Brigade serves a medium size municipality<sup>3</sup> (about 160,000 inhabitants), including urban and suburban populations, as well as the wildland environment surrounding the city.

<sup>2</sup> In Portugal, career firefighters usually volunteer in their Brigade and/or other brigades.

<sup>3</sup> The Fire Brigade shares the territory protection with another smaller Fire Brigade.

Sixteen firefighters participated in the pilot study, including firefighters that are only volunteer (25%,  $n = 4$ ) and both career and volunteer (75.00%,  $n = 12$ ). 12.5% of the participants were female ( $n = 2$ ) and 87.5% ( $n = 14$ ) were male. The average age of the respondents was 37 years (ranging from 21 to 61 years;  $SD = 11$ ). The average years of experience in firefighting was 17 for male participants (ranging from 4 to 33 years;  $SD = 10$ ), and 0.75 year for female respondents.

### 3.2 Turnout Gear Selection

For many years, the Fire Brigade has been investing in specifically tailored turnout gear. For this, a manufacturer assists firefighters in selecting their turnout coat and pants, providing a sample set of sizes and making adjustments to tailor items to individual measurements. However, at the beginning of a new purchasing process, not all firefighters have their turnout gear replaced<sup>4</sup>.

The main adjustments made by the manufacturer were in sleeve length (5 participants had their coat sleeve shortened) and in the pants leg length (3 participants had their pants legs shortened). Even with the assistance of the manufacturer, 2 participants (12.5%) affirmed having difficulties in selecting the turnout coat size and 2 participants (12.5%) affirmed the same for the pants. 2 participants described their experience when they had their gear substituted:

*"it was difficult to select the size... there was a size M, which is the size I usually wear, on normal clothes, but I saw, in terms of comfort, tasks, all this, it was not the most appropriate... [So, you have chosen the L size?] Yes, you have more comfort and maneuverability" (male/career and volunteer).*

*"My previous coat was an L size... I asked for an XL, but they still gave me an L... when it is a bit loose we always can move better, but sometimes, to pass like, through a window, if it is a bit tighter, it is easier" (male/career and volunteer).*

### 3.3 Turnout Gear Protection Level

Concerning the protection level, 75% ( $n = 12$ ) of the participants affirmed feeling very protected by their turnout coat, and 25% ( $n = 4$ ) affirmed feeling somewhat protected. One participant who affirmed feeling somewhat protected mentioned that his coat is too worn out. Another participant affirmed that he does not feel very protected by his coat, and cited that:

*"not so much... the velcro does not stick anymore" (male/volunteer).*

The firefighters' perceptions regarding the pants were slightly better, as 81.25% ( $n = 13$ ) of the respondents affirmed feeling very protected and 18.75% ( $n = 3$ ) affirmed feeling somewhat protected. One participant mentioned that he has sewed the suspenders on the pants, as the fastening had broken.

<sup>4</sup> According to a participant, career firefighters have priority over volunteers, as they use their equipment more frequently. All the participants that are volunteers wear available turnout ensemble from former firefighters.

None of the participants affirmed having had any injuries caused by the fit of the turnout coat and pants.

### 3.4 Turnout Coat Fit Issues

Figure 1 shows the participants' responses to fit issues in specific parts of the turnout coat.

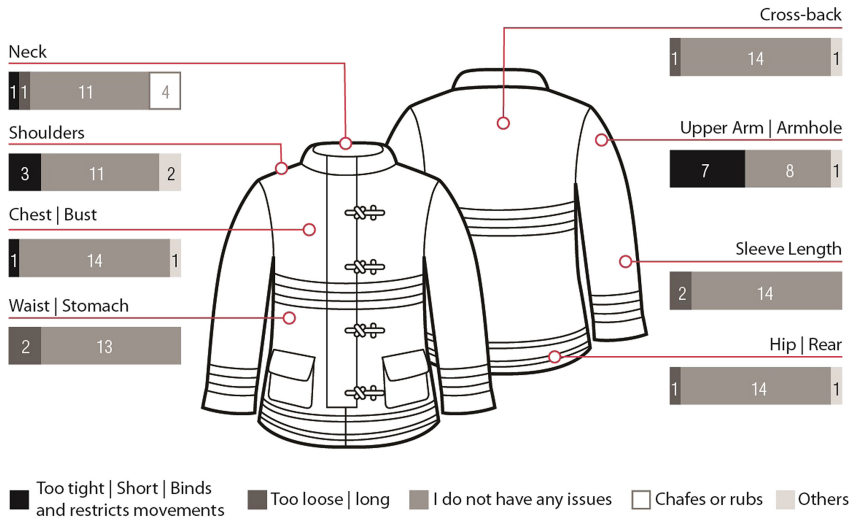


Fig. 1. Turnout coat fit issues.

The upper arm/armhole area was the most cited area by firefighters. For 43.75% (n = 7) of the participants, it binds and restricts movements or is too tight. The main impact in the use is related to movements in an upper head level, as described by 2 participants:

*“it is difficult to make maneuvers above the head” (male/career and volunteer).*  
*“the armhole region restricts movements a bit, even being specifically selected [for me]” (male/career and volunteer).*

Still, it was cited that the most impacted activity is the extrication, when tools are used to cut the vehicles metal sheets. According to another participant, the armhole is just a bit tight (6.25%). Other participants also pointed out the impact of the fabric in this specific region:

*“yes, it is a bit... donning it is a bit hard, because the coat is not very flexible, and also, we put the SBCA<sup>5</sup> on, which also hampers the maneuvers” (male/career and volunteer).*  
*“I think it is a bit tough... there is a small discomfort” (male/career and volunteer).*

<sup>5</sup> Self Containing Breathing Apparatus.

The other 50% ( $n = 8$ ) of the participants affirmed to not having any issues about the upper arm/armhole area. In the same way, the turnout coat shoulders appeared as the second area with more fit issues, with 18.75% ( $n = 3$ ) of the responses for binds and restrict movements. A participant clarified:

*“the coat interferes with moving... the shoulders bind and restrict movements... after being fully equipped, you can’t move your arms” (male/career and volunteer).*

For 2 participants (12.5%) the turnout coat is not flexible because it was recently purchased, explaining that after some cleaning, it tends to become softer:

*“the shoulders restrict movement, in this area [shoulder region] is a bit tight... but I think that’s because it is still new... after washing, it will have a better fit” (male/career and volunteer).*

*“you know, at this moment, it still has the fabric starch as it is new... and this is a bit restricting...” (male/career and volunteer).*

Still, 68.75% ( $n = 11$ ) of the participants affirmed not experiencing any fit issues relating to the shoulders area.

According to 18.75% ( $n = 3$ ) of the participants, the turnout coat waist/stomach area is too loose, while 81.25% ( $n = 13$ ) affirmed not having any fit issue related to this area. One male participant noted the flexibility of the fabrics impact in this region:

*“it is a bit difficult to bend... you know, after a while even the fabric starts losing its rigidity, and maybe it can get better... but when it is still new, it is not very flexible” (male/career and volunteer).*

The turnout coat neck main fit issues are related to causing chafing and and rubbing, cited by 18.75% ( $n = 3$ ) of the participants as being too tight. However, one participant (6.25%) considered the coat neck too loose. For 68.75% ( $n = 11$ ) of the participants, the turnout coat neck did not present any fit issues.

The sleeve length was cited as too long by 12.50% ( $n = 2$ ) of the participants.

Concerning the turnout coat cross-back area, 6.25% ( $n = 1$ ) of the participants affirmed it to be too loose, 6.25% ( $n = 1$ ) of the participants affirmed it to be a bit loose, and 87.5% ( $n = 14$ ) of the participants expressed no fit issue.

Regarding the hip/rear area, 6.25% ( $n = 1$ ) affirmed it to be too loose, while 87.50% ( $n = 14$ ) of the participants affirmed not having any fit issue. A female participant stated that her coat was a bit short in the hip area and that this was important when she selected her coat size:

*“the coat is unisex, but it is a bit short, if I had chosen a smaller size it would have been really short... it needs to be longer for when we are bending over” (female/volunteer).*

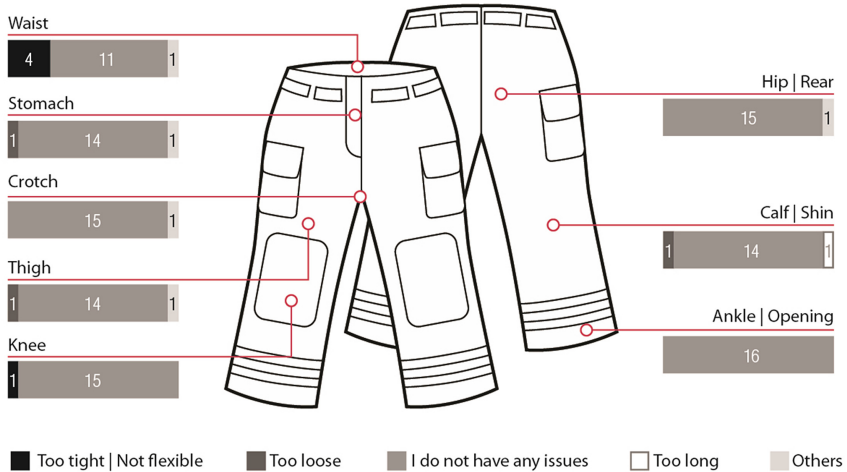
Still, another participant clarified that when wearing the SBCA inside the fire truck or ambulance, the rear tends to become exposed:

*“when we are on the way to a fire, we put on the SBCA inside the vehicle, and the back hip area tends to rise... we always take a look at each other to check...” (male/career and volunteer).*

The chest/bust area was cited as too loose by 1 participant (6.25%), a bit tight by 1 participant (6.25%), while most of the participants (87.5%, n = 14) affirmed not having any fit issue regarding this area.

### 3.5 Turnout Pants Fit Issues

Participants' perceptions with regard to specific areas of the turnout pants are shown in Fig. 2.



**Fig. 2.** Turnout pants fit issues.

The waist region appeared as the most problematic. 25.00% (n = 4) of the participants affirmed that the waist is too loose. One female participant even affirmed tying up the region with an elastic band. On the other hand, for a male participant, the waist is too tight, as well as the stomach and hip region, which makes it difficult to bend over or to climb a small fence.

For other 6.25% of the participants, the stomach region of the turnout pants is too loose, while 87.5% (n = 14) of the participants this region did not present any fit issue.

Regarding the hip/rear region, most of the participants (93.75%, n = 15) stated to not having any fit issue.

93.75% (n = 15) affirmed not having any fit issue with the turnout pant crotch. Only one participant (6.25%) mentioned the crotch as a problematic area, and described that

*“climbing stairs restricts [movements] a little bit” (male/career and volunteer).*

In the thigh region, one participant (6.25%) considered it too loose, and another participant (6.25%) mentioned that the thermal liner of his pants is already too damaged in this area, as well as the crotch region, which ends up bruising the skin due to the contact with the moisture barrier.

In respect of the knee region of the turnout pants, only one participant (6.25%) cited having a fit issue:

*“it is not flexible, and doesn’t bend easily” (male/career and volunteer).*

The other 93.75% ( $n = 15$ ) affirmed not having any fit issue in the knee region.

Concerning the shin/calf area, 6.25% ( $n = 1$ ) of the participants mentioned it as being too long, 6.25% ( $n = 1$ ) affirmed it as being too loose, and 87.5% ( $n = 14$ ) affirmed not experiencing any fit issue. None of the participants mentioned having any fit issue in the ankle region.

## 4 Discussion

In general, participants of the pilot study revealed being satisfied with their personal protective gear, and many positive comments were obtained during data collection. However, some fit issues expressed by participants are also described in similar studies, which corroborates with their perceptions.

### 4.1 Turnout Ensemble Sizing

As stated by Torvi and Hadjisophocleous [10], correct sizing is particularly important in protective clothing, as the performance of the clothing depends on the correct fit. In the pilot study, it was possible to note the effort of the Fire Brigade to improve the fit of the turnout gear, as assisted by a manufacturer, by purchasing specifically tailored gear.

However, the adjustments were restricted to the sleeve length and pants leg length. Despite the fact that sleeves and pant legs must be of the correct length to provide protection for the wrists and ankles [10], they can be limited in dealing with issues such as the interface with other protective clothing items, for example boots and gloves, and the adjustment of fit to women’s anatomy.

### 4.2 Turnout Ensemble Fit

**Coat Length.** The turnout coat length is of paramount relevance in protecting fire-fighters, as a short coat left them vulnerable to the risk of burn injuries because their back was likely to be exposed to external heat and steam during active body movements such as bending, crawling, and reaching overhead [6]. On the other hand, a coat that is too long increases the risk that the hem can be caught by a ladder while ascending or descending, which becomes a safety issue [6]. In the pilot study, this aspect was cited by many participants. They also pointed out a strategy among peers of ensuring that their back does not become exposed when donning the SBCA inside the fire truck or ambulance. Some participants also mentioned a new style turnout coat that has been introduced with a longer hem in the rear, which is better than the previous style.

**Suspenders.** The suspenders place most of the weight of the pants on shoulders, where the SBCA also rests, and can lead to fatigue when firefighters are in their gear for long periods of time [2]. Many participants of the pilot study expressed concerns regarding the suspenders. Participants revealed a desire for a different system for supporting the weight of the pants and stated having trouble adjusting the suspenders. Despite the fact that suspenders were not included in the survey questions, some participants mentioned their problems with them. One of the first participants discussed them as follows:

*“the only thing missing [in the survey] are the suspenders... ok, it is part of the protection system, it is, and also they stand for the pants, but sometimes, when we are donning, the suspenders can get twisted... and these new ones are even better than the previous, [as the straps are] in an “X” shape, and the old ones were in “H” shape... and the new ones are cushioned... they are getting a bit better, but when donning, of course, we are doing this in a rush, [straps] can twist...” (male/career and volunteer).*

One participant cited that the only thing she would like to change in the gear would be the suspenders, and mentioned that wearing the SCBA hurts her clavicle bones:

*“I would like to remove the suspenders, but I know they are necessary, otherwise the pants would fall... in my case it ends up being uncomfortable, someone puts it on, but it never goes straight, folds... in this area, over these bones, it hurts me, I have prominent bones in this area...but this is in my case” (female/career and volunteer).*

Another male participant mentioned that the suspenders need to be tightened up, and after putting the SCBA, it ends up having two straps on shoulders. Other participants mentioned that they do not like the suspenders, and even questioned their utility:

*“the pants can be adjusted by the belt” (male/career and volunteer).*  
*“it disturbs me... mine is always loose” (male/volunteer).*

**Pockets.** Some studies [2, 6] have cited the lower satisfaction of participants with their gear pockets. However in this pilot study, pockets were not cited as an issue by any of the participants.

### 4.3 Gear Fabrics

Firefighting turnout coat and pants are made with three functional layers for enhanced thermal protection: an outer shell, a moisture barrier, and a thermal liner. Fabrics of firefighting gear appear as a problematic issue in many studies [2, 6], mainly related to flexibility. Participants of Boorady *et al.* [2] study expressed a reduced sensation for touch, and tears in the gear.

This aspect was also cited by the participants of the pilot study who discussed a feeling of reduced mobility. However, many participants felt that the fabric's rigidity was due to the fact that the gear is still new, and tends to become softer after several cleanings.

### 4.4 Turnout Gear Maintenance

It is very difficult to estimate the useful lifetime of turnout gear for firefighters: while some obvious incidences of degradation are easy to detect, such as rips in the outer



shell, degradation due to repeated laundering, or exposure to high heat fluxes or to certain types of radiation may not be apparent [10]. In addition, simply stating that a garment can be used for a certain number of years of service is not sufficient, since fire departments may have different levels of usage and exposure to ultraviolet radiation, various approaches to firefighting, and different cleaning frequencies. Even gear belonging to different firefighters in the same department will be exposed to different conditions over the garment's lifetime.

As previously mentioned, in the past 2 years, most career firefighters of the Fire Brigade had their turnout gear replaced. However, as described by some participants, the average length of service from the past turnout gear varied from 8 to 12 years. Some participants expressed concerns regarding their equipment maintenance, which were directly connected to their protection level perceptions.

#### 4.5 Personal Hygiene

Commonly, firefighters wear their turnout ensemble over the station uniform or their own normal everyday clothing [11]. In the pilot study, most participants confirmed that they wore the turnout coat over the station t-shirt, and the turnout pants over cotton pants. However, this is a personal choice, for a better personal hygiene and comfort. As stated by the participants, some firefighters prefer to not wear any pants under the turnout ensemble, or wear a one-piece jumpsuit underneath.

One participant suggested development of a removable liner for more frequent cleaning:

*"maybe the liner, I believe would be an advantage to be removable for better personal hygiene... sometimes we are in a fire, and it [the turnout ensemble] doesn't get really dirty outside, but only the fact of wearing the gear, we start sweating, and they will not clean the gear only because we sweat... the fabrics also start to loose quality... the liner should be removable for laundering" (male/career and volunteer).*

#### 4.6 Study Limitations

This pilot study investigated Portuguese firefighters' perceptions regarding the ensemble they are currently wearing. Despite the valuable contributions and insights provided by the participants, it is not possible to make generalizations from this pilot study. However, it has revealed the priorities that need to be considered in the next study phase, around the country.

Another limitation is related to the fact that participants wear different styles of turnout gear, as some of them had their equipment replaced recently, and others have a variety of other styles of equipment (individually purchased or offered by private companies). In addition, specific equipment for different missions (e.g., wildfires) were not included in the study.

## 5 Final Considerations

Firefighting is considered one of the most dangerous, arduous and physically demanding occupations. Due to elevated and diverse threats, firefighters' personal protective equipment has evolved. However, issues concerning fit, sizing, comfort, protection and health remain as relevant in firefighters' PPE.

This pilot study investigated Portuguese firefighters' perceptions and experiences when wearing their turnout ensemble. In general, the participants of the study reported that they feel very satisfied with their gear. The main issues identified by the participants were the turnout coat shoulders and armhole, and the pants waist region. Additional insights concerning maintenance, personal hygiene, fabrics, and the suspenders were cited as areas needing improvement.

Findings from this pilot study serve as a guide for adjusting the current study in future and provide qualitative insights to recommend ergonomic improvements of the Portuguese firefighters' gear.

**Acknowledgments.** We would like to acknowledge the 2C2T – Science Center for Textile Technology from University of Minho. This work is financed by FEDER funds through the Competitive Factors Operational Program (COMPETE) POCI-01-0145-FEDER-007136 and by national funds through FCT-Portuguese Foundation for Science and Technology, under the project UID/CTM/000264 and by Fundo às Vítimas dos Incêndios de Pedrógão.

## References

1. Langseth-Schmidt, K.: Anthropometric Fit Evaluation of Structural Firefighters' Protective Pants: a Gender Comparison Study. Master Thesis, Colorado State University, Fort Collins, Colorado (2014)
2. Boorady, L.M., Barker, J., Lee, Y., Lin, S., Choo, E., Ashdown, S.P.: Exploration of firefighter turnout gear part 1: identifying male firefighter user needs. *J. Text. Apparel Technol. Manage.* **8**, 1–13 (2013)
3. Coca, A., Roberge, R., Shepherd, A., Powell, J.B., Stull, J.O., Williams, W.J.: Ergonomic comparison of a chem/bio prototype firefighter ensemble and a standard ensemble. *Eur. J. Appl. Physiol.* **104**, 351–359 (2008)
4. Coca, A., Williams, W.J., Roberge, R.J., Powell, J.B.: Effects of fire fighter protective ensembles on mobility and performance. *Appl. Ergon.* **41**, 636–641 (2010)
5. Park, H., Park, J., Lin, S., Boorady, L.M.: Assessment of firefighters' needs for personal protective equipment. *Fashion Text.* **1**(8), 1–13 (2014)
6. Park, H., Hahn, K.H.: Perception of firefighters' turnout ensemble and level of satisfaction by body movement. *Int. J. Fashion Des. Technol. Educ.* **7**(2), 85–95 (2014)
7. OSHA – Occupational Safety and Health Administration: Personal Protective Equipment. Booklet OSHA 3151-12R (2004). <http://www.osha.gov/Publications/osh3151.pdf>. Accessed 15 Jan 2019
8. Akbar-Khanzadeh, F., Bisesi, M.S., Rivas, R.D.: Comfort of personal protective equipment. *Appl. Ergon.* **26**, 195–198 (1995)

9. INE – Instituto Nacional de Estatística/Portugal.: Bombeiros por localização geográfica (2017). [https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine\\_indicadores&indOcorrCod=0007234&contexto=bd&selTab=tab2](https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0007234&contexto=bd&selTab=tab2). Accessed 15 Jan 2019
10. Torvi, D.A., Hadjisophocleus, G.V.: Research in protective clothing for firefighters: state of the art and future directions. *Fire Technol.* **35**, 111–130 (1999)
11. Cotterill, D., Easter, E.P.: Firefighter turnout gear durability study – evaluation of visibility trim. *Fire Technol.* **47**, 601–613 (2011)



# “Possible But Improbable Spaces”: From Interior Design Experience to Jewellery Creation

Mónica Romãozinho<sup>1,2</sup>✉

<sup>1</sup> CIAUD, Lisbon School of Architecture, Universidade de Lisboa,  
Rua Sá Nogueira, 1349-063 Lisbon, Portugal

monica.romaoz@gmail.com

<sup>2</sup> ESART-IPCB, Lisbon, Portugal

**Abstract.** The present project was born from the interaction between jewellery scale and interior design principles. We had started with drawings and cardboard models around housing typologies inspired by nature, by its asymmetric and modular geometrical shapes, by its capacity to metamorphose. This experimental process was the platform for the creation of contemporary jewellery lines, focusing main principles such as spatiality, abstraction, mutability, versatility and ergonomics. We had explored the movement of undulating surfaces, the relation between shadow and light, scale variations, the opposition between empty and full spaces, chromatic or texture contrast. On the other hand, jewellery can be an extension of our selves just like interior design, assuming changes everyday life according to our mood. Our methodology also includes 3D software and 3D prototypes without forgetting traditional jewellery skills or the assemblage technique applied to the most recent pieces. From printed components, wastes or mass-produced objects that are no longer useful, crossed with a traditional material like copper, we proceed to the production of limited series pieces suitable for a public who values jewels by its unique design regardless of the value of its material.

**Keywords:** Interior design · Jewellery · Versatility

## 1 Genesis of the Project

The present research project, which was part of a post-doctorate in Design and developed within the CIAUD (Lisbon School of Architecture, Universidade de Lisboa), consists of the design of the jewellery collection “Possible but improbable spaces”. It started with the experimentation around space, its principles, its geometry and crosses with the Architecture and the Interior Design at the conceptual and methodological level. This same collection unfolds in lines of a unique character united by the same philosophy.

In Interior Design, we seek to respond to the needs and aspirations of society. It is also up to us to follow the ethical duty not to produce surplus objects that are irrelevant to society and which do not add to our quality of life. We can communicate a specific message, awaken emotions, arouse dreams, these are fundamental functions also performed by jewellery. A piece of jewellery does not work as a shelter given its scale, it

can and should be ergonomic, but not necessarily utilitarian because its dimension requires a broader view, an anthropological perspective: “Jewellery has a physical existence, but the reason why we wear it is far more mysterious and invisible. Its mobile aspect gives jewellery potential as a constant, if quiet intervention in everyday life. A piece of jewellery is carried close to the body and it can therefore be an extension of the body itself, a part of that person’s identity” [1]. We believe that its primary function is to constitute itself as a platform for our individuality, such as a house, a room, an intimate space. Jewellery and space can share principles such as: plasticity, inner-outer dialectic, set of scales, contrast of colour or texture, alternation between light and shadow, opposition between full and empty, movement, rhythm, repetition, versatility or even mutability.

Our initial incursion focused on the design of organic architectures inspired by nature, with asymmetrical and irregular contours resulting from tensions between colours, materials and transparencies. The sense of anti-decomposition and consequently unity are compositional principles that approximate these designs of so-called organic architecture, because the essential organization arises from the internal needs and external conditions, in which each architect tries to connect their own volumetry and geometry of space projected to the topography of the land itself. What intrigues us is to draw inhabitable and inhabited spaces as opposed to cells inhabiting anonymously, seeking to explore a strong sense of identity that we have tried to transpose to the scale of jewellery: “There should be as many kinds (styles) of houses as there are kinds (styles) of people and as many differentiations as there are different individuals. A man who has individuality (and what man lacks it?) has a right to its expression in his own environment” [2]. We rethought the territory through the design of fluid, experimental, irregular spaces, wrapped in organic membranes that adapt to the morphology of the terrain (Fig. 1). There is space and time to ramble and contemplate nature. We have tried to systematize solutions in response to these “functions”, tested in small 1:50 scale models. We standardised some components, namely interior volumes, coverings or furniture that also arises from the geometry of these spaces, yet evoking the sense of intimacy. Carpets model spaces, in the image of “tatamis”.

In this transposition to the field of jewellery, the design attitude is close to the “Avant-Craft” tendency, the result of artistic vanguards, the so-called author’s jewellery, resulting from independent and experimental research, disconnected from the logic of production, communication and distribution, by crossing heterogeneous languages, materials and techniques [3]. Oblique surfaces and ceilings translate into a set of irregular contour shapes that integrate the modular forms of hand-scale pieces and principles such as the use of vast transparencies or opacities that relate to exterior and interior, the unfolding of the interior into volumes that define a border between public and private, the contrasts between full and empty, the opposition between colours and textures, the question of shadow and light.

We established typologies to be developed as well as functions and one of the fundamental premises was to look at jewellery as a versatile object, just as a spatial solution does not necessarily have to be imposed on the public. The versatility and mutability, explored in the present project, arises from the willingness to flexibly respond to different occasions, states of humour or even events. We refer to the possibility of the piece being able not only to change in its positioning and relation with the

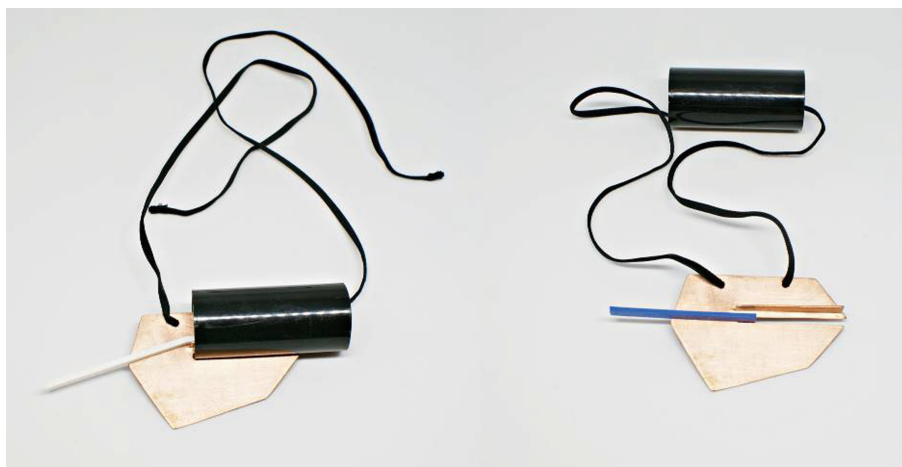


**Fig. 1.** Example of experimental drawings that were in the genesis of the jewellery project: utopia #VI-13. 2017. Mónica Romãozinho.

body, but also to mutate. The same assumptions were explored by the artistic avant-gardes of the twentieth century, such as Russian artists and designers who developed transformable and versatile equipment applicable to everyday life and exploited in a very particular way in scenography by the hand of designers such as Popova (1889–1924) or Stepanova (1894–1958). In the case of art and fashion, we can highlight the role of artists such as Giacomo Balla (1851–1978) who in 1914 suggested a series of modifying elements in clothing that allowed anyone not only to modify but also to invent a new suit for a new state of mind [4]. Also, under the influence of the *Art Déco* movement there were pieces such as the Van Cleef & Arpels’ Pass-Partout Necklace (1930s), consisting of a gold snake-shaped chain that included clips that could be removed and applied to hats or clothing [5].

As in Architecture and Interior Design, we start from the volumetry and the relationship with the place to reach the scale of the door handle. The poetic exploration that transcends all of this process arises from the reinterpretation of organic spaces, namely their interiors unfolded in undulating contours and sense of lightness, in a search for economy in their lines and surfaces. Other materials or components are incorporated at a certain point, which do not offer the greatest utility. We sought to explore the possibility of mutation by drawing a necklace that results from the exploration of a cylindrical volume in PVC (reused object) that symbolizes the idea of an organic habitat always changing like the organisms of nature (Fig. 2). The pre-existing cylindrical object was our starting point, our pre-existence, just as the understanding of

the terrain, of the “genius loci” is the lever for an architectural project. We are, however, faced with a more plastic and conceptual exploration in which the line is affirmed as the first and last thing in the same way that Aleksander Rodchenko (1891–1958), a constructivist designer, stated in his speech and work: “Both in painting as in any construction in general, line is the first and the last thing” [6]. Incidentally, the design and also the set design of artists of the Russian avant-garde are for us a reference almost transversal to all the projects. One of the most interesting examples was the constructivist scenario for “The magnanimous Cuckhold” (Premiere in Moscow 25th of April of 1922, with a production by Fernand Crommelynck) developed by Popova that would find the ideal platform for the development of this biomechanical agility, a wooden plank for the actor, comparable to a circus acrobatic apparatus [7]. This necklace unfolds in different solutions, corresponding to several “acts of a play”, through the adding of his structural and linear elements such as a horizontal plank, a ramp or simply through a new combination solution between the cylinder and the copper module. We have chosen two main colour variants: one more contrasting and one more neutral. What pleases us in particular is the pleasure of manipulating objects, playing with elements resulting from varied production processes and relating in the same dynamic composition as if it were an *assemblage*.

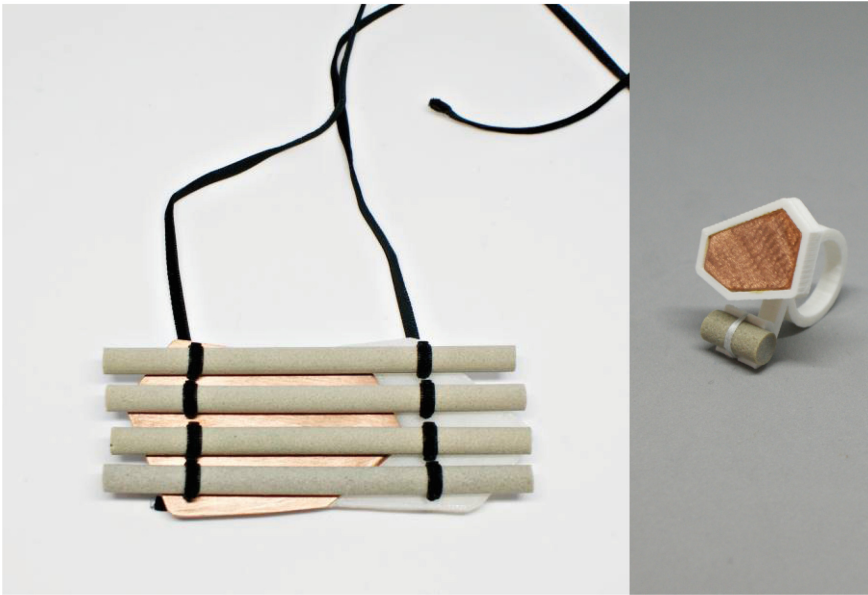


**Fig. 2.** Collection “possible but improbable spaces”. Line “abstract spaces”. Mutable necklace (single piece). PVC (reuse), PLA and copper. Mónica Romãozinho.

The reuse of pre-existing materials has already occurred in the first necklace of this same line in which the formal composition unfolds on a translucent and modular piece that functions as the basis for the design of multiple pieces of different scales of the collection “Possible but improbable spaces” (Fig. 3). In the perforations of this surface we have interwoven a velvet ribbon that supports a rhythmic sequence of rubbers.

Essentially, we intend to create an open collection that is not exhaustive in the pieces presented, which means to assume a transversal narrative to all the pieces of





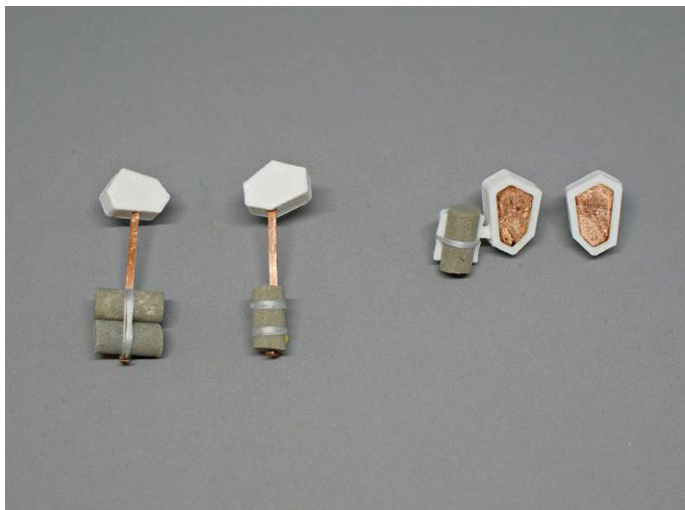
**Fig. 3.** Collection “possible but improbable spaces”. Line “abstract spaces”. Necklace (single piece) and ring (limited edition). PLA (waste), Rubber (reuse) and copper. 2016–2017. Mónica Romãozinho

different lines within the same collection. Specific elements ensure the guiding thread between parts that deviate from any intention of replicating a unilateral design to all the projective solutions.

An example of this is the prototypes developed in the field of earring typologies (Fig. 4). In the initial typology of earrings of this line, we explored asymmetric base modules that integrate ear pins combined with linear copper posts that support, by using the sewing thread, rubbers arranged horizontally or vertically. In the case of the second pair of earrings, its contained size and lightness due to the material itself, allows for a rotation of the piece, allowing for a positioning in different angles. As in the ring, the base module undergoes a recess by receiving the copper inlay.

Earrings work for us as the “constructive detail” of each jewellery line, never seen as miniaturizing the larger pieces. On the other hand, earrings do not play such a preponderant role in a historical perspective, unlike brooches, necklaces, rings or hair ornaments. Even in the period dominated by the *Art Nouveau* movement that celebrated jewellery so highly, the earrings were somewhat devalued, summing them up as small clusters or solitaires [8], devoid of the asymmetrical sense and movement present in the interiors and furnishings of a Henry Van de Velde or Victor Horta. At present, it is possible to find solutions of asymmetric earrings in the so-called high jewellery, such as the sets of chandelier earrings with inverted designs created by De Grisogono [9]. The *Tubetto* collection is a great example of this type of composition. It is also possible to note that this compositional strategy extends to more commercial brands such as *Tous* (Earrings *Hill*, for example).



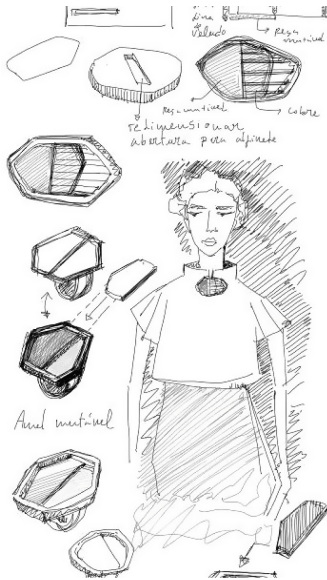


**Fig. 4.** Collection “possible but improbable spaces”. Line “abstract spaces”. Earrings (single pieces). PLA, rubber (reuse) and copper 2017. Mónica Romãozinho.

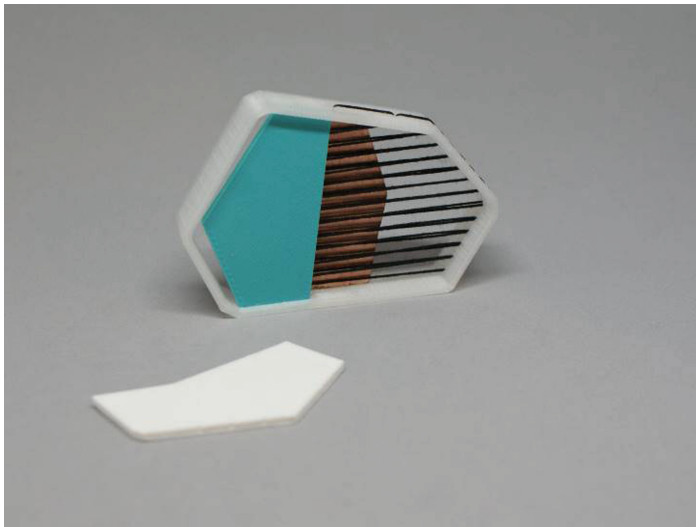
In the last pair developed (Fig. 5), also guided by a final effect of asymmetry, the reused cylindrical object receives a piece of PLA (in three possible colours) containing a rail along which the blade of copper slides and engages (using positive-negative method), also caught by the same method when it fits into the initial volume.

Throughout the whole process we have departed from any explicit transposition of imagined architectures. The abstract forms reveal or imply multiple meanings, as opposed to any figurative realism, and, on the other hand, facilitate the search for informative economy in the whole design concept, which corresponds to a culmination of an intention to achieve the essentiality.

After experimenting around necklaces and changeable earrings, we chose to explore the same level of changeability in the design of a brooch (Figs. 5 and 6), a piece that can play a more interactive relation with shirts, coats among other examples. Brooches were very iconic pieces along history if we think about the clasps that in Classical Antiquity were attached to the “chiton”, used by men and women only with variants in height. [10]. Two scenarios were created: one of a neutral character through the introduction of a white blade, another more contrasting through the insertion of a surface in PLA in the colour “turquoise”. The base element is translucent and receives not only these two pieces, but also a horizontal line sequence and a last “wall” in copper, so the sense of depth is played in this way in this succession of spaces that are guessed, like a house viewed in perspective. The same acrylic sewing threads define the reading of a “brise soleil” that separates the interior from the exterior.



**Fig. 5.** Collection “possible but improbable spaces”. Line “abstract spaces”. Ipad pro drawing and prototype of mutable earrings (limited edition). PVC (reuse), PLA and copper 2018. Mónica Romãozinho.



**Fig. 6.** Collection “possible but improbable spaces”. Line “abstract spaces”. Mutable brooch 2018. Mónica Romãozinho.

## 2 Project Methodology

The sketches are always present, insofar as “For a designer, the sketchbook is not only for drawing, but also for recording and ordering thoughts, for graphically gathering of information and for seeking solutions to a design problem through the creative process” [11]. We use bristol models, three-dimensional modelling and 3D printing, in order to test fittings and respective clearances, density and quality levels, minimum section bearable in the perforated zones, minimizing the expense of the material consisting of PLA (biodegradable polymer termed polylactic acid).

In mutable versions of necklace and earrings, the fixation of the pieces in different colours (white, turquoise, traffic blue and turquoise) was solved by inserting them into longitudinal tears made in the copper shapes, which also received a surface locking the movement of the overall part by engaging the cylindrical elements. The first two pairs of earrings contain a hole in the small volumes, where the hypoallergenic post would be engaged and then covered by a perforated circular piece. The advantage of materials such as plastic or resin also derives from their extreme lightness as it allows you to rotate the pieces causing different effects. In the case of the changeable earrings, we chose to weld a silver spike to the copper blade, but the pin would be inserted into a recess made in the back of the brooch in a manner similar to other earrings.

3D printing has opened the door to all these possibilities, but we do not see it as an ideal and exclusive method not only because the PLA colour palette is limited, but also because no effective solution to the matter of filament recycling has yet been found. The quality of the filaments is also variable from colour to colour which makes printing unpredictable. Copper was the second material chosen for its reddish colour, due to the mutations that it undergoes over time and oxidation, gaining greenish tones, its versatility and resistance resulting from its high melting point, although we have only used solder in the changeable solutions. In the solutions most exposed to contact with the body, we chose to use an oxidation retardant varnish. The cut is manual using the goldsmith's saw, followed by a brushed finish.

“PLA” can be biodegradable (under certain conditions) and it is obtained from plant starch such as corn, which has a low environmental impact. However, we are concerned with the reuse of interim prototypes, either of surplus objects or parts, and at one point the project started to integrate these processes, considering some of the fundamental strategies that integrate the concept of Ecodesign: opt for low-impact materials; minimize the amount of material to be used; optimizing production techniques [12, p. 3]. Giving priority to solutions that work by fitting, minimizing the use of bonding, safeguarding all possible residues of metals such as copper that can be melted, re-entering the production cycle.

## 3 Conclusive Synthesis

One of the fundamental objectives of this line of jewellery is to explore the design from the perspective of connecting with our identity, with a target audience that is not reviewed in mass solutions but also whose economic status does not allow access to high jewellery. This point of view which we share entirely, leads us back to a certain

romanticism proclaimed by the doctrines of William Morris (1834-1836) for whom art was “made by the people and for the people, as a happiness for the maker and the user” Pevsner [13]. We have explored principles such as the versatility, the mutability that provide a manual experience of transformation, but above all the idea of conveying a critical narrative of how our cities’ architecture and interiors evolve. They are limited series pieces so that whoever uses them feels that they communicate their individuality such as a house. Finally, all the pieces are the result of a work that continues to contemplate artisan processes in its execution. In this sense, we cannot fail to evoke the words of Puig Cuyàs (1953), an unavoidable figure in the context of contemporary jewellery: “I like to consider myself to be that craftsman that Walter Gropius dreamed of when he said that the artist is a craftsman who, during rare moments of clarity, transcends his will and art flourishes unconsciously out of his hands. (...) Making jewellery is an adventure which times transforms the world of uncertainty in which I make my works into a world of certainties which, no matter how provisional pose new questions and keep up the tension and energy of artistic evolution [14].

## References

1. Nygaard, G., Winther, J.: Makers move: jewellery as a medium of exchange. *J. Jewel. Res.* **01**, 67–77 (2018). <http://www.journalofjewelleryresearch.org/current-volume/>
2. Wright, F.L.: In the cause of architecture. *Archit. Rec.* **23**, 155–221 (1908)
3. Cappellieri, A.: Brilliant! I futuri del gioiello italiano. In: XXI Esposizione Internazionale della Triennale di Milano. Corraini Edizioni, Mantova (2016)
4. Lee, S.: Fashioning the Future. Thames & Hudson, London (2005)
5. Cappellieri, A.: Twentieth-Century Jewellery: From Art Nouveau to Contemporary Design in Europe and the United States. Skira Editore S.p.A, Italy (2010)
6. Rodchenko, A.: Line. In: Alexander Rodchenko. Museum of Modern Art, Oxford (1979)
7. Braun, E.: Meyerhold on Theatre. Methuen, London (1988)
8. Cappellieri, A.: Twentieth-Century Jewellery: From Art Nouveau to Contemporary Design in Europe and the United States. Skira Editore S.p.A, Italy (2010)
9. Liu, M.: Jewelry, matching just isn’t cool any more. *New York Times* 1–5 (2017). <https://www.nytimes.com/2017/11/22/fashion/jewelry-assymetrical-earrings.html>
10. Laver, J.: A roupa e a moda: Uma História concisa. Trad. Glória Maria de Mello Carvalho, 4th edn. Companhia das Letras, São Paulo (1999)
11. Silva, A.: Esquismo versus Novas Tecnologias. *Convergências – Revista de Investigação e Ensino das Artes*, vol. XI, no. 21 (2018). <http://convergencias.esart.ipcb.pt/?p=article&id=311>
12. Vicente, J., Frazão, R., Silva, F.: The Evolution of Design with Concerns on Sustainability. *Convergências – Revista de Investigação e Ensino das Artes*, vol. V, no. 19 (2012). <http://convergencias.esart.ipcb.pt/?p=article&id=124>
13. Pevsner, N.: *Pioneers of Modern Design: From William Morris to Walter Gropius*, p. 1991. Penguin Books, London (1936)
14. Puig Cuyàs, R.: Maestros de la Joyería contemporánea, pp. 154–155. Promopress, Barcelona (2014)



# Service Mapping: Case Study of University Waste Management System

Flávia Azevedo<sup>(✉)</sup> and Luciana Cruz

Fluminense Federal University - UFF, Passo da Pátria Street 153,  
Niterói 22471-210, Brazil  
flaviamaxma@id.uff.br

**Abstract.** This paper has the premise of understanding the people's relationship with the waste generated in a public university in Rio de Janeiro, Brazil. In a place designed to be the locus of knowledge construction, the proper waste management issue is still neglected. This research with the exploratory character has the goal of understanding the reason for such a situation, identifying the main agents and mapping the system in order to further reframe it. Through a holistic approach, service design methods and ergonomics were integrated. Ergonomics and its ethnographic methods and tools regarding service design contributed to accurately mapping the current system, giving a basis to plan its reconfiguration with its stakeholders.

**Keywords:** Service design · PSS · Ergonomics · Methodology · Recycling · Waste management

## 1 Introduction

It is widely known that society's current lifestyle generates too much waste. According to the Brazilian Institute of Geography and Statistics [1], in 2008, the total of 259.547 tons of solid waste were collected per day in Brazil. From this amount, 32% of material is recyclable [2] and therefore, could be reinserted in the production chain. On a global perspective, the global municipal solid waste generation levels reached to an amount of 74 kg per person per day with an expectation of 70% increase from 2016 to 2050 [3].

The National Policy on Solid Waste (n°12.305/2010) determines the shared responsibility between industries, society and government for proper destination of solid waste. However, there is considerable lack of application of such responsibility. In 2016, the Panorama of Solid Waste in Brazil shows that 59,7% of municipality destine their waste to inadequate places [4].

Considering that every university should be the repository of knowledge and innovation development [5] restructuring the waste handling system within the university is a significant issue.

In order to go through the current waste management system, focal points in the university campus were chosen for the design development process. These points consist of four cafeterias, which are the places most –mainly recyclable- waste is generated. Since the waste is managed by each cafeteria's preferred manner, the waste collection varies in some aspects, but all places share in the fact that there is no

environmentally-oriented way of managing their waste. Due to the fact it's an area of high concentration of produced waste, the outcomes of the project would be beneficial, and the process, worthwhile.

The project conducted has the goal of mapping the waste management system existent in the university campus through ergonomics methods and reframe it through service design approach in order to provide applicability for shared waste responsibility between the students, university's staff, and the local waste management company. This paper is mainly exploratory, aimed at demonstrating the merging of ergonomics methods to service design process towards the implementation of a selective collection system.

## **2 Methodology**

### **2.1 Product-Service-System (PSS)**

A PSS is defined by "a mix of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling final customer needs" [6]. This shift from a perspective focused on goods to a systems focus that will lead to a desired, common end [7, 8] is particularly clear in the waste management process. It is composed by different actors from varied environments combined in relationships on a superficial level that, through service design, it is possible to understand it, and reshape it.

The PSS referenced in this paper concerns the waste management system within the Praia Vermelha campus and the application of service design methods was mainly used for building understanding of the system within and outside the campus as well as for co-creating proposals for the system reconfiguration.

### **2.2 Ergonomics in PSS**

Services are 'situated actions' [9]; this means they are affected not only by people's behavior, but by the user's sociocultural and organizational contexts [10]. Therefore, ergonomics discipline as the basis of the empathy process of design has a significant relevance.

Understanding human properties in a holistic way as ergonomics approach is likely to, is considerably more relevant in designing services than the traditional design focus on products. This is mainly due to the PSS' specific characteristics of inseparability and heterogeneity. Considering inseparability as the requirement of the customer's presence for the production of services and heterogeneity as the dependence on the situation and service participants [11], ergonomics has a central role in grasping the sociocultural and organizational contexts as well as the "user's properties, individual's motives, experiences, wishes" and so forth [12]. Therefore, ergonomics is an especially efficient approach to design something as reliant on human behavior as services.

The development process is divided in the understanding phase, where we seek to map the current system’s functioning and people’s perception and behavior towards it. The second phase, concerns the service’s reconfiguration co-created by the previous’ stage conclusions.

### 3 Mapping

Since service design specially requires a perspective on the entire system instead of isolated problems, each user played a critical role in building a whole setting of the current system. And once there was a gap from agent to agent within the service as to knowledge on how waste is handled, the mapping also made possible for each user to understand the service as it was to discuss its further development.

A Table 1 was made representing the mapping process according to user and its contribution to the development.

**Table 1.** Methods in mapping process.

User	Method	Conclusion
Cafeterias	Interviews Assistematic observations	<ul style="list-style-type: none"> <li>• Task analysis</li> <li>• Destination of waste within the university</li> <li>• Amount and quality of waste generated</li> </ul>
Waste management Company	Interviews Blueprint Virtual prototyping	<ul style="list-style-type: none"> <li>• The waste trajectory outside the campus</li> <li>• Requirements for selective collection</li> <li>• Discussion of current system</li> <li>• Co-creation by discussing different possibilities</li> </ul>
Student’s employees	Interviews Questionnaire Assistematic observations	<ul style="list-style-type: none"> <li>• People’s mindset and behavior towards waste generation and management</li> <li>• Requirements for proper functioning</li> </ul>

#### 3.1 Current System

The waste management system consists of four cafeterias within the campus that produce waste, all destined to a single waste storage container at the ground-floor. Of all places, one was engaged in separating aluminium and – within inconsistent periods-destine it to a local recycling company. After having understood the role of each user in the process related to waste generation and disposal, in and outside the campus, a service map was made presenting the touchpoints throughout the process, from waste generation to final destination.

The waste produced in these focal points are put on a common waste bin and further taken to a collective waste storage on the ground floor. This is made by the cafeteria staff itself and its frequency of this action goes from 2 to 5 times a day. After it is placed there, the company waste management company is entitled to collect the garbage and destine it to a waste treatment center that, in fact, does not deal with recyclable materials, but provides a controlled management of the existent waste (Fig. 1).



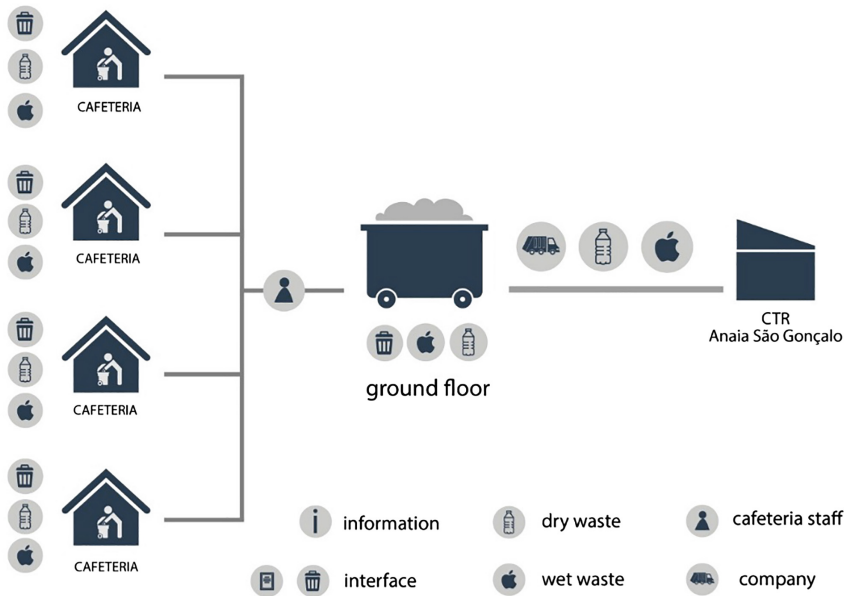


Fig. 1. Service map of the current system

### 3.2 Problems Identified

Through the phase of understanding the specific local context, the users and interactions within, choices of improvements could be designed. Relying on general ethnographic data would likely lead to proposals not suitable enough for something as reliant on local context as services. Therefore, Ergonomics methods such as interviews, questionnaires, observations were tools used for defining each user's role in the system and grasping their needs and impressions on the service.

#### Local Waste Management Company

As to the local waste management company, a blueprint was used as a main tool for discussing the current system and rethinking different service settings. It was observed that its main obstacle regarding the implementation of waste system regarding recycling was the university's people compliance to the separation requirements. Added to this, the company's lack of transport options and need for more recycling material were motivating factors for the implementation of the selective collection on the campus, as well as its cooperation through the process.

#### University Students and Staff

Regarding the students' and university's employees, a questionnaire was made. It has 87 answers, consisted of 93,1% from students or employees at the university, from 32 different courses and the majority of users (92%) were from the ages between 18 to 28 years old. The form of its application was chosen to be online, reaching for larger qualitative data. Being online, we were able to have larger amount of data than from



personal interviews and longer answers than surveys due to reasons of the user's current comfort state that the virtual often provides.

The goal of this questionnaire was to understand students' and employees' relationship with the current waste management system and waste in general. A virtual response analysis was made using color codes to classify certain answers, causing a clearer analysis and discussion.

The questions covered issues such as if the person separates his/her waste at home, why (if not) and how (if yes); if there are recycling waste bins at the campus they study; if they believe if the waste management system functions properly and why; if they know what happens to the waste generated within the university campus.

The answers related to justification for the referred behavior of not preforming any collective separation were classified in three criteria:

- **Intrinsic:** answers concerning personal motivation.
- **Extrinsic:** referring to the environment's infrastructure.
- **Mixed:** answers concerning the combination of extrinsic and intrinsic reasons.

As to the issue of lack of reliability in the current system, the main factors raised by people that are responsible for its apparent inefficiency are:

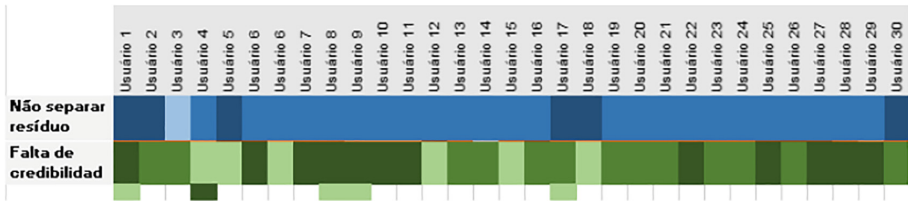
- Individuals
- Agents responsible for the waste service handling (e.g. waste management companies).
- Infrastructure (e.g. lack of proper place for it).

A color was stipulated for each criteria and the answers considered worth for further qualitative analysis were the ones concerning the reason for the people's disbelief on the current system as well as why they don't make the proper waste separation (Figs. 2 and 3). The Table 2 below demonstrates the correlation between criteria, color and type of answers using examples from the actual questionnaire.

None collective separation		Lack of confiability	
Intrinsic		Individuals	
Extrinsic		Responsables for management	
Mixed		Infrastructure	

Fig. 2. Colors subtitle for analyses

Most part of the reasons for not preforming waste separation is contained in the category of extrinsic reason. This means that this behavior is often impaired by the lack of right conditions, such as space, inexistence of proper waste bins and, specially, by the fact that the agents that will handle the waste after it's generated often mix the recyclable with the non-recyclable waste.



**Fig. 3.** First 30 answers analyzed in color code

**Table 2.** Correlation between criteria, color and type

Falta de separação de resíduo	
<i>Classification</i>	<i>Answer samples</i>
Intrinsic reasons	<ul style="list-style-type: none"> <li>• “Too much work”</li> <li>• “I don’t have this habit”</li> </ul>
Extrinsic reasons	<ul style="list-style-type: none"> <li>• “Because I live in a slum and the waste is mixed and there is nowhere to separate it”</li> </ul>
Intrinsic + extrinsic	<ul style="list-style-type: none"> <li>• “Lack of time and recipients proper for sorting”</li> </ul>
Lack of credibility in the system	
<i>Classification</i>	<i>Answer samples</i>
Individuals	<ul style="list-style-type: none"> <li>• “People don’t respect the materials that must go to each waste bin part and the cleaning staff often mix all together in one bag that is later disposed”</li> </ul>
Agents responsible for the waste service handling	<ul style="list-style-type: none"> <li>• “There is no transparency as to where things go”</li> </ul>
Infrastructure	<ul style="list-style-type: none"> <li>• “Some waste bins have no indication of the kinds of material there should be”</li> </ul>

As to the lack of reliability in the current system, the motives raised were mainly the lack of transparency over what happens to the waste after it is produced. This is a specially demotivating factor once there were many reports stating the behavior of further agents (e.g. cleaning staff) in the process would mix the types of waste formerly separated on a single bag. Issues such as lack of people’s habit and knowledge on waste sorting were also mentioned.

As to the whole questionnaire data conclusions, other problems were raised such as lack of a general culture amongst people of waste sorting, the majority of waste bins don’t have sorting option and 96,6% of people that answered the questionnaire didn’t know the waste trajectory after it is generated at the campus.

### Cafeterias

Lastly, most cafeterias were not actively involved in any kind of significant environmentally friendly waste management process. There was little expectation on an environmentally aimed approach towards management of the produced waste and since there was a perceived demotivation in cooperation, the cost of compliance should not be greater than the benefits warning (Wogalter et al. 1987 [13]; 1989 [15]).

## 4 Co-created Action Plan

After the mapping stage we were able to grasp the actual system's logic, identifying the touchpoints. This information was especially useful for co-creating the service's new configuration with the local waste management company.

It was discovered that the main problem was the gap between waste generation and collection with the final steps of waste's treatment and final disposal. The little transparency, and lack of actual cooperation between different stakeholders involved in the process impaired any kind of waste sorting from each actor, solidifying the disbelief on people's attitudes. Added to this, the behavior non-compliance with selective collection system relied mainly on lack of external apparatus and distrust on agents in charge of the waste management.

Therefore, the solution reached as an outcome of this process is constituted in a service aimed at building trust between the actors involved and feasibility for the adoption of the service's reconfiguration.

### 4.1 System's Reconfiguration

The waste management system was built by the help of visualization methods such as blueprint, service maps and virtual prototyping for proper understanding of it by the design team, as well as by the users within the system. After the previous service map was showed and discussed, another was sketched with the company waste management responsible for the collection of the campus' recyclable waste as part of a co-creation process.

The reconfiguration of the service consists of separating the recyclable material from the general waste container and by coupling modular and low-cost waste bins for the separating of materials before they reach the final waste destination within the university. The waste management company, in this scenario, is destined the recyclable waste to cooperatives of recyclable material. The system's tangible and intangible factors are demonstrated in the service map below (Fig. 4).

In order for this setting to work, it had to contemplate the factors pointed as the main hurdles for people to engage in waste sorting attitudes such as mistrust in the waste management system and lack of motivation from cafeteria staff to engage in such actions by enabling bigger feasibility.

### 4.2 Building Trust

According to the framework for the stages of information processing to consequently produce behavior Wogalter et al. [13] developed, if a warning's content is not aligned with the individual's personal belief, they must be persuasive enough to overlap pre-existing mindset (Fig. 5). Therefore, once there is significant unreliability issues from students' and university's staff regarding the current waste system due to the lack of proper functioning, an informational content was made to tackle this. It contains information selected along with the waste management staff, reassuring its accuracy.

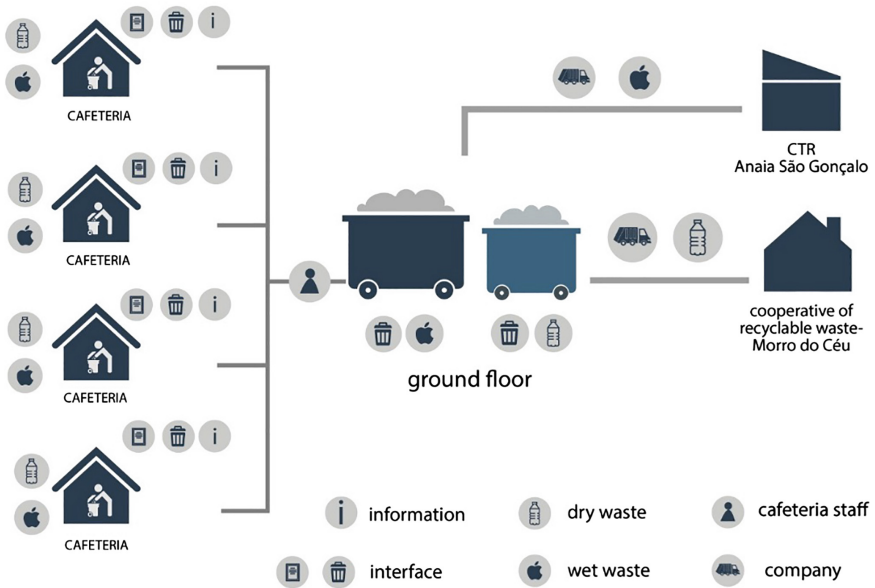


Fig. 4. System reconfiguration



Fig. 5. Information regarding types of recyclable, organic and non-recyclable waste (left); the trajectory of the collected waste (right)

### 4.3 Feasibility

The waste bins with separated spaces were the physical factor as a starting point for waste sorting, being a physical touchpoint to build trust and feasibility within the service (Fig. 6). Familiarity provides the belief that the product or situation is known (Wogalter et al. 1991 [16]). This belief then leads to an “overconfidence that reduces the likelihood that a person will seek additional information” (Wogalter et al. 1991 [16]). Therefore, the recycling bins added and the intervention on the existent bin used different colors from the current system in order to provide more attention to it.



**Fig. 6.** Virtual prototype of physical touchpoints: waste sorting bins.

## 5 Discussion

When regarding waste generation system, it was discovered that the non-existence of any type of waste sorting was mainly due to an overall distrust in other people's actions in managing waste in all phases of its trajectory (from generation to disposal). And although the majority of students and university staff had little or no knowledge of the destination of the waste produced, most shared the belief it wouldn't be to an appropriate place. The small amount of waste bins for waste sorting and information on how to preform proper separation were also pointed as a hurdle for proper selective collection adoption.

During the process, although benefiting from a waste sorting initiative in the university campus, the waste management company hadn't had past cooperation because of non-compliance with requirements for the collection of waste to properly occur. The cafeterias, on the other hand, do not have an environmentally responsible mindset towards the waste generated and it was inferred that this is mainly due to the fact that the cost of behavior adoption larger than its benefits.

These results highlight the need for a proposal that would both enhance the credibility of the waste service within and outside the university (tackled by waste trajectory information) as well as facilitate the compliance of waste sorting in the university's focal points of waste generation.

The questionnaire was provided through online environment, making the type of user sample stricter and since this is a preliminary study on the implementing of waste sorting, its further development consists prototypes application with one of the cafeterias in order to evaluate its efficiency. Furthermore, the goal of the project is to conduct broader action plans for environmental education as to enhance a sustainable culture within the academia environment.

## 6 Conclusion

This study's purpose was to both analyze the current waste management situation and how people relate to it as well as proposing different configurations. Approaching an issue with as much disbelief as waste sorting system in the current context, design had the role of proposing solutions for the restauration of both the system's functioning as well as its credibility.

Ergonomics discipline was mainly used to collect data from different users within the system as well as to understand the local context. Additionally, it showcases the application of service design tools as way for enhancing visualization of current and future service settings, and as a tool for gathering and mapping the system from the ergonomics data previously collected. Through this, design is able to translate systems apparently distant and complex as waste management to people in order to discuss and develop it.

The final proposed PSS is the result of Ergonomics methods and was co-created deriving from the dialog between the users and the design team through service design tools enabling clearer system's visualization. Further testing and prototypes are needed to be tested with all stakeholder, with possible consequential changes in order to implement the service in the whole campus for its complete efficiency.

## References

1. IBGE: Pesquisa Nacional de Saneamento Básico - Tabela de resultado nº 103. IBGE - Instituto Brasileiro de Geografia e Estatística (2008). [www.ibge.gov.br](http://www.ibge.gov.br). Accessed 04 Dec 2018
2. Calderoni, S.: Os Bilhões Perdidos no Lixo. São Paulo, 4ªed. Humanitas Ed. (2003)
3. The World Bank. <https://www.worldbank.org/en/news/press-release/2018/09/20/global-waste-to-grow-by-70-percent-by-2050-unless-urgent-action-is-taken-world-bank-report>. Accessed 02 Dec 2018
4. Filho, C., Sartini, G., Romero, F., Segantini, O.: Panorama dos resíduos sólidos no Brasil. Abrelpe, São Paulo (2016)
5. Vezzoli, C., Penin, L.: Campus: "lab" and "window" for sustainable design research and education. *Int. J. Sustain. High. Educ.* **7**, 69–80 (2006)
6. Tukker, A., Tischner, U.: Product-services as a research field: past, present and future. Reflections from a decade of research. *J. Cleaner Prod.* **14**, 1552–1556 (2006)
7. Mont, O.: Functional Thinking. The Role of Functional Scales and Product Service Systems for a Functional Based Society. Research report for the Swedish EPA, IIIIEE. Lund: Lund University (2002)
8. Stahel, W.: The Performance Economy. Basingstoke Press, London (2006)
9. Maffei, S., Sangiorgi, D.: From communication design to activity design. In: *Designing Effective Communications: Creating Contexts for Clarity and Meaning*, pp. 83–100. Allworth Press, New York (2006). J. Frascara
10. Klaus, P.G.: Quality epiphenomenon: the conceptual understanding of quality in face-to-face service encounters. In: *The Service Encounter*, Lexington (1985)
11. Meroni, A., Sangiorgi, D.: *Design for Services*. Gower Publishing, Ltd., Aldershot (2011)
12. Osborne, D.J.: *Ergonomics at Work*, 3rd edn, 442 p. Wiley, London (1995)

13. Wogalter, M.S., Godfrey, S.S., Fontenelle, G.A., Desaulniers, D.R., Rothstein, P.R., Laughery, K.R.: Effectiveness of warnings. *Hum. Factors* **29**, 599–612 (1987)
14. Wogalter, M.S., Dingus, J.A.: Methodological techniques for evaluating behavioral intentions and compliance. In: Wogalter, M.S., DeJoy, D.M., Laughery, K.R. (eds.) *Warnings and Risk Communication*, pp. 53–82. Taylor and Francis, London (1999)
15. Wogalter, M.S., Allison, S.T., McKenna, N.A.: The effects of cost and social influence on warning compliance. *Hum. Factors* **31**, 133–140 (1989)
16. Wogalter, M.S., Brelsford, J.W., Desaulniers, D.R., Laughery, K.R.: Consumer product warnings: the role of hazard perception. *J. Saf. Res.* **22**, 71–82 (1991)



# Current Theoretical Developments and Applications of Fitts' Law: A Literature Review

Rong Jiang and Zhenyu Gu<sup>(✉)</sup>

Department of Industrial Design, School of Design,  
Shanghai Jiao Tong University, Shanghai 200240, China  
{jiangrong1994, zygu}@sjtu.edu.cn

**Abstract.** Fitts' law is a performance model of human movement especially the act of pointing which is widely used in Ergonomics and Human-Computer Interaction. The aim of this review is to provide an overview of the discussions and extensions of Fitts' law as well as the relevant applications in recent years (2013–2018). The present paper shows that the related discussions mainly focus on the theoretical basis and performance of Fitts' law. In addition, several new predictive models are proposed to improve accuracy or extend the law to three-dimensional space. The applications apply Fitts' law into different input methods and user populations to explore the feasibility of it in specific conditions. The review shows that despite the theoretical and practical development about this topic, differences of views still remain and further research is needed.

**Keywords:** Fitts' law · Human-Computer Interaction · Ergonomics · Development

## 1 Introduction

Fitts' law is the most studied and a widely used performance model in the area of Ergonomics and Human-Computer Interaction (HCI). In the 1940s, information science became a new subject, and then a group of informatics theories came into the view of experimental psychologists. In 1954, Dr. Paul M. Fitts proposed Fitts' law, inspired by Shannon's *theorem 17* in informatics [1].

Fitts' law shows the linear relationship between movement time (MT) and index of difficulty (ID):

$$MT = a + b \times ID \quad (1)$$

where  $a$  and  $b$  are empirical constants. Here, ID is a function of the movement amplitude (A, i.e. the distance between the starting place and the center of the target) and the target size or width (W) [2]. Fitts' law could be used in prediction and measurement. For predicting, the time to move to a target can be given based on A and W. For measuring, using throughput (TP), the ratio of ID to MT, human performance can be quantified by Fitts' law, where TP is independent of A and W [2]. The widely used extensions and revisions of Fitts' law before 2013 are shown in Table 1 [3–6].



They mainly focused on 1-D and 2-D pointing tasks and the size of the target were taken into consideration.

**Table 1.** The extensions and revisions of Fitts' law before 2013 [3–6].

No	Year	Author(s)	Equation(s) of model	Remarks
1	1954	Fitts	$MT = a + b \log_2 \left( \frac{2A}{W} \right)$	Original model
2	1968	Welford	$MT = a + b \log_2 \left( \frac{A}{W} + 0.5 \right)$	\
3	1988	Meyer et al.	$MT = a + b \sqrt{\frac{A}{W}}$	Square-root model
4	1992	MacKenzie	$MT = a + b \log_2 \left( \frac{A}{W_e} + 1 \right)$	ID > 0, $W_e$ : effective width

In recent years, with the continuous development of interactive technology and the deepening of research, a batch of new studies have led to further development of Fitts' law. In order to further explore the relevant theories and applications, it is necessary to sort out recent studies. This paper is aiming at summarizing the discussions and extensions of Fitts' law, and also the relevant applications in recent years (2013–2018) to obtain a more complete understanding of the topic.

## 2 Methods

In four databases (Elsevier, Scopus, Springer and Google Scholar) article search was conducted. The key words “Fitts' law” and “Fitts' task” were used for searching. Titles, abstracts and the contents of papers were selected by the author. Papers are selected according to the following criteria: published between 2013 and 2018; original research published in English; experimental, qualitative, quantitative or multiple research methods were used; and research aimed at discussing and extending Fitts' law or applying Fitts' law into practice. Based on the criteria, a total of 28 papers were chosen and reviewed.

## 3 Results and Discussion

### 3.1 The Discussion of Fitts' Law

Several studies compared models shown in Table 1 about their theoretical basis and performance. In 2013, Hoffmann [7] discussed the theoretical basis of Model 1, 2 and 4 shown in Table 1. He argued that the equation originally proposed by Fitts et al. in 1954 [3] and the model proposed by Welford [4] had theoretical bases. However, the theoretical basis of the model proposed by McKenzie [6] was questionable according to the information theory. In addition, he indicated that it was the effective target width  $W_e$  adopted by McKenzie, rather than the +1 in the equation, played a major role in improving the fitting effect. Goldberg et al. [8] compared the performance of Model 1, 3 and 4 in Table 1 based on two very large databases including 94,580 measurements.

The results showed that the square-root model proposed by Meyer et al. [5] was more suitable for fixed  $W$  and  $A$  targets except the most difficult target (with large  $A/W$ ). As for targets with varying  $W$  and  $A$ , Meyer's model, Fitts' model and MacKenzie's model had better performances for easy (with small  $A/W$ ), medium (with medium  $A/W$ ) and difficult targets respectively.

In addition, some studies tried to develop Fitts' law further. Wang and Ravani developed a control theoretic alternative to Fitts' law according to a modified crossover model [9]. Zhang et al. proposed that not only did  $W$  and  $A$  have to do with the efficiency of finger motion, but direction also had to do with it [10]. Tang et al. proposed that the performance of the previous trial had a predictable effect on the next trial when Fitts' law was used in measuring [11]. Bertuccio et al. tested the relationship between MT and ID at the level of movement planning, aiming at the quick pointing behavior. The results showed that, due to the difference of moving parts, the change of  $A$  may lead to the change of the relationship between MT and ID [12].

There were also a few articles that have argued against the previous researches on Fitts' law. Two studies argued that for MT, the minimum movement time, except for the average movement time, should be considered [13, 14]. Another study showed that because of more efficient online control processes, the MTs to the last target in an array were shorter than the prediction with Fitts' law [15]. In addition, an article suggested that for periodic impact tasks, Fitts' law may not be applicable [16].

### 3.2 The Extensions of Fitts' Law

Table 2 showed the extensions and revisions of Fitts' law between 2013 and 2018. Five models were reviewed which extended Fitts' law to finger touch input system, 3-D environment and multiple joints movements. Details were described below.

**Table 2.** The extensions and revisions of Fitts' law between 2013 and 2018 [16–20].

No	Year	Author(s)	Equation(s) of model	Remarks
1	2013	Xiaojun Bi et al.	$MT = a + b \log_2 \left( \frac{A}{\sqrt{2\pi e(\sigma^2 - \sigma_a^2)}} + 1 \right)$	Finger touch input
2	2013	Cha, Myung	$MT = a + b\theta_1 + c \sin \theta_2 + d \log_2 \left( \frac{2A}{W+F} \right)$	3-D tasks
3	2018	Murata, Fukunaga	$MT = a + b \log_2 \left( \alpha \beta \left( \frac{A}{W} \right) + 1 \right)$	3-D tasks, eye-gaze input system
4	2015	Gupta, Dantu, Nana	$MT_i = a + b \lambda_i \alpha_{atomic} \log_2 \left( \frac{A}{W} + 1 \right)$	Multiple joints, for $i$ th joint
5	2016	Gupta, Dantu	$MT = a + b \sum_{i=1}^n \beta_i \lambda_i \alpha_{atomic} \log_2 \left( \frac{A_i}{W_i} + 1 \right)$	Multiple joints, for entire movement

Specifically, in 2013, Bi et al. [17] proposed a FFitts (Fitts' law for finger touch input) model for finger touch screen operation based on the dual-distribution hypothesis (Model 1 in Table 2) where  $\sigma$  reflects the standard deviation of the touch points, and  $\sigma_a$

was the absolute precision of the input finger. Three groups of 1-D and 2-D experiments done by the authors showed that FFitts law was more accurate in modeling finger input on touch screens.

Two studies tried to extend Fitts' law into 3-D environments. One was proposed by Cha and Myung [18] (Model 2 in Table 2). In this model,  $\theta_1$  was the inclination angle, and  $\theta_2$  was the azimuth angle,  $F$  was the size of a multi-finger trackpad and  $a$ ,  $b$ ,  $c$  and  $d$  were empirical constants. According to empirical data, the fitting effect of this model on 3-D touch tasks was better than that of previous models. Model 3 in Table 2 was proposed by Murata and Fukunaga [19] focusing on eye-gaze input system. Here,  $\alpha$  was the compensation coefficient ( $\alpha = \sqrt{W/H}$ ), and  $\beta$  was the ratio of the slope to that of the right movement direction. The results indicated that the model could fit experimental data well and predict the pointing time of various HCI tasks more effectively.

In 2015, Gupta, Dantu and Nana [20] extended Fitts' law to model movement by multiple body joints (Model 4 in Table 2). To do so, they introduced the concept of atomic movement as the movement of the fastest joint. In the equation,  $\alpha_{atomic}$  was the coefficient of the atomic joint, and  $\lambda_i$  was the ratio of atomic movement between the atomic joint and the  $i$ th joint. One year later, Gupta and Dantu [21] further proposed a model for the entire multi-joint motion (Model 5 in Table 2) where  $\beta_i$  was a factor that took into account the multiple motions required to finish a task. The experimental results showed that Fitts' law could actually be effectively extended to multiple joints.

### 3.3 The Applications of Fitts' Law

A lot of applications apply Fitts' law into different input methods and user populations to explore the applicability of it in specific conditions and evaluate the performances of different devices. Comparisons of existing approaches, exploration of new input devices and care for people with disabilities were hot topics.

Between 2013 and 2018, six studies compared the performances of different input methods including mouse, touch screen, gesture, trackpad, gaze, head point, and thumbstick based on Fitts' law [22–27]. Table 3 showed the comparisons of the TPs of those input devices. It could be found from the table that touch screen had the highest performance, followed by mouse. However, those newer input methods generally performed poorly. This is perhaps why the mouse and touch screen were the most popular input devices. In addition, although participants generally performed better with the touch screen than with the mouse, the error rate was significantly lower with the mouse based on the results of Burno et al. [25], as well as Sambrookes and Wilkinson [26].

It's worth noting that Ramcharitar and Teather's results [22] differed from those of other authors as to which worked better, the mouse or the touch screen. Their experiment showed that the TPs of mouse and touch screen were 4.73 bps and 2.98 bps respectively. It seemed that, with mouse, the performances of the users were significantly better than those with touch screen while other studies have shown the opposite results. This suggests that more research is needed to confirm the results.

**Table 3.** The comparisons of the TPs of mouse, touch screen, gesture, trackpad, gaze, head point, and thumbstick between 2013 and 2018 [22–27].

No	Author(s)	Mouse	Touch screen	Gesture	Trackpad	Gaze	Head point	Thumbstick	Task type
1	Ramcharitar, Teather	High	Middle	Middle	/	/	/	Low	Standard 2-D
2	Hansen et al.	High	/	/	/	Low	Middle	/	Standard 2-D
3	Rybanov, Tretyakova	Middle	High	/	Low	/	/	/	Customized
4	Burno et al.	Middle	High	Low	/	/	/	/	Customized
5	Sambrooks, Wilkinson	Middle	High	Low	/	/	/	/	Standard 2-D
6	MacKenzie	Low	High	/	/	/	/	/	Standard 1-D, 2-D

Several studies used Fitts' law to test the performance of new input devices. Morelli and Ripke [28] proposed an alternative input method for mobile devices, back-pointer, where the back-facing camera captured the motion of index finger. Based on Fitts' law analysis, the experimental results indicated that the performance of this input method was acceptable only if users could see the gestures on the screen. Burstyn et al. [29] tested the performance of flexible display interactions and the results showed that bend input was shown to conform to Fitts' law. Another study researched a head-tracking interface motivated by the front camera of mobile devices [30]. According to the experiments, head-tracking was correlated with Fitts' law.

Finally, some studies analyzed Fitts' law for special populations. Two studies evaluated the applicability of Fitts' law to input devices that provide haptic feedback in non-visual environments for blind users [31, 32]. Their results all showed that Fitts' law could be effectively applied for the visually impaired using an input device with haptic feedback, such as a vibrating touch screen. In 2017, Velasco et al.'s experiments based on Fitts' law explored the effectiveness of a head-worn inertial interaction for cerebral palsy (CP) users and the results of which showed that there was a weak correlation between movement and Fitts' law for dystonic CP patients, and there was no correlation for dyskinetic CP patients [33]. Besides, using a Fitts' task, the lower limb movement performances of the participants with and without lumbar spinal stenosis (LSS) were tested [34]. The results indicated that Fitts's Law was applicable, and, with increasing task difficulty, LSS participants' movements were more adversely impacted.

## 4 Conclusion

In general, this paper reviewed 28 articles related to Fitts' law in recent 6 years (2013–2018). Some studies compared previous models about the theoretical basis and performance to screen out better models when a few studies tried to develop Fitts' law further or argued against the previous researches on Fitts' law to understand it more deeply. Besides, five studies extended Fitts' law to finger touch input system, 3-D

environment and multiple joints movements. Finally, a lot of applications apply Fitts' law into different input methods and user populations to explore the applicability of it in specific conditions and evaluate the performances of different devices. It is worth mentioning that there is still a big gap between the performance of the emerging interactive technologies and the traditional mouse and touch screen. One thing to be aware of is that there is no consensus on a number of Fitts' law related issues and points of view, both in theory and in practice which means further research is needed.

## References

1. MacKenzie, I.S.: Fitts' law. In: *The Wiley Handbook of Human Computer Interaction*, vol. 1, pp. 347–370. Wiley, Singapore (2018)
2. Ljubic, S., Glavinic, V., Kukec M: Finger-based pointing performance on mobile touchscreen devices: fitts' law fits. In: *UAHCI 2015, Part I, LNCS 9175*, pp. 318–329, Springer, Cham (2015)
3. Fitts, P.M.: The information capacity of the human motor system in controlling the amplitude of movement. *J. Exp. Psychol.* **47**(6), 381–391 (1954)
4. Welford, A.T.: *Fundamentals of Skill*. Methuen, London (1968)
5. Meyer, D., Abrams, R., Kornblum, S., Wright, C., Keith, S.J.: Optimality in human motor performance: ideal control of rapid aimed movements. *J. Psychol. Rev.* **95**(3), 340–370 (1988)
6. MacKenzie, I.S.: Fitts' law as a research and design tool in human-computer interaction. *Int. J. Hum. Comput. Interact.* **7**(1), 91–139 (1992)
7. Hoffmann, E.R.: Which version/variation of fitts' law? A critique of information-theory models. *J. Motor Behav.* **45**(3), 205–215 (2013)
8. Goldberg, K., Faridani, S., Alterovitz, R.: Two large open-access datasets for fitts' law of human motion and a succinct derivation of the square-root variant. *IEEE Trans. Hum.-Mach. Syst.* **45**(1), 62–73 (2017)
9. Wang, C., Ravani, B.: Development of a control theoretic alternative to fitts' law with application to in-vehicle touchscreen interface. In: *ASME 2015 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. American Society of Mechanical Engineers, pp. V009T07A004–V009T07A004. ASME, New York (2015)
10. Zhang, C., Li, X., Gao, F., Zhou, F., Xu, L.: An experimental research on the directivity of fitts' law in human-computer interaction. In: *IEEE International Conference on Progress in Informatics & Computing*. IEEE Press, New York (2016)
11. Tang, R., Shen, B., Sang, Z., Song, A., Goodale, M.A.: Fitts' law is modulated by movement history. *J. Psychon. Bull. Rev.* **25**, 1833–1839 (2017)
12. Bertucco, M., Cesari, P., Latash, M.L.: Fitts' law in early postural adjustments. *J. Neurosci.* **231**, 61–69 (2013)
13. Gori J., Rioul O., Guiard Y., Beaudouin-Lafon, M.: One fitts' law, two metrics. In: *INTERACT 2017, LNCS, vol. 10515*. Springer, Cham (2017)
14. Gori, J., Rioul, O., Guiard, Y.: Speed-accuracy tradeoff: a formal information-theoretic transmission scheme (FITTS). *J. ACM Trans. Comput.-Hum. Interact.* **25**(5), 33 (2018)
15. Glazebrook, C.M., Kiernan, D., Welsh, T.N., Tremblay, L.: How one breaks fitts's law and gets away with it: moving further and faster involves more efficient online control. *J. Hum. Mov. Sci.* **39**, 163–176 (2015)

16. Petric, T., Simpson, C.S., Ude, A., Ijspeert, A.J.: Hammering does not fit fitts' law. *J. Front. Comput. Neurosci.* **11**, 45 (2017)
17. Bi, X., Li, Y., Zhai, S.: FFitts law: modeling finger touch with fitts' law. In: *Sigchi Conference on Human Factors in Computing Systems*, ACM, pp. 1363–1372. ACM, New York (2013)
18. Cha, Y., Myung, R.: Extended fitts' law for 3D pointing tasks using 3D target arrangements. *Int. J. Ind. Ergonomics* **43**(4), 350–355 (2013)
19. Murata, A., Fukunaga, D.: Extended fitts' model of pointing time in eye-gaze input system - incorporating effects of target shape and movement direction into modeling. *J. Appl. Ergonomics* **68**, 54–60 (2018)
20. Gupta, N.K., Dantu, S., Nana, A.: Relationship between multiple joint movements using fitts law. In: *ICSH. Springer, Cham* (2015)
21. Gupta, N.K., Dantu, S.: Index of difficulty between multiple joint movements using fitts law. In: *2016 IEEE First International Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE)*. IEEE, New York (2016)
22. Ramcharitar, A., Teather, R. J.: A fitts' law evaluation of video game controllers: thumbstick, touchpad and gyrosensor. In: *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, pp. 2860–2866. ACM, New York (2017)
23. Hansen, J.P., Rajanna, V., MacKenzie, I.S., Bækgaard, P.: A fitts' law study of click and dwell interaction by gaze, head and mouse with a head-mounted display. In: *Proceedings of the Workshop on Communication by Gaze Interaction*, p. 7. ACM, New York (2018)
24. Rybanov, A., Tretyakova, V.: Application of fitts's law to the assessment of users' skills of work with computer devices of targeting. *J. Pedagogical and psychological problems of the modern society [L 22]*, pp. 39–47 (2015)
25. Burno, R.A., Wu, B., Doherty, R., Colett, H., Elnaggar, R.: Applying fitts' law to gesture based computer interactions. *J. Procedia Manuf.* **3**, 4342–4349 (2015)
26. Sambrooks, L., Wilkinson, B.: Comparison of gestural, touch, and mouse interaction with fitts' law. In: *Proceedings of the 25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration*, pp. 119–122. ACM, New York (2013)
27. MacKenzie, I.S.: Fitts' throughput and the remarkable case of touch-based target selection. In: *International Conference on Human-Computer Interaction*, pp. 238–249. Springer, Cham (2015)
28. Morelli, T., Ripke, T.: Back-pointer—fitts' law analysis of natural mobile camera based interactions. In: *2015 IEEE Games Entertainment Media Conference (GEM)*, pp. 1–6. IEEE, New York (2015)
29. Burstyn, J., Carrascal, J.P., Vertegaal, R.: Fitts' law and the effects of input mapping and stiffness on flexible display interactions. In: *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pp. 3649–3658. ACM, New York (2016)
30. Roig-Maimó, M.F., MacKenzie, I.S., Manresa-Yee, C., Varona, J.: Head-tracking interfaces on mobile devices: evaluation using fitts' law and a new multi-directional corner task for small displays. *Int. J. Hum.-Comput. Stud.* **112**, 1–15 (2018)
31. Charoenchaimonkon, E., Janecek, P.: Characterizing non-visual target acquisition tasks with the aid of a tactile display: investigating factors beyond the classical fitts' theorem. *Univ. Access Inf. Soc.* **14**(4), 459–475 (2015)
32. Lahib, M.E., Tekli, J., Issa, Y.B.: Evaluating fitts' law on vibrating touch-screen to improve visual data accessibility for blind users. *Int. J. Hum.-Comput. Stud.* **112**, 16–27 (2018)

33. Velasco, M.A., Clemotte, A., Raya, R., Ceres, R., Rocon, E.: Human-computer interaction for users with cerebral palsy based on head orientation. Can cursor's movement be modeled by fitts's law? *Int. J. Hum.-Comput. Stud.* **106**, 1–9 (2017)
34. Passmore, S.R., Johnson, M.G., Kriellaars, D.J., Pelleck, V., Enright, A., Glazebrook, C.M.: Fitts's law using lower extremity movement: performance driven outcomes for degenerative lumbar spinal stenosis. *J. Hum. Mov. Sci.* **44**, 277–286 (2015)



# On Girls Bra Design for the Demand of User

Ding-Bang Luh and Yu-Lin Zhao<sup>(✉)</sup>

School of Art and Design, Guangdong University of Technology,  
Guangzhou 510090, China  
512080653@qq.com

**Abstract.** Good bra design has an important impact on the healthy development of women's chest, especially on the breast health of adolescent girls. This paper selected Guangzhou, Guangdong Province, China for field interviews and questionnaires to collect girls' needs and expectations for bra design. Principal Component Analysis (PCA) was used to select the demand factors that have a greater impact on bra design: chest protection, corrective posture, size standards and pain relief, and the weight ratio of different factors was defined. It is found that protecting the chest and correcting posture are the most important requirements of bra design for adolescent girls. Establishing the size standard of underwear for adolescent girls and alleviating the pain during development are important complements to the optimization strategy, which can provide basic data support for further optimization research of underwear design for adolescent girls.

**Keywords:** Girls bra · Demands of girls · Design analysis · Principal component analysis

## 1 Introduction

With continuous improvement in the quality of life, people pay more intimate attention to the bra. Bra is treated as the second skin of the human body. It is one of the important branches of underwear which have the higher standard of fitness and comfort. So the rationality of bra design is critical. As the subdivision of Chinese underwear market, the girls' undergarment has a huge number of user, so we cannot underestimate the strong demand for the rationality of girls' bra design caused by this phenomenon. Within this industry, girls' underwear looks obviously full of commercial prospects, but there is few focus on researching the user demand of this category. Currently, most of the underwear enterprises focus on the adult female underwear design research and development, even though there is some company to produce girls' underwear which is just according to the size and standard of adult female underwear or with a little difference from adult women underwear on the fabrics and colors. Therefore, in view of this gap in the market, this study probes into the life behavior of girls and their bra design needs, in order to propose a comfortable and effective bra design method that can meet the needs of girls. For this vacancies in the market, this paper mainly discusses from the angles of girls' behavior and the bra design's requirements in order to propose a comfortable and effective design method of bra for adolescent girls.



## 2 Research Status of Girls Bra

Girl bra is a bra specially designed for girls (about 8–18 years old) who have just started breast development and are in the stage of breast development. It is emphasized here that a girl's bra is not the same as a girl's bra. But at first, the so-called girl bra of Chinese underwear enterprises or brands actually belongs to the girl style bra. It only adds the elements of girl style such as pink and bow to the design, and the product itself still belongs to the conventional underwear (just reducing the cup). However, with the deepening of Chinese understanding of underwear, higher requirements have been put forward for girls' underwear. Girls' underwear launched for different developmental stages of girls has officially appeared, and the sales market of girls' underwear has also shown great potential. However, most of the underwear brands on the market are adult underwear brands, and there are few underwear specially developed for girls. Although some brands claim to have girls' underwear series, in fact, they only add pink, bows and other girls' style elements to their appearance design. The product itself is still a regular underwear.

## 3 Research Method

In this study, principal component analysis method is chosen as the research method. It is a statistical method to study the distribution of standard deviation, variance, covariance and covariance matrix of the data obtained from multiple measurements, or to obtain the weight ratio of multiple indicators. Different women encounter different problems during their development, so they have different needs for bra design for girls. Principal Component Analysis (PCA) converts the initial complex factors into relatively independent ones. The purpose of PCA is to screen out the more important and influential demand indicators, and then to design the follow-up according to these indicators.

### 3.1 Extraction of Influencing Factors

Interview is a research method to understand the interviewee's psychology by talking with him. In the process of extracting influencing factors, we can collect relevant opinions by visiting some experts and users. Nilsen believes that in-depth interviews with 10 users can find 85% of the problems. This paper mainly focuses on the design and analysis of women's underwear needs in the development period. Firstly, user interviews should be conducted to determine the influencing factors of girls' underwear design, which is also the preliminary work of questionnaire design steps. Previous surveys before formal interviews revealed that it was difficult for women to establish the impression of wearing the right underwear at the beginning of their development, and it was not until the university that they knew they were wrong to wear the underwear and choose the right way to buy it. Experienced or experienced users are more aware of their needs and can better examine the shortcomings of bra design for girls. Therefore, interviews with women who have experienced adolescent development, reviews their worries during development and expectations of underwear,

and then identifies the interviewees as follows: 10 students aged 18–25, with good physical development and years of underwear wear experience. Women living in Guangzhou.

The interviews are about teenage girls' troubles in their development, problems they encounter and their expectations for bras.

Through actual interviews, 50 girls' worries during development and their needs and expectations for underwear design were obtained. By combining repetitive questions and combing relevant literature, the underwear demand factors affecting underwear design of girls were determined to include four factors (first-level indicators) and 16 influencing factors (second-level indicators) (Table 1).

**Table 1.** Screened requirement factor

First-level indicators	Second-level indicators	Explicate
Constitution design	Light material	Girls have a lot of exercise, so they are prone to sweat. The breathable material can make sweat evaporate quickly
	Shoulder strap	There will be boys playing tricks on girls' shoulder straps
	Cup thickness	Underwear shows different degrees when wearing shirts and sports uniforms
	Easy to wear	It's troublesome to buckle underwear hooks from the back
	Adjust size by self	Chest development is too fast and bras are frequently purchased
Function	Avoid oppression	Avoid oppression because of pain during development
	Sweat absorption	Too much sweating can easily lead to papillitis
	Privacy protection	Development leads to shyness and does not want to appear big-breasted
	Chest protection	Reducing vibration and avoiding impact
	Corrective posture	Develop shy, chest-hunched, hump-backed
Education and guidance	Establishing the right first experience	The first time a girl wears a bra, she can build up the right idea
	First wear tips	Girls don't know when to wear bras when they are just growing up
	Developmental knowledge	For example, breast size problems are normal
	Standard of size	Establishment of a Girl Bra specific size
Technology intelligence	Bras change reminder	Intelligent tips for replacing more appropriate bra
	Relieve pain	Use modern technology to alleviate developing pain

### 3.2 Questionnaire Design

According to the indicators, the indicators are quantified by questionnaire survey. In the process of quantification, we need to use the Likert scale method to determine the specific value, and calculate the average value of the score. Likert scale is a kind of score summation scale. It was proposed by American psychologist Richter in 1932. It mainly matches the attitudes of the investigators to a group of statements by specific values, so as to achieve quantitative results. The survey was made by Level 7 Likert Scale. The survey lasted from Dec. 10 to Dec. 17, 2018. 71 questionnaires were collected online, of which 63 were valid and 25 were offline. Among them, 20 were valid and 83 were all valid questionnaires.

### 3.3 Basic Information of Research Subjects

The subjects were girls aged 8–18 years old, healthy and well-developed. According to the preliminary statistics of questionnaire information, the number of subjects aged 12–15 years old is the largest, and the proportion of people with higher education level in senior high school, vocational high school and above is large, all of them have bra wearing experience.

## 4 Discussion and Analysis

### 4.1 Reliability and Validity of Questionnaires

Questionnaire reliability analysis is an effective method to judge whether the questionnaire evaluation system is stable and reliable. The standard value of reliability test is generally greater than 0.6. In this paper, 83 questionnaires are tested by SPSS statistical software. Cronbach's Alpha coefficient is 0.821, which meets the reliability requirements. For validity, in factor analysis, the variance contribution rate of structural validity of the questionnaire is 53.2%, so it meets the validity requirements.

### 4.2 Weight Ratio Analysis of Bra Demand Factor for Girls

Firstly, comb and count the questionnaire data.

Second, data standardization. Each dimension of the data set of demand factors for girls' bras will be processed, and the average value of each element in the data set will be subtracted from that dimension (data standardization), and the data set of built environment factors with the average value of 0 will be obtained.

Thirdly, the covariance matrix is calculated. The covariance matrix of an N-dimensional array is defined as follows:

$$C^{n*n} = [c_{ij}, c_{ij}, = \text{cov}(Dim_i, Dim_j)] \quad (1)$$

In the formula,  $C^{n*n}$  denotes a matrix of N rows and N columns, and  $Dim_x$  denotes the X dimension.

Fourthly, the eigenvectors of covariance matrix and their corresponding eigenvalues are calculated. It can be found that the covariance matrix is a square matrix. Computing the eigenvectors and their corresponding eigenvalues of the covariance matrix is the core of the principal component analysis method. Lines describing data sets can be extracted by solving eigenvectors of covariance matrix. Secondly, the data of demand factor for bra of adolescent girls are transformed to match the straight line of the obtained feature vector.

Fifthly, the principal components are selected to form feature vectors, i.e. data compression and dimensionality reduction. The eigenvalues of different bra demand factors are different, and the eigenvector corresponding to the largest eigenvalue is the principal component of the data set. Then, the eigenvalues are sorted from large to small, and the demand factors of young girls' bras with smaller components can be ignored. The feature values and information of these dimensions are very few, ignoring part of the components (dimensions), the final dimension of the data set will be less than the original data set, thus completing the important step of building demand factor screening, that is, data dimension reduction.

Sixth, generate new data sets. After determining the principal components and constructing the feature vectors, a new "data set" is formed by using the data combination after dimensionality reduction, that is, the weight ratio that affects the bra design of girls.

### 4.3 Research Results and Analysis of Weights of Factors

#### (1) Analysis of Total Variance

Before analyzing the weight ratio of bra demand factors for girls, the questionnaire was tested by KMO and Bartlett spherical test. Through SPSS statistical software, the KMO value was 0.632, because it was greater than 0.6, which indicated that the questionnaire data was suitable for factor analysis. The significance P value of Bartlett spherical test was 0.000, because it was less than 0.05, which also indicated that the data was suitable for factor analysis. By using factor analysis module and inputting the influencing factors of girls' bra demand, the total variance of the explanation was obtained (Table 2).

**Table 2.** Total variance explained

Component	Initial eigenvalue		
	Eigenvalue	Variance (%)	Cumsum (%)
1	9.167	42.512	42.512
2	2.651	12.231	54.743
3	1.737	9.612	64.355
4	1.342	7.309	71.664
5	1.159	6.400	78.064

In this paper, the variance contribution rates of five principal components with eigenvalues greater than 1 are 42.512%, 12.231%, 9.612%, 7.309% and 6.400%, respectively, and the cumulative variance contribution rates are 78.064%. The eigenvalues are 9.167, 2.651, 1.737, 1.342 and 1.159, respectively, and the factor load matrix is further obtained.

## (2) Factor Weight Analysis

According to the relevant knowledge of mathematical statistics, the transformation matrix of principal component analysis, i.e. principal component load matrix  $U$ , factor load matrix  $A$  and eigenvalue  $\lambda$ , is mathematically related, such as formulas (2):

$$U_i = A_i / \sqrt{\lambda_i} \quad (2)$$

In the formula,  $I$  is the principal component factor of 1–5.

Five principal component factors are introduced into the formula, namely  $U_1 = A_1/\text{SQRT}(9.167)$ ,  $U_2 = A_2/\text{SQRT}(2.651)$ ,  $U_3 = A_3/\text{SQRT}(1.737)$ ,  $U_4 = A_4/\text{SQRT}(1.342)$ ,  $U_5 = A_5/\text{SQRT}(1.159)$  (SQRT is Square Root Calculations, square root calculation), and the load values in the principal component load matrix  $U_4$  are obtained. The variance contribution rates of the five main components in the interpreted total variance diagram are calculated with  $U_1$ – $U_5$ , respectively, and the formulas (3):

$$Y_i = U_{1i} \times G_1 + U_{2i} \times G_2 + U_{3i} \times G_3 + U_{4i} \times G_4 + U_{5i} \times G_5 \quad (3)$$

In the formula,  $Y$  is the linear combination of the original influence factors,  $G$  is the variance contribution rate of the five principal component factors, and  $i$  is the 16 influence factors. The results are shown in Table 3.

**Table 3.** Weight of influence factor

Factor	Weight	Factor	Weight
Light material	0.058	Chest protection	0.076
Shoulder strap	0.059	Corrective posture	0.071
Cup thickness	0.022	Establishing the right first experience	0.047
Easy to wear	0.034	First wear tips	0.050
Adjust size by self	0.061	Developmental knowledge	0.050
Avoid oppression	0.051	Standard of size	0.070
Sweat absorption	0.039	Bras change reminder	0.027
Privacy protection	0.058	Relieve pain	0.066

Through the above research, it was found that the weight of significant bra requirement factors affecting bra design for girls were chest protection (0.076), corrective posture (0.071), size standard (0.070), pain relief (0.066) and self-adjusting size (0.061).

## 5 Conclusion

First, breast protection is the biggest demand factor for bra design for girls. Because teenagers are active and love sports, and their breasts are still developing, they will feel strong pain when they are impacted or collided. In addition, collisions in daily life are inevitable. This is also the most common problem that teenagers often encounter in their development. Therefore, proper pressure should be considered in bra design to protect their breasts from severe shaking and collision and avoid injury. It is harmful to young girls' breasts, which leads to the significant effect of this factor on the design of girls' bras.

Secondly, the effect of corrective posture on bra design of adolescent girls should not be neglected. Because girls feel embarrassed about their fast-growing breasts, they develop the habit of walking with their heads down and wearing tight underwear. Little do you know, wearing small underwear will affect breast development, adverse to health. In addition, there are lungs, heart, blood vessels, esophagus and so on in the human thorax. These are the most important organs in the human body, which will restrict the growth of these organs. Especially when the lung is compressed, it will make the vital capacity of the lungs smaller, and the physical quality will also decline. For adolescent girls, long-term study at the desk not only has the above-mentioned harm, but also may lead to breast dysplasia due to chest and hump caused by the desk at the desk. Teenagers' hunchbacks not only affect physical beauty, but also affect cardiopulmonary development, making them prone to fatigue and unable to stand for a long time.

Thirdly, as one of the important factors affecting the design of girls' underwear, the establishment of a size standard for girls' underwear has long been neglected by most scholars. Scientific clothing size system should be based on accurate anthropometric data, which can guide enterprises to make suitable clothes for consumers, and help consumers buy suitable clothes quickly and accurately. However, the study found that at present, more than 70% of women wear bras of wrong size, which causes great harm to women's breast health. Girls during development have higher breasts, smaller breast spacing, narrower anterior axillary distance, obvious breast contour and flatter dish shape, which are quite different from adult women. In addition, the breast shape of girls at different age stages is also different. Therefore, the design of bra for girls should be classified from increasing the breast type of girls, dividing the age groups, and the size of cup and breast shape, and so on. Match the size and so on, instead of shrinking according to the adult underwear model.

Fourth, the ability to adjust the size of underwear is also a clear demand for underwear design for girls. According to the interviews, girls' bras are purchased by their families, because their families do not know their development status and the bras they buy are often inappropriate. It is also an important consideration in bra design that they can adjust their underwear to their own condition.

Fifth, the factors affecting the design of girls' underwear do not exist independently. Therefore, it is an important direction for future research to pay attention to the comprehensive effects and the optimal composition of factors such as chest protection, corrective posture, size standard, pain relief and so on.

## References

1. Xiaoxiao, W.S., Hoi-To, W., Lin, L., et al.: A review of distributed algorithms for principal component analysis. *Proc. IEEE* **106**(8), 1321–1340 (2018)
2. Li, H., Feng, Z.H.: Study on the fitness of the cup mold for female teenager's bra. *Adv. Mater. Res.* **796**, 497–501 (2013)
3. Chan, C., Yu, W., Newton, E.: Evaluation and analysis of bra design. *Des. J.* **4**(3), 33–40 (2001)
4. Burbage, J., Cameron, L.: An investigation into the prevalence and impact of breast pain, bra issues and breast size on female horse riders. *J. Sports Sci.* 1–7 (2016)
5. Chen, X., Gho, S.A., Wang, J., et al.: Effect of sports bra type and gait speed on breast discomfort, bra discomfort and perceived breast movement in Chinese women. *Ergonomics* 1–31 (2015)



# Effects of Playing Surface on Physiological Responses and Performance Variables of Hockey Players

Ajita D. Singh<sup>(✉)</sup> and Ajay Deswal

Department of Sports Science, Faculty of Medicine,  
Punjab University, Patiala, Punjab, India  
ajita\_dsingh@yahoo.co.in

**Abstract.** The purpose of this study was to investigate the effect of playing surface on physiological responses and performance variables of hockey players. Astroturf, also known as synthetic grass, increases the physiological demand of the game. The game is faster as compared to the game played on grassy field. It may be attributed to the fact that there is a natural difference in the design characteristics of both the courts. The performance of a player depends upon a combination of all the human factors including physical, physiological and biomechanical components of the player. Energy demand of the game is more on Astroturf as compared to the grassy field. Similarly agility of a player to cope with the fast defensive movements and to hold the ball is a deciding factor to escape from getting injured. As the game is fast on astroturf and the player has to depend upon more sprints or in other words more anaerobic components. The present study was conducted on selected national level hockey players of Punjab. The findings of the study indicated the significant differences in terms of physiological components like VO<sub>2</sub>max, Anaerobic threshold and ATVO<sub>2</sub> but no significant difference in the physical characteristics of the player.

**Keywords:** Grassy field · Astroturf · Agility performance · Hockey players

## 1 Introduction

During the last decades there is an advancement in the field of technology and it has touched our every aspect of life. This technology has increased the speed of our life. This technology has also been introduced in the field of sports. The role of technology in sports is in terms of sports clothes, sports equipments and even the playing surfaces. Different sports are played on natural grounds have been now replaced with different synthetic surfaces and even the same sports can be played on different surface like hockey is played on grass, turf & clay surface, basketball is played on wooden surface and concrete, tennis on grass clay and hard court; volleyball on clay and wooden. There are different kinds of artificial surfaces available which can be used by the subjects to play the game, e.g. natural grass, turf, asphalt and wooden. One of the important aspects in construction of sports surfaces is to improve athletic performances.



## 2 Aims and Objectives of the Study

This study aimed to investigate the selected anthropometrical, physical, physiological variables among Hockey players trained on synthetic turf and natural grassy turf achieving the following objectives which are as follows:

1. To evaluate physical variables among the female Hockey players trained on synthetic turf and natural grassy turf.
2. To evaluate maximum aerobic capacity among the Hockey players trained on synthetic turf and natural grassy turf.
3. To evaluate heart rate during actual game play among the Hockey players trained on synthetic turf and natural grassy turf.

### 2.1 Hypotheses of the Study

It is hypothesised that the metabolic demand of the game played on synthetic Astroturf is more as compared to the natural grassy turf and thus the physiological capacity of the players trained on synthetic turf will be more as compared to the players trained on and natural grassy turf.

### 2.2 Method and Procedure

**Selection of Subjects:** Total 44 female hockey players out of which 23 hockey players were trained in the synthetic turf and 21 players used to train on the natural grassy field. The age range of all the players was 18–25 years and all players were of national level.

**Selection of Variables:** The variables selected for the study were as follows:

**Physical Parameters:** Age - in years, Height - in cm, Weight – in kg, BMI  
Equipment

1. Anthropometric rod
2. Weighing machine

Measuring techniques:

1. Height – height was measured with the help of anthropometric rod. Firstly the anthropometric rod was assembled, then subjects were asked to stand straight. The rod then placed close to the subject and the scale attached to the rod measured the height through vertex.
2. Weight was measured with the help of the weighing machine. subjects were asked to stand at the centre of the weighing machine wearing minimal clothes and bare foot

Applications to the measured values.

To calculate BMI – it is calculated by formula

$$\text{BMI} = \text{body weight in kg}/(\text{height in meter})^2$$

### Physiological Parameters

Indirect measurement of VO<sub>2</sub>max: It was measured by using indirect test i.e. Queen step test.

Procedure: The objective of the test had clearly stated and explained to the subject and also the instruction how to perform the test had been given. The subject was asked to stand in front of 16.25 in. bench and do the stepping according to the beat of the metronome (22 steps per minute for females and 24 steps per minute for males) keeping the angle of knee to the bench at 90° and full foot must be put on the bench. Performing test continuously for 3 min, subject signaled to stop stepping and after 5 s the pulse rate was counted by observing carotid artery from 3:05 min to 3:20 min. later pulse count was multiplied by 4 to get the H.R in one minute.

Application of the measured value.

To calculate VO<sub>2</sub>max-

An estimation of vo<sub>2</sub> was done by using the formula given by McArdle et al., 1972.

A rating was determined by using VO<sub>2</sub>max norms.

For women (ml/kg/min) = 65.81 – (0.1847 × heart rate (bpm))

**Direct Measurement:** The were advised to follow a graded exercise protocol on a Bicycle Ergo meter to measure the physiological changes during exercise. The protocol of exercise was designed in such a way that it started with 1 W/kg with 60 rpm and the load was increased by 0.5 W/Kg after every 2 min. The subject was advised to perform exercise until her exhaustion. The criteria for arrival of maximal level were taken on the basis of volitional exhaustion by the subject and attainment of plateau of oxygen consumption. All the parameters were recorded breath by breath on a computerised gas analyser, oxygen champion (Erich Jaeger, Germany).

Measurement of Heart rate during actual game play: Heart rate was recorded during the actual game play with heart rate monitor. The chest belt and the watch was tied on each subject during the actual game play. The average heart rate and the maximum heart rate was decoded after the completion of the game.

## 2.3 Results and Discussion

Table 1 shows the comparison of mean and SD values of Physical parameters of the Hockey players playing on Natural grassy surface and Synthetic turf surface. It is clear from the table that both groups don't show any statistically significant difference between the two groups in terms of age, height, weight, body mass index and body fat percentage values.

Table 2 shows the comparison of mean and SD values of Physiological parameters of the Hockey players playing on Natural grassy surface and Synthetic turf surface. It is clear from the table that both groups don't show any statistically significant difference between the two groups in terms of VO<sub>2</sub>max values measured with direct method, oxygen consumption values at anaerobic threshold level (ATVO<sub>2</sub>) and fractional utilisation of oxygen (ATVO<sub>2</sub>%) except aerobic capacity measured with indirect method. But mean values of each parameter shows that the players who train at synthetic turf possess higher values of aerobic capacity and possess higher values of fractional utilisation of oxygen at anaerobic threshold level which indicate their metabolic adaptation to higher intensity of exercise.

**Table 1.** Comparison of mean and SD values of Physical parameters of the Hockey players playing on Natural grassy surface and Synthetic turf surface.

Players	Age (years) Mean ( $\pm$ SD)	Height (cms) Mean ( $\pm$ SD)	Weight (Kg) Mean ( $\pm$ SD)	BMI Mean ( $\pm$ SD)	Body Fat % Mean ( $\pm$ SD)
Synthetic turf surface players (n = 23)	19.21 ( $\pm$ 3.37)	157.54 ( $\pm$ 5.10)	50.10 ( $\pm$ 4.6)	20.23 ( $\pm$ 2.12)	22.53 ( $\pm$ 3.01)
Natural grassy surface players (n = 21)	16.76 ( $\pm$ 3.58)	158.32 ( $\pm$ 5.67)	49.47 ( $\pm$ 7.40)	19.67 ( $\pm$ 2.14)	23.57 ( $\pm$ 3.43)
t-test	0.012	0.32	0.37	0.19	0.145

**Table 2.** Comparison of mean and SD values of Physiological parameters of the Hockey players playing on Natural grassy surface and Synthetic turf surface.

Players	VO2max (indirect) (ml/Kg/min) Mean ( $\pm$ SD)	VO2max (direct) (ml/Kg/min) Mean ( $\pm$ SD)	ATVO2 (ml/Kg/min) Mean ( $\pm$ SD)	ATVO% Mean ( $\pm$ SD)
Synthetic turf surface players (n = 23)	41.78 ( $\pm$ 1.44)	48.27 ( $\pm$ 4.2)	37.49 ( $\pm$ 4.07)	77.83 ( $\pm$ 7.14)
Natural grassy surface players (n = 21)	38.96 ( $\pm$ 1.44)	48.84 ( $\pm$ 6.04)	35.36 ( $\pm$ 5.26)	73.40 ( $\pm$ 7.70)
t-test	4.22*	0.36	0.07	0.02

Further, the game was also analysed for its heart rate recording during their actual game play in both the groups and Table 3 Comparison of mean and SD values of average heart rate and maximum heart rate values during actual game play of the Hockey players playing on Natural grassy surface and Synthetic turf surface. It is clear from the table that although the mean values of average heart rate of the players belonging to both the groups show almost same values and thus don't show any statistically significant difference but the mean values of the maximum heart rate of the players belonging to synthetic turf shows lower values as compared to the players belonging to natural grassy surface players. As the intensity of exercise is increased the oxygen demand of the body is also increased. The average heart rate depicts the adaptation of the cardiovascular system to that particular intensity and the maximum heart rate depicts the intensity of the exercise because in order to meet the oxygen demands of the skeletal muscle and myocardial oxygen consumption heart rate increases which is one of the major three major determinants of myocardial oxygen consumption other than myocardial contractility, and wall stress. During high intensity exercise this increase in heart rate is much more higher than its resting level.

**Table 3.** Comparison of mean and SD values of average heart rate and maximum heart rate values during actual game play of the Hockey players playing on Natural grassy surface and Synthetic turf surface.

Players	Average Heart rate (b/min) Mean ( $\pm$ SD)	Maximum heart rate (b/min) Mean ( $\pm$ SD)
Synthetic turf surface players (n = 23)	163.69 ( $\pm$ 5.03)	188.52 ( $\pm$ 7.14)
Natural grassy surface players (n = 21)	163.85 ( $\pm$ 5.29)	192.47 ( $\pm$ 6.93)
t-test	0.46	0.035

### 3 Conclusion

The metabolic demand of the game played on the synthetic turf is more as compared to the natural grassy turf.

As hockey is an intermittent game during actual game play, the players play at the level of their anaerobic threshold level. Thus, if anaerobic threshold heart rate can be considered as training heart rate than their will be a delay in the anaerobic threshold level and the player will play at a higher fractional utilization of maximum oxygen consumption for longer time without getting fatigued.

### References

1. Astrand, P.O., Rodahl, K.: Textbook of Work Physiology: Physiological Bases of Exercise. McGraw-Hill, NewYork (1986)
2. Brooks, G.A.: Anaerobic threshold: review of the concept and directions for future research. Med. Sci. Sports Exerc. **17**(1), 22–31 (1984)
3. Bunc, V., Heller, J., Leso, J., Sprynarova, S., Zdanowicz, R.: Ventilatory threshold in various groups of highly trained athletes. Int. J. Sports Med. **8**, 275 (1987)
4. Singh, A.D., Goswami, A.: Anaerobic threshold and oxygen consumption as a measure of training status in female. In: Developments in Agricultural and Industrial Ergonomics: General Studies, vol. 1, pp. 27–33 (2007)
5. Ghosh, A.K., Ahuja, A., Khanna, G.L., Kelley, R., Sam, J.: Intergroup variations in physiological characteristics of Indian basketball players. In: Proceedings of the FISU Conference, Kobe, Japan (1985)
6. Ghosh, A.K., Mazumdar, P., Goswami, A., Khanna, G.L.: Aerobic-anaerobic transition level of Indian middle & long distance runners. Indian J. Med. Res. **88**, 371–375 (1988)
7. Kenney, W.L., Hodgson, J.L.: Variables predictive of performance in middle-distance runners. Br. J. Sports Med. **19**, 207 (1985)
8. Khanna, G.L., Ghosh, A.K., Sharma, J.G., Malhotra, M.S.: Physiological status of some judoists in India. SNIPES J. **6**, 21–27 (1983)
9. Kumagai, S., Tanaka, K., Matsura, Y., Matsuzaka, A., Hirakoba, K., Asano, K.: Relationship of the anaerobic threshold with the 5 km, 10 km and 10 mile races. Eur. J. Appl. Physiol. **49**, 13–23 (1982)

10. Tanaka, K., Matura, Y., Matsuzaka, A., Hirakoba, K., Kumagai, S.: A longitudinal assessment of anaerobic threshold and distance running performance. *Med. Sci. Sports Exerc.* **16**, 278 (1984)
11. Wasserman, K., Whipp, B.J., Koyal, S.N., Beaver, W.L.: Anaerobic threshold and respiratory gas exchange during exercise. *J. Appl. Physiol.* **35**, 236 (1973)
12. Wasserman, K., Hansen, J.E., Sue, D.Y., Whipp, B.J.: *Principles of Exercise Testing and Interpretation*. Lea & Febiger, Philadelphia (1994)
13. Whipp, B.J.: The control of exercise hyperpnea. In: Hornbein, T. (ed.) *The Regulation of Breathing*, pp. 1069–1139. Dekker, New York (1981)
14. Whipp, B.J., Ward, S.A.: Physiological determinants of pulmonary gas exchange kinetics during exercise. *Med. Sci. Sports Exerc.* **22**(1), 62–71 (1990)
15. Withers, R.T., Roberts, R.G.D.: Physiological profiles of representative women softball, hockey and netball players. *Ergonomics* **24**, 583–591 (1981)
16. Yoshida, T., Watari, H.: Metabolic consequences of repeated exercise in long distance runners. *Eur. J. Appl. Physiol.* **6**(3), 261–265 (1993)



# Role of Postural Control Exercises and Pelvic Floor Strengthening Exercises on Chronic Low Back Pain of Women with Sitting Jobs

Ajita Dsingh<sup>(✉)</sup> and Amanpreet Kaur

Punjabi University, Patiala, Punjab, India  
ajita\_dsingh@yahoo.co.in

**Abstract.** A lot of factors can give rise to low back pain and spinal instability attributes to one of them. Stability of spine is directly dependent on the strength of postural muscles which can be linked easily with postural control. Hence, postural control is likely to directly alter the spinal stability. Muscles of pelvic floor function along with muscles of back and abdomen to support the spine. This study aims to evaluate the effect of exercises to strengthen pelvic floor muscles and exercises for postural control in the treatment of chronic LBP and on posture, pain, and quality of life. [Subjects and Methods] Sample size of twenty-five participants was taken based on inclusion and exclusion criteria and divided to three groups namely PFM exercises group ( $n = 8$ ), postural control exercises group ( $n = 8$ ) and the control group ( $n = 9$ ). All the three groups were given treatment for half an hour a day, thrice a week for 5 weeks. Conventional treatment that includes electrotherapy and general exercises was given to control group. Experimental groups received conventional treatment and additional exercises for pelvic floor muscles and posture control. [Results] Pain and functional disability was significantly reduced after treatment ( $p < 0.01$ ) in all the three groups, but there was no significant difference ( $p > 0.05$ ) found in both experimental groups. All the outcome measures were improved significantly ( $p < 0.01$ ) in all groups although both experimental groups demonstrated significant improvement in Visual Analog Scale scores, and World Health Organization Quality of Life Assessment-BREF scores in contrast to control group. [Conclusion] Study concluded that the exercises to strengthen the pelvic floor muscles combined with conventional treatment and exercises for postural control combined with conventional treatment can provide better outcome as compared to conventional treatment alone in patients with chronic low back pain. Controlling the posture and muscular activities through these exercises also improves the patients' quality of life.

**Keywords:** Pelvic floor muscle · Chronic low back pain · Posture control · Low back pain · Postural exercises · Pelvic floor muscle strengthening exercises

## 1 Introduction

Low back pain is quite a common worry among worldwide population, with 60–80% of people being affected at certain age or point in their lives [1–3]. It has profound effect on quality of life, impacting the capability for maintaining posture while standing, walking

and sitting [4, 5]. In most cases, these symptoms are instantaneous and fade away within six weeks, but estimated one-fifth of these individuals with low back pain do not show any progress in these symptoms, which may result in chronic low back pain. This chronic stage of low back pain is rigid and cannot be treated easily with wore prognosis and create a vicious cycle with compensatory postural and mechanical misalignments in body [6]. In any functional activity, static and dynamic postural control is needed to avoid further malformations [7]. In individuals suffering from chronic low back pain, the extent of postural control can vary leads to compromised activities of day to day life [7–10]. The procedure that leads to lack of postural control remain debatable. Pain being an important factor in compensatory alterations, but the degree to which it affects posture is yet to be determined. The main causative factor that can cause back pain is poor posture while sitting, standing and lifting heavy weights. Other factors that can cause low back pain include spinal disorders and systemic diseases [11]. Exercises are the most used invention to manage chronic low back pain, especially focusing the core muscles along with pelvic floor muscles [12–14]. Although pelvic floor muscle dysfunction is proven to be associated with the development of low back pain [15, 16]. The pelvic floor resembles a hammock of muscles that provide an attachment for the pubis to the tailbone and ischial tuberosities [17]. A variety of agents such as pain, poor movement patterns, trauma, surgery or childbirth can instigate decrease in the strength of pelvic floor muscles [15]. Muscle imbalances due to uneven strength do not recurvate right away, and can induce pain in low back, pelvis and/or hip [16]. The pelvic floor is an important constituent of the core stabilization, but still most neglected in treatment plans [18]. Over and above, there is not much proof that combined conventional treatment (hot fermentation, short wave diathermy, interferential therapy, and lumbar stretching and core strengthening exercises), postural training and pelvic floor muscle strengthening present with an edge over sole conventional treatment.

Numerous studies deduced that both exercises for postural control and exercises for pelvic floor muscle strengthening are favourable for low back pain patients. Scrutiny of their effects needs to be done for comparability and to render early and better comfort from the symptoms. The present study determined the efficacy of conventional treatment with or without postural and pelvic floor muscle exercise inpatients with chronic low back pain.

### **1.1 Need of the Study**

Low back pain is the common disability for females with sitting jobs and hinders their functional ability along with quality of life. Postural exercises and Pelvic floor muscle strengthening exercises showed marked improvement. There is a need to compare both the treatment regime in order to provide better results in less time.

### **1.2 Aim of the Study**

To study the effect of Postural exercises and strengthening exercises for pelvic floor muscles in low back pain female patients with sitting jobs.

### 1.3 Objective of the Study

- To evaluate the effect of Postural exercises on low back pain and quality of life.
- To evaluate the effect of strengthening exercises for pelvic floor muscles on low back pain and quality of life.

### 1.4 Hypothesis

#### Null Hypothesis

There will be no significant difference in the effect of Postural exercises and Pelvic floor muscle strengthening exercises in female patients with low back pain.

#### Alternate Hypothesis

There will be significant difference in the effect of Postural exercises and Pelvic floor muscle strengthening exercises in female patients with low back pain.

## 2 Review of Literature

Musculoskeletal pain and posture are interrelated and this equation helps physiotherapists to achieve symptomatic relief for patients with low back pain by correcting the posture [19]. Corrective exercises for posture have been proven for a better prognosis for low back pain [23–25].

A study was done by Pereira Baldon V, Sadanobu Hirakawa H and Driusso P to determine the correlation between low back pain and pelvic floor muscle function in young women. Forty women were selected as a sample in the study (Aged:  $23.5 \pm 3.2$  years; Body Mass Index:  $21.1 \pm 1.5 \text{ kg/cm}^2$ ). This study proved that there is a correlation between low back pain and Pelvic floor muscle function. It was demonstrated that the lower the Pelvic floor muscle function, the higher was the pain related symptoms.

Xia Bi et al. did a study in 2013 to evaluate the effect of pelvic floor muscle exercises in chronic low back pain patients. The study took a sample of 47 patients (control group  $n = 24$ ; intervention group  $n = 23$ ). Study concluded that Pelvic floor exercises in combination with conventional treatment resulted in significant symptomatic relief over sole conventional treatment.

## 3 Methodology

Experimental study design. Outpatient department of Physiotherapy, Gupta Hospital, Bathinda, Punjab, India. Study duration: 6 months. Population Sample: 25 patients. Sampling technique: Random Sampling Technique, Inclusion criteria: 18–45 years age females with nonspecific low back pain and sitting jobs for last 3 months or more, with or without radiculopathy.



Exclusion criteria: subjects who are not cooperative or participating in another research study involving back, patients with diabetics, patients with ankylosing spondylitis, other significant spinal pathology, post-surgical cases, patients with neurological, cardiovascular or metabolic disease.

### 3.1 Procedure

Sample size of twenty-five participants was taken based on inclusion and exclusion criteria. After taking consent, the subject were randomly divided into three groups named A (n = 8, pelvic floor muscle strengthening group), B (n = 8, postural exercises group) and C (n = 9, control group). 5-week treatment plan was allocated to subjects of all the three groups of conventional treatment, with postural exercises and pelvic floor exercises. A registered physical therapist carried out all the three treatment plans. Conventional treatment included hot fermentation (15 min), ultrasonography (1 MHz at  $1.2 \text{ W/cm}^2$  for 5 min in continuous mode), short-wave diathermy (continuous mode for 15 min) and lumbar strengthening exercises [26]. Conventional treatment was performed thrice a week for 5 weeks. The pelvic floor muscle exercise programme included a regimen of making subjects do pelvic floor muscles contractions with a speed of five cycles per minute that included six second hold and six second relax pattern. This speed of contractions was increased as the treatment progressed in the span of five weeks.

### 3.2 Dependent Variables

Visual analogue scale (VAS), Quality of life scale (WHO).

### 3.3 Independent Variable

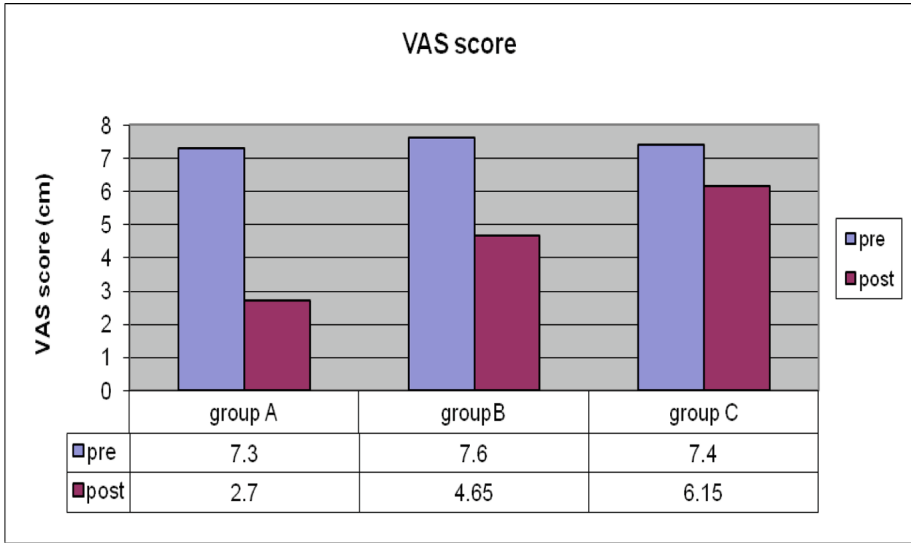
Pelvic floor strengthening Exercises and Postural Exercises.

## 4 Results

Results were analysed by paired, unpaired t-test and ANOVA. Paired t-test was applied to analyse pre and post values of VAS and QOL of all the groups. Unpaired t-test was applied to the difference of pre and post values of group A with difference of pre and post values of group B. Unpaired t-test was applied to the difference of pre and post values of group A with difference of pre and post values of group C. Unpaired t-test was applied to the difference of pre and post values of group B with difference of pre and post values of group C. ANOVA was applied to the differences of post values of the three groups.

**Table 1.** Mean and standard deviation of pre-treatment, post-treatment and their difference of VAS score of the groups.

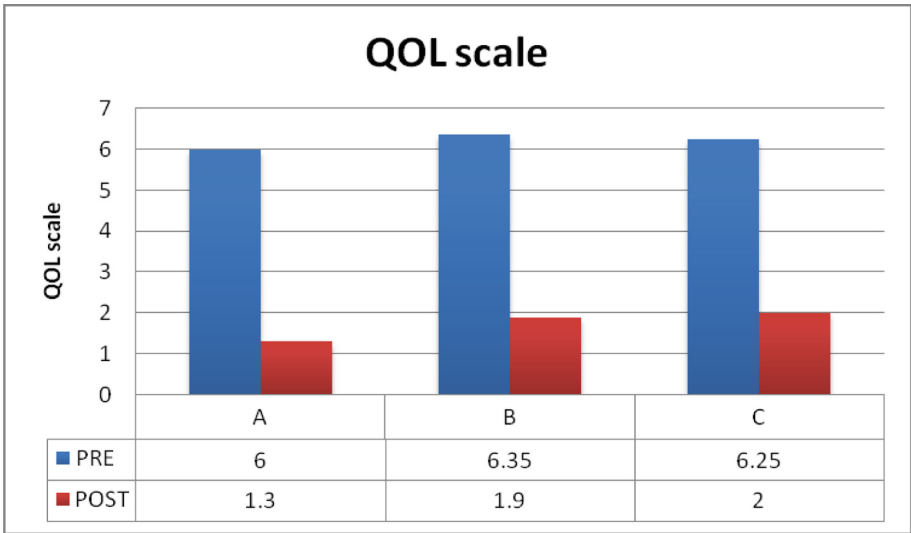
Groups	Pre Mean $\pm$ SD	Post Mean $\pm$ SD
A	7.3 $\pm$ 0.801	2.7 $\pm$ 0.66
B	7.6 $\pm$ 0.753	4.65 $\pm$ 0.74
C	7.4 $\pm$ 0.882	6.15 $\pm$ 1.089



**Fig. 1.** Graph represent mean of VAS at Pre, Post interval for the subjects of Group A, Group B and Group C

**Table 2.** Mean, SD and SE of QOL at Pre, Post and Mean diff. (Pre-Post) interval for the subjects of Group A, Group B and Group C

Groups	Pre Mean $\pm$ SD	Post Mean $\pm$ SD
A	6 $\pm$ 0.858395	1.3 $\pm$ 0.470162
B	6.35 $\pm$ 0.74516	1.9 $\pm$ 0.788069
C	6.25 $\pm$ 0.71635	2 $\pm$ 0.725476



**Fig. 2.** Graph represent mean of QOL at Pre, Post interval for the subjects of Group A, Group B and Group C

## 5 Discussion

Low back pain is an important public health, social and economic problem. It is a disorder with much possible aetiology, concerning different groups, and also a most commonly seen health concern among workers. In India only, statistics of low back pain is dismaying; up to 60% of Indian population have substantial back pain at some time or the other in lives. Estimated 35% people endure chronic back pain, which significantly hinder their activities of day-to-day lives.

A statistically significant difference ( $p \leq 0.05$ ) in VAS score readings and quality of life scale of the three groups was observed while using ANOVA (Table 1) analysed in Figs. 1 and 2. Group A seems to be more effective than the other two groups (Table 2).

Many drawbacks are there in the study under consideration. Firstly, it was carried out in one location only which could not guarantee a heterogeneous sampling due to small size of sample drawn from the inhabitants of same geographical area; which in turn could not help generalise the conclusion. Secondly, individual variations were there in the way of exercising among the sample. Finally, aetiology of low back pain in the sample was nonspecific or unknown which makes it impossible to think of these results as a reference for low back pain of different aetiologies.

## 6 Conclusion

Present study concluded that the female patients of low back strain within the age group of 18–45 years are benefited more by the combination of pelvic floor muscle strengthening exercises, postural training and conventional physiotherapy rather than sole conventional physiotherapy. In future, this study can act as a pavement to embark on high-scale studies which can trace retrospective and prospective factors (cause and also the long term impacts) for generalising the results to a wider population.

## References

1. Beith, I.D., Kemp, A., Kenyon, J., Prout, M., Chestnut, T.J.: Identifying neuropathic back and leg pain: a cross-sectional study. *Pain* **152**, 1511–1516 (2011)
2. Lamb, S.E., Hansen, Z., Lall, R., Castelnuovo, E., Withers, E.J., Nichols, V., Potter, R., Underwood, M.R., Back Skills Training Trial Investigators: Group cognitive behavioural treatment for low-back pain in primary care: a randomised controlled trial and cost-effectiveness analysis. *Lancet* **375**, 916–923 (2010)
3. Andersson, G.B.: Epidemiological features of chronic low-back pain. *Lancet* **354**, 581–585 (1999)
4. Gutke, A., Ostgaard, H.C., Oberg, B.: Pelvic girdle pain and lumbar pain in pregnancy: a cohort study of the consequences in terms of health and functioning. *Spine (Phila Pa 1976)* **31**, E149–E155 (2006)
5. Scholich, S.L., Hallner, D., Wittenberg, R.H., Hasenbring, M.I., Rusu, A.C.: The relationship between pain, disability, quality of life and cognitive-behavioural factors in chronic back pain. *Disabil. Rehabil.* **34**, 1993–2000 (2012)
6. Ruhe, A., Fejer, R., Walker, B.: Center of pressure excursion as a measure of balance performance in patients with non-specific low back pain compared to healthy controls: a systematic review of the literature. *Eur. Spine J.* **20**(3), 358–368 (2011)
7. Della-Volpe, R., Popa, T., Ginanneschi, F., Spidalieri, R., Mazzochio, R., Rossi, A.: Changes in coordination of postural control during dynamic stance in chronic low back pain patients. *Gait Posture* **24**(3), 349–355 (2006). <https://doi.org/10.1016/j.gaitpost.2005.10.009>
8. Kuukkanen, T.M.: An experimental controlled study on postural sway and therapeutic exercise in subjects with low back pain. *Clin. Rehabil.* **14**(2), 192–202 (2000). <https://doi.org/10.1191/026921500667300454>
9. Henry, S.M., Hitt, J.R., Jones, S.L., Bunn, J.Y.: Decreased limits of stability in response to postural perturbations in subjects with low back pain. *Clin. Biomech. (Bristol, Avon)* **21**(9), 881–892 (2006). <https://doi.org/10.1016/j.clinbiomech.2006.04.016>
10. Brumagne, S., Janssens, L., Knapen, S., Claeys, K., Suuden-Johanson, E.: Persons with recurrent low back pain exhibit a rigid postural control strategy. *Eur. Spine J.* **17**(9), 1177–1184 (2008). <https://doi.org/10.1007/s00586-008-0709-7>
11. Cox, J.M., Trier, K.: Exercise and smoking habits in patients with and without low back pain. *J Manipulative Phys. Ther.* **10**, 224–239 (1987)
12. Hayden, J.A., van Tulder, M.W., Malmivaara, A., Koes, B.W.: Exercise therapy for treatment of nonspecific low back pain. *Cochrane Database Syst. Rev.* **3**, CD000335 (2005)
13. Wang, X., Zheng, J., Liu, J.: Effect of core stability training on patients with chronic low back pain. *HealthMED* **6**, 754–759 (2012)

14. Hodges, P.W.: Core stability exercise in chronic low back pain. *Orthop. Clin. North Am.* **34**, 245–254 (2003)
15. Sjö Dahl, J., Kvist, J., Gutke, A., Oberg, B.: The postural response of the pelvic floor muscles during limb movements: a methodological electromyography study in parous women without lumbopelvic pain. *Clin. Biomech. (Bristol, Avon)* **24**, 183–189 (2009)
16. Arab, A.M., Behbahani, R.B., Lorestani, L., Azari, A.: Assessment of pelvic floor muscle function in women with and without low back pain using transabdominal ultrasound. *Man Ther.* **15**, 235–239 (2010)
17. Fowler, S.B.: Pelvic floor muscle training versus no treatment, or inactive control treatments, for urinary incontinence in women. *Clin. Nurse Spec.* **25**, 226–227 (2011)
18. Talasz, H., Himmer-Perschak, G., Marth, E., Fischer-Colbrie, J., Hoefner, E., Lechleitner, M.: Evaluation of pelvic floor muscle function in a random group of adult women in Austria. *Int. Urogynecol. J. Pelvic Floor Dysfunct.* **19**, 131–135 (2008)
19. Fann, A.V.: The prevalence of postural asymmetry in people with and without chronic low back pain. *Arch. Phys. Med. Rehabil.* **83**(12), 1736–1738 (2002)
20. Harrison, D.E., Cailliet, R., Betz, J.W., Harrison, D.D., Colloca, C.J., Haas, J.W., Janik, T.J., Holland, B.: A non-randomized clinical control trial of Harrison mirror image methods for correcting trunk list (lateral translations of the thoracic cage) in patients with chronic low back pain. *Eur. Spine J.* **14**(2), 155–162 (2005)
21. Hrysomallis, C.: Effectiveness of strengthening and stretching exercises for the postural correction of abducted scapulae: a review. *J. Strength Cond. Res.* **24**(2), 567–574 (2010)
22. Lynch, S.S., Thigpen, C.A., Mihalik, J.P., Prentice, W.E., Padua, D.: The effects of an exercise intervention on forward head and rounded shoulder postures in elite swimmers. *Br. J. Sports Med.* **44**(5), 376–381 (2010)
23. Revel, M.: Rehabilitation of low back pain patients. A review. *Rev. Rhum. Engl. Ed.* **62**(1), 35–44 (1995)
24. Quittan, M.: Management of back pain. *Disabil. Rehabil.* **24**(8), 423–434 (2000)
25. Curnow, D., Cobbin, D., Wyndham, J., Boris Choy, S.T.: Altered motor control, posture and the Pilates method of exercise prescription. *J. Bodyw. Mov. Ther.* **13**(1), 104–111 (2009)
26. Kumar, S., Sharma, V.P., Shukla, R., et al.: Comparative efficacy of two multimodal treatments on male and female sub-groups with low back pain (part II). *J. Back Musculoskelet. Rehabil.* **23**, 1–9 (2010)
27. Cammu, H., Van Nysten, M., Amy, J.J.: A 10-year follow-up after Kegel pelvic floor muscle exercises for genuine stress incontinence. *BJU Int.* **85**, 655–658 (2000)
28. Suryapani, R.: Backache, borne of modern lifestyle. *Tribune* **6**, 16 (1996)



# The Role of Organizational Factors in Development and Progression of Wrist Disorders: Psychosocial Aspects

Arunita Paul<sup>(✉)</sup> and Urmi R. Salve

Department of Design, Indian Institute of Technology Guwahati,  
Guwahati, Assam, India  
{arunita, urmi.salve}@iitg.ac.in

**Abstract.** Psychosocial risk factors are closely associated with organizational structure. Although psychosocial factors do not act directly like physical risk factors, still they exert a significant proportion in progression of the wrist disorders. The aim of this study is to identify the optimization points for psychosocial risk factors of CTS and other wrist disorders in present context. A survey was done among a cluster of subjects suffering clinically diagnosed wrist disorder in a group of workplaces. With the responses principal component analysis was done. The PCA extracted 4 psychosocial or organizational factors. The Stress factor contains 5 components. The job satisfaction factor consists of 4 components. The work environment factor also affects the total risk of wrist disorders. This factor is consisted of two components. The fourth important factor is reward factor in a workplace. These extracted factors can be used to reduce the risk of wrist disorders from organizational and work design perspective.

**Keywords:** Wrist disorder · Organizational risk factors · Relationship pattern

## 1 Introduction

Work-related musculoskeletal disorders (WMSDs) are defined as injuries or disorders of the muscles, nerves, tendons, joints, cartilage, and spinal discs associated with exposure to risk factors in the workplace [1]. WMSDs do not include disorders caused by slips, trips, falls, motor vehicle accidents, or similar accidents [1]. These disorders continue to exert negative effect on overall health and output of different work groups [2]. These disorders have proven to have multifactorial etiology [3] commonly categorized in:

- **Physical Risk Factors:** derived from physical characteristics of work by humans, such as movements, posture, vibration, force, hazards etc.
- **Personal Risk Factors:** risk depends on several inherent or intrinsic characteristics of a person or ethnic groups; example: anthropometric characters. Gender, presence of other disorders, lifestyle etc.
- **Psychosocial Risk Factors:** these include the intrinsic psychological effects from jobs. These are closely related with organizational structure. So the term organizational factors are also used for these. Examples include: job stress, exhaustion after work, control over job etc.

Hand-wrist musculoskeletal disorders are of very much importance in the area of occupational health and WMSDs. These represent a substantial proportion of work-related illness and are associated with relatively high medical costs and loss of work. In a study it was reported that among top 10 industries reporting WMSDs, half are prone to develop UEWMSDs through the use of hand tools or the performance of hand intensive tasks. These are: assemblers, construction workers, supervisors in sales, carpenters and cashiers. In a report, the NIOSH has divided the hand-wrist musculoskeletal disorder category into three components [3]. These are:

- Carpal tunnel syndrome (CTS);
- Hand-wrist tendinitis (e.g., DeQuervain's tenosynovitis, trigger finger); and
- Hand-arm vibration syndrome (HAVS).

According to the Bureau of Labor Statistics News (2001) among these components CTS was associated with the highest median days away from work [3]. At present the condition needs to be investigated more extensively because the epidemiological scenario around WMSDs is dynamic, changing continuously with socio-economical structure and working pattern. For example, considering the present condition, the epidemiology of WMSDs has changed significantly. If investigated properly, a huge change can be seen happening consistently in work pattern and lifestyles. This era is of technological intervention. Technology is making the control and execution of many bigger jobs possible with a palm-length device. Also, technological intervention is reaching every tiers of society at considerable pace. These reasons in turn changed the work pattern and lifestyle drastically. Whether it is office, or industry, or even in household chores, the use of technology is altering the movement and physiological reaction of human body. Even few decades ago working included movement of whole body or larger body parts more. At present, the activity is increased for the extremities. In turn many of the physically active jobs have turned into sedentary. This situation is increasing stress on the extremities leading to more cases of cumulative disorders of these regions. One of such area is wrist and its surrounding region. Due to this delicate structure the wrist is already prone to suffer from acute and chronic injuries. Wrist is particularly important because now-a-days the devices that are being used have interfaces that involve wrist and finger extensively. The example of this can be seen in the increased incidence rate of wrist disorders, including non-descriptive chronic wrist pains. From different studies and reports of different organizations it is clear that the occurrence of upper extremity musculoskeletal disorders is on rise [4]. All of these disorders affect a person's standard of living and health status extensively. To reduce the occurrence and improve the management of these disorders the understanding of the causal factors is very much necessary. Specifically the extrinsic factors, that is, risk related with job or organizational design, should come under critical examination as these factors are modifiable.

In several studies it has been observed that psychosocial factors have an influential role on development of CTS [5–13]. Commonly reported associations are described between surgical CTS patient's disability/pain with depression, pain anxiety and catastrophization. In a study at a footwear industry the authors have found that despite presence of personal and physical predispositional factors, psychosocial factors play the major role in development of CTS. They have deduced that these factors are the cause rather than the consequence of CTS. Few studies have tried to establish the inter-relationship between psychosocial and physical exposure. These have identified the statistically significant correlation of increased job physical exposure and worsening psychosocial conditions. Some associations among have been identified as unique. Such as perceived physical exhaustion are mostly dependent on force, whereas depression is mostly associated with repetitiveness of the job. Some studies have provided with hypothetical theories of causal pathways that lead to upper extremities musculoskeletal disorders. In a study a biopsychosocial model for CTS has been conceptualized and it was concluded that job psychosocial factors are more important than personal psychological factors in development of CTS. This model says that every physical chronic, accumulative disorder has three causal components; these are: physical, psychological and social. However quantification of effects of psychosocial factors with a specific outcome, in this case CTS, needed to be established. In a study work organizational factors have been considered as risk factors for CTS. It has been found that payment on a piecework basis and work rate depending upon automatic rate are associated with CTS. It was also observed that the impact of these factors is not reduced by the impact of biomechanical exposures. The identified work organizational factors are: Depression, anxiety, job satisfaction, job strain and control, educational attainment, psychological demand, decision latitude, social support, payment method and work pace are important risk factors [5–13].

Although these studies clearly showed effect of psychosocial factors on development of wrist disorders there is still need of extensive research on the interaction among the factors, specifically in the context of present use of digital devices. Also, the relationship with clinically diagnosed wrist disorders has to be explored. For psychosocial factors it is important to identify the pattern of relationship to understand the role of organization. Although psychosocial factors do not act directly like physical risk factors, still they exert a significant proportion in progression of the wrist disorders. The advantages with psychosocial factors are these are more easily manageable than the physical risk factors. Some simple changes in work organization structure can ease out the symptoms.

The aim of this study is to identify the optimization points for psychosocial risk factors of CTS and other wrist disorders in present context.

The objectives are the following:

- To identify the relationship pattern among the risk factors of wrist disorders
- To extract the combined risk factors from interacting singular risk factors of wrist disorders



- To extract the factor loadings of individual risk factors on combined risk factors of wrist disorders
- To extract the squared factor loadings of combined risk factors on total risk of wrist disorders

## 2 Methodology

### 2.1 Identification of Workplaces and Subjects

The sample was selected by purposive sampling method. Sample was selected following inclusion and exclusion criteria.

#### Inclusion Criteria:

- The subjects should have/had any particular wrist disorder, **diagnosed by a physician**;
- Any kind of job including homemaking was considered;
- Any gender was included.
- Only adult subjects were considered.

#### Exclusion Criteria:

- The presence of any particular disease that may cause wrist disorders secondarily, e.g., diabetes mellitus, renal diseases.
- Presence of wrist problems due to some accidents, e.g., fracture of wrist bones etc.

Based on these criteria 100 subjects were selected from different clinics and hospitals through purposive sampling. To identify the specific work pattern that is responsible for the increased chance of wrist problems the workplace and activities of daily work and lifestyle has been collected from the patients. Based on the data several common working sectors, work and daily activities were identified.

### 2.2 Survey on Different Psychosocial Factors and Principal Component Analysis (PCA)

A questionnaire was developed on the basis of different identified factors from previous studies on role of psychosocial factors on wrist disorders and WMSDs in general [5–13]. The questionnaire was administered to the previously identified subjects with clinical wrist problems. The questionnaire was administered to the subjects either directly or through e-mail. Before administration, the rationale and possible benefits has been discussed with the subjects. Also the possible treatments of responses have been mentioned.

The data from previous survey was utilized to find out the relationship among different psychosocial risk factors for wrist disorders as CTS. To identify the relationship among different variables several statistical methods are available. As a number of

variables are associated for this case and also the factor loads are needed Factor Analysis was done for dimension reduction. The extraction method was chosen as Principal Component Analysis (PCA). The rotation was chosen as Varimax. The number of factors extracted was mentioned as Eigenvalue above 1. The factor loadings below 0.3 were ignored.

The analysis was done in SPSS, version 23.

### 3 Results

#### 3.1 Demographic Data

Demographic data including gender, age, height and weight were collected from the subjects to understand the distribution of the disorder among the population.

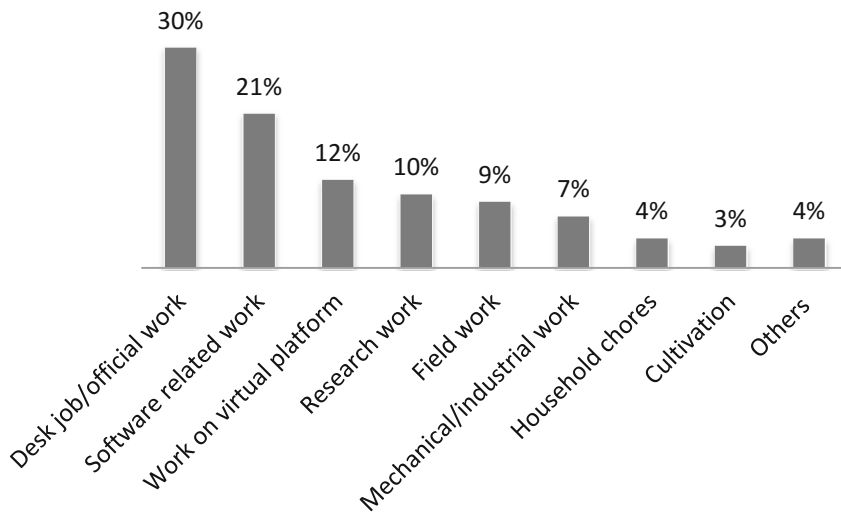
**Age, Height and Weight:** Mean values of age, height and weight (including standard deviation) were calculated. The mean age of the subjects is 33.76 ( $\pm 7.42$ ) years, which falls under the so called 'working age'. The mean height of the subjects is 168.48 cm ( $\pm 7.23$  cm) and the mean weight is 67.28 kg ( $\pm 9.89$  kg).

**Gender Distribution:** The gender was obtained and described in percentage of the total subjects; 61% of the subjects were male and 39% were female.

**Reliability of Questionnaire:** To measure the internal consistency the reliability of the newly developed questionnaire was measured by the method of Chronbach's alpha and also by the Split-half (with Spearman-Brown adjustment) method. The Chronbach's alpha value is 0.72, which comes under moderate reliability. As the questionnaire has many optional parts where the values could come as 0, split-half method with Spearman-Brown score has also been calculated. The split-half score is 0.88 and with Spearman-Brown adjustment it becomes 0.94 which indicates high reliability and internal consistency.

#### 3.2 Work Sectors and Activities

In this case first of all the common job sectors has been identified. Occupational sector is particularly chosen because this is where a person spends the most time in a day working. Household chores has also has been chosen as occupation as prescribed by ILO and other organizations. It can be observed that there are several common work sectors among the subjects. Most important of them is desk job or official job, which consists of 30% of the total subjects. This is followed by software related works and work on virtual platform, which are accounted by 21% and 12% of the subjects respectively. 10% of the subjects identified research and academics as their work area; 9% of the subjects have field work in their jobs. The rest of the work patterns include mechanical or industrial work, household chores, cultivation, driving, handicraft making, training etc. (Fig. 1).



**Fig. 1.** Common jobs identified from the patients

**3.3 PCA**

The total variance indicates how much of the variability of the data is modeled by the extracted factors. It can be observed that in this case 4 combined psychosocial risk factors have been extracted with Eigenvalue greater than 1. The first factor has Eigenvalue of 3.75 and account for 26.80% of total variability. For the second factor Eigenvalue is 2.35 and it accounts for 16.80% of total variability. The third and fourth factors have Eigenvalues of 2.02 and 1.28 respectively. Also these account for 14.44% and 9.11% of total variance respectively. Together the 4 extracted factors account for 67.14% of total variance.

The component matrix shows the component variables for each combined risk factor and their loadings on the combined factors. Total 4 components have been extracted. Factor loading scores less than 0.3 were ignored. To be able to interpret the factors' meaning one needs to apply the rotation method. Varimax rotation was done. It can be observed that as unrotated factor matrix, 4 components were extracted (Tables 1 and 2).

**Table 1.** Total variance explained with initial eigenvalues and extraction sums of squared loadings

Component	Initial eigenvalues			Extraction sums of squared loadings	
	Total	% of variance	Cumulative %	Total	% of variance
1	3.752	26.801	26.801	3.752	26.801
2	2.351	16.796	43.596	2.351	16.796
3	2.021	14.437	58.034	2.021	14.437

(continued)

**Table 1.** (continued)

Component	Initial eigenvalues			Extraction sums of squared loadings	
	Total	% of variance	Cumulative %	Total	% of variance
4	1.275	9.109	67.142	1.275	9.109
5	.980	6.999	74.141		
6	.666	4.758	78.899		
7	.602	4.297	83.196		
8	.519	3.708	86.905		
9	.453	3.232	90.137		
10	.367	2.618	92.755		
11	.327	2.334	95.089		
12	.278	1.988	97.077		
13	.219	1.561	98.638		
14	.191	1.362	100.000		

Extraction method: Principal Component Analysis

**Table 2.** Component matrix of rotated psychosocial factors

	Component			
	1	2	3	4
job_strs	.794			
ph_ex	.786			
tot_strs	.777			
hlth_sameage	.754		.376	
job_recmd		.864		
job_sats		.793		
take_job_again		.727		.417
care_health_work		.549	.513	
coworker			.786	
depression			.713	
ment_ex	.484		-.551	
control_job				.807
payment_sys				.779
work_appre	.340	.386	.365	.498

Extraction method: principal component analysis Rotation method: Varimax with Kaiser Normalization<sup>a</sup>. <sup>a</sup>rotation converged at 6 iterations

From the PCA data 4 combined psychosocial risk factors for wrist disorders were extracted. Components for each combined risk factor were chosen depending upon the highest loading score value and direction of the load.

**Table 3.** Components of combined risk factor 1

Variables	Factor loading
Job stress	0.79
Physical exhaustion after work	0.79
Total stress	0.78
Health compared to same age people	0.75
Mental exhaustion after work	0.48

This factor can be called as ‘Stress Factor’ and it exerts a weightage of 3.75 in total risk for wrist disorders from psychosocial variables.

**Table 4.** Components of combined risk factor 2

Variables	Factor loading
Job recommendation to other people	0.86
Job satisfaction	0.79
Willingness to take the job again	0.73
Care for health by job authority	0.55

This factor can be called as ‘Job Satisfaction Factor’ and it exerts a weightage of 2.35 in total risk for wrist disorders from psychosocial variables.

**Table 5.** Components of combined risk factor 3

Variables	Factor loading
Relationship with co-workers	0.79
Depression or feeling blue	0.71

This factor can be called as ‘Work Environment Factor’ and it exerts a weightage of 2.02 in total risk for wrist disorders from psychosocial variables.

**Table 6.** Components of combined risk factor 4

Variables	Factor loading
Control over job	0.81
Payment system	0.78
Appreciation by superiors	0.50

This factor can be called as ‘Reward Factor’ and it exerts a weightage of 1.28 in total risk for wrist disorders from psychosocial variables.

## 4 Discussion

The PCA of psychosocial risk factors for wrist disorders has shown a unique relationship pattern among them. There are 4 combined factors extracted from the variables which can be easily divided as Stress factor, Job satisfaction factor, Work environment factor and Reward factor. In several studies many components of these combined factors were observed to be associated with development and progression of the wrist disorder.

The Stress factor contains 5 components (Table 3). Among them job stress (0.79) and physical exhaustion after work (0.79) exerts the maximum effect. These were closely followed by total stress (0.78). From the survey also it can be seen that these factors have a tendency towards higher presence for the patients suffering from wrist disorders. The fourth component is health compared to same age group which also exerts a similar load on the factor (0.75). Mental exhaustion after work has lesser effect on the total stress factor. Different studies have already proved that different stress components enhance the symptoms and progression of wrist disorders. This factor has the highest load on total risk of wrist disorders by psychosocial factors. So reduction of the component factors through proper work management will be effective to optimize the symptoms of wrist disorders.

The job satisfaction factor has components related to contentment about workplace. It consists of 4 components (Table 4): job recommendation to other people, job satisfaction, willingness to take this job again and care about health by work administration. The positive aspect of these components can ease out the symptoms of wrist disorders. As this factor has the second highest loading in total variability, it is also a suitable point for job organizational restructuring.

The work environment factor also affects the total risk of wrist disorders significantly. This factor is consisted of two components (Table 5): relationship with coworkers and depression. Thus modifying these components can result not only in a healthy psychological effect but also can ease out progression of wrist problems.

The fourth important factor is reward factor in a workplace. A good reward system can significantly improve the whole psychosocial aspect of a workplace, which can have an optimized effect on wrist disorders. The components of reward factor are (Table 6): control over the job, payment system and appreciation of work by supervisors.

From the previous studies the presence of these factors can be observed in workplaces with high chances of CTS and other wrist disorders [5–13]. The extraction of all the variables into 4 main factors will help to point several aspects where organization can work to reduce the severity of symptoms and chances of occurrence of disorders. Although the mode of action of psychosocial factors is still under investigation there are several theories present.

It is an established fact that psychosocial factors play a role in development of work related musculoskeletal disorder. Relationship with both personal and workplace factors and WMSDs has been observed in different studies. The effects of psychosocial

factors have been observed mostly in the case of neck, shoulder and low back pain including strongest association with neck pain. However, there are very few studies exploring the contribution of psychosocial factors on upper extremities musculoskeletal disorders. Also these factors are still under extensive investigation due to the interest in their mode of action. The causal pathway of psychosocial factors in development and progression of WMSDs is a matter of great debates. Different models have been proposed to understand the mode of action of psychosocial risk factors [11–13]. One of these models was first described as demand-control-support model [12] of work related psychosocial stress. It was described particularly in the context of cardiovascular disorders in occupational settings. Follow-up research has tried to extend the model to other health outcomes, most notably musculoskeletal research. The model can be described as three factors least control over job, highest demand and least amount of support results in highest level of risk from workplace. A similarly impressive relationship as with cardiovascular disorders has not been established in the case of musculoskeletal disorders. The reasons are less number of studies and less clearly defined output. The Conceptual Model of Siegrist [13] says: “a mismatch between high cost spent and low gains received in occupational life” may lead to physical and psychosocial disorders. It has not been entirely true for musculoskeletal disorder. However, it may be related to the fact that psychosocial stress may lead to some physical changes through neuroendocrine responses. In another model biological effect of stress on musculoskeletal system has been described. This model explains the psychological stress and musculoskeletal system’s feedback relationship. According to this, psychosocial factors (example, job control) influence biomechanical loads through enhancement or reduction of tolerance. In turn, biomechanical factors affects psychosocial load through hormones such as cortisol or muscle tension. This feedback system cumulatively changes the tissue response to a particular job [11].

In summary, although psychosocial factors do not directly affect the risk of wrist disorder, but it definitely modifies the perception of symptoms. Thus the interrelationship model for these will help to identify the modifiable points. Although modification generally means job organizational restructuring but some physical design variable may have influence indirectly. For example, colour, orientation, light etc. have indirect effect on psychosocial factors specifically on stress and work environment components.

## 5 Conclusion

From this study, the relationship among individual and combined psychosocial risk factor was observed. There are 4 main factors that exert significant effect on risk of wrist disorders. These are: stress factor, job satisfaction factor, work environment factor and reward factor respectively on their weightage. Organizational structure, work design and management can be very influential in these cases. There are some other design variables, like colour and architecture, can affect them indirectly.

## References

1. Nunes, I.L., Bush, P.M.: Work-Related Musculoskeletal Disorders Assessment and Prevention. In: Nunes, I.L. (ed.) *Ergonomics - A Systems Approach*. ISBN 978-953-51-0601-2 (2012)
2. Bernard, B.P.: Musculoskeletal disorders and workplace factors. U.S. Department of Health and Human Services (1997). Accessed Dec 2016
3. Barr, A.E., Barbe, M.F., Clark, B.D.: Work-related musculoskeletal disorders of the hand and wrist: epidemiology, pathophysiology, and sensorimotor changes. *J. Orthop. Sports Phys. Ther.* **34**(10), 610–627 (2014)
4. Evanoff, B., Dale, A.M., Deych Ryan, E.D., Franzblau, A.: Risk factors of incident carpal tunnel syndrome: results of a prospective cohort study of newly hired workers. *Work* **41**(01), 4450–4452 (2012)
5. Goodson, J.T., DeBerard, J.T., Wheeler, A.J., Colledge, A.L.: Occupational and biopsychosocial risk factors for carpal tunnel syndrome. *J. Occup. Environ. Med.* **56**, 965–972 (2014)
6. Petit, A., et al.: Risk factors for carpal tunnel syndrome related to the work organization: a prospective surveillance study in a large working population. *Appl. Ergon.* **47**, 1–10 (2015)
7. Harris-Adamson, C., Eisen, E.A., Dale, A.M., et al.: Personal and workplace psychosocial risk factors for carpal tunnel syndrome: a pooled study cohort. *Occup. Environ. Med.* **70**(8), 529–537 (2013)
8. Thiese, I.L., Hegmann, K.T., Kapellusch, J., Merryweather, A., Bao, S., Silverstein, B., Garg, A.: Associations between distal upper extremity job physical factors and psychosocial measures in a pooled study. *BioMed Res. Int.* (2015)
9. Rigouin, P., Bodin, C.J., Le Manac'h, A.P., Descatha, A., Goldberg, M., Roquelaure, Y.: Organizational and psychosocial risk factors for carpal tunnel syndrome: a cross-sectional study of French workers. *Int. Arch. Occup. Environ. Health* **87**(2), 147–154 (2014)
10. Carayon, P., Smith, M.J., Haims, M.C.: Work organization, jobstress, and work-related musculoskeletal disorders. *Hum. Factors* **41**(4), 644–663 (1999)
11. Huang, G.D., Feuerstein, M., Sauter, S.L.: Occupational stress and work-related upper extremity disorders: concepts and models. *Am. J. Ind. Med.* **41**(5), 298–314 (2002)
12. Theorell, T.: Possible mechanisms beyond the relationship between the demand-control-support model and disorders of the locomotor system. In: Moon, S.D., Sauter, S.L. (eds.) *Beyond biomechanics - Psychosocial aspects of musculoskeletal disorders in office work*. Taylor & Francis, Bristol (1995)
13. Siegrist, J.: Adverse health effects of high-effort/low-reward conditions. *J. Occup. Health Psychol.* **1**, 27–41 (1996)





# Developing a Framework that Can Assist Designers to Identify and Incorporate Notable Cultural Elements into Products Designed for Tourists

Wanrisa Bok Kharkongor<sup>(✉)</sup> and Debkumar Chakrabarti

Ergonomics Laboratory, Department of Design, IIT Guwahati, Guwahati, India  
wanrisa89@gmail.com, dc@iitg.ernet.in

**Abstract.** In the ever-changing lifestyles and trends of today, preserving culture and tradition and projecting them to tourists can give a boost to the Tourism Industry. In many cases, travelers have created a mental model of stereotyping a place based on what they hear or feel. There is a need to find out methods that can incorporate deeper meanings of a culture into the products and services designed to give travelers the much-needed exposure to culture and in a way preserving it. A case study has been done on three states of India. These include Bengal, Kerala and Meghalaya to find out the notable and identifiable cultural elements and categorize them based on their projection in the field of tourism by designers. For this study card-sorting method was used to cluster and categorize cultural elements. A framework is devised to assist the designers in designing cultural products to be presented to the tourists.

**Keywords:** Cultural design framework · Cultural elements preservation · Tourists' experience

## 1 Introduction

Travelers these days are in search of destinations whose authenticity can captivate them, leaving a feeling of belongingness to the place. Tourism is a cultural phenomenon. It affects cultures and society, and is shaped by cultures and society [1]. Cultural Tourism is one of the many forms of Tourism that has made its way to give travelers the best experience and attachment with the destination. In this regard, there are unexplored tourist destinations that have a rich culture but lack the ability to portray and display their culture to the tourists. In many cases, travelers have created a mental model of stereotyping a place based on what they hear or feel.

Hall in his Iceberg model of Culture has used the analogy of an iceberg when explaining about culture. He states that culture is made up of three parts; 70% Internal/subconscious – below the water/wave line, 20% External/conscious – above the water/wave line, 10% ± the grey area/the wave line - exposed/hidden by the wave action. The “tip of the iceberg” which is just a small portion of the iceberg, symbolizes the observable behaviours in a culture both tangible and intangible such as dress, language, food, music, architecture, signs of affection, etc. and beneath the water level

are the elements of Culture, which are not observed such as the rituals, norms, values and principles [2].

Culture of a society has become a tourist attraction that draws tourists to participate in new and deep cultural experiences, whether it is on the aesthetics, intellectual, emotional, or psychological level [3]. In the early 1980s, a rising awareness of a connection between aspects of the urban cultural environment and local economic development began to make its appearance [4]. Imagination, myths, and rituals (being the language of emotion) will have an effect on our behaviors, ranging from our buying decisions to our communication with others [5]. Souvenirs for example communicates the Culture of a place to travelers. For a better cultural exposure through products and services, there is a need to find out methods that can incorporate deeper meanings of a culture into such products designed to give travelers the much-needed exposure to culture and in a way enabling the locals in preserving it.

There is a tough competition in marketing of the products, which speaks out the cultural identity of a place. In modern production, functions and technology are essential features, so companies and design studios are looking for ways to use symbolic values in product design to achieve a good competitive position among markets [6].

The selected cultural meaning, which is infused into products, has to be proper and have a pleasing combination with products in accordance to a systematic cultural knowledge and context. By doing this the products will differentiate themselves from others and have their own value and worth [7].

Functionality, attractiveness, ease-in-use, affordability, recyclability, and safety are all attributes that are expected to exist in a product. Users are expecting more from everyday products [8]. While functionality and usability have been regarded as the basic attributes of a product, the intangible emotion or value of a product can even lead to the faith of customers to a company [9].

There is a lack of in-depth research and appropriate methods to assist designers on how culture can be consciously integrated in product design.

This is supported by evidence from the literature, which indicate that there is no solid theoretical framework, which can assist designers to consciously integrate users' culture in designing products in some cultural context. This challenges designers to gain a deeper understanding of users' culture and find strategies on how they can use culture as a resource in product development and promote culture-orientated product innovation [10].

It is observed that in the design field, major topics in cultural design are still only limited to identifying aesthetic stereotypes such as the national shape or colour. These manifestations show that there isn't a well-defined framework that can assist designers to respond to many unanswered questions and problems with regard to the integration of culture in design. The relationship between design and culture has taken many twists and turns throughout the last century, as design is seen as both a mirror and an agent of change. It is observed that modifications in the former's evolution both reflect and determine developments in the latter [11].

There are still few papers discussing design rules for applying cultural characteristics [6].

To understand the unobserved Cultural Elements as defined by Hall and devising a method or guideline to foster more cultural meaning into products, this study aims to understand the representation of Culture by designers in the Indian Context and providing a set of methods to incorporate cultural elements into the products.

It is important for designers to audit existing information types and sources used as design inputs and to test the effect of different types of information on creative inspiration at different phases of the design process [12].

Inspiration can facilitate design thinking and function as ‘triggers for idea generation, and as anchors for structuring designers’ mental representations of designs. Any kind of perceptual experience or memory can give a designer an idea [13]. Through this study, a framework is designed to evoke past memories in the designers of their Culture linked with Myths, Rituals and Symbols that can assist them in deeper thinking while designing the Cultural products.

2 Methodology

A case study has been done on three states of India. These include Bengal, Kerala and Meghalaya to find out the notable and identifiable cultural elements belonging to each of the three states and categorize them based on their projection in tourism by designers. This study gave an overall understanding of how the culture of the three groups is seen from the perspective of a tourist.

For this study there were two methods followed for extracting the cultural elements and categorizing them (Table 1).

Table 1. Methods used in the study

Phases of study	Tools used	Analysis
P1: extracting distinct elements	Questionnaires and interviews	Descriptive analysis spider plots
P2: card sorting	Physical cards and interviews	Cluster analysis dendrograms

P1: Phase 1, P2: Phase 2

2.1 Phase 1: Extracting Cultural Elements from Tourists

For this part of the study, the distinct features of each of the three states viz. Bengal, Kerala and Meghalaya were extracted. A survey was done on 30 participants (tourists) visiting these places. The following question was asked:

1. Write down four things or more that come to your mind when you think of Bengal
2. Write down four things or more that come to your mind when you think of Kerala
3. Write down four things or more that come to your mind when you think of Meghalaya.

These distinct elements have helped in identifying the cultural features of a place for the Card Sorting method described in the next section. The results and analysis of these observed distinct features are discussed in the results section.

### 2.2 Phase 2: Categorizing the Cultural Elements Using Card Sort

Card sorting method was used to cluster and categorize cultural elements in terms of their use and projection in the tourism industry. Classification is the process by which objects are grouped and classified which helps to define how knowledge is represented. Card sorting requires participants to organize a set of instances, referred to as cards due to the original use of analog index cards, into internally-homogenous groups, or categories, according to similarity along an identified sorting principle, or criterion [14]. Depending on the card sorting variant, the sorting criterion and categories may or may not be provided and the kind of information placed on the cards may be different (text, images, icons, etc.) [15].

The different methods of card sorting are as follows:

1. Open, closed and hybrid, 2. Team or individual, 3. Manual or with software [15].

For this study, the methods used were Manual Closed Card Sort carried out individually. This was followed by an in depth interview to understand the mental models of the participants while they perform the card sorting exercise.

### 2.3 Participants Demographics

For this study a sample set of 30 participants having a background in Design-32%, HSS (Humanities and Social Science)-29%, Fine Arts-10% and other educational backgrounds-29% were selected based on purposeful sampling.

A study on the existing theoretical cultural models and framework was also done to extract the cultural elements to be used for the framework design. From Hall’s Model explained earlier the following Cultural Elements were extracted [2]. 54 Cultural elements were extracted and these were printed in cards to be categorized by the participants. The following figure shows the physical cards (Fig. 1).



Fig. 1. Cultural elements

The above cards were sorted and categorized into three groups defined below. The groups are defined, based on the scope of display of culture by designers especially in the field of Tourism. These categories are given below (Fig. 2):



**Fig. 2.** Categories-cultural representations

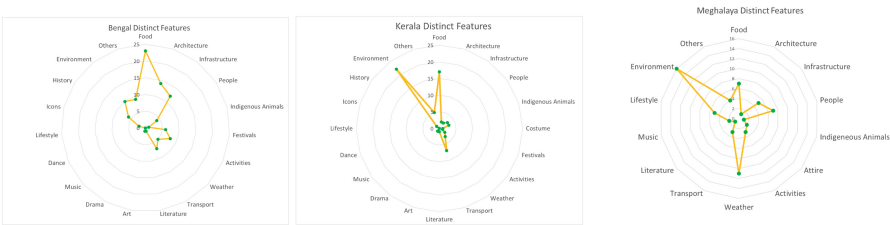
The description of the groups is given as follows:

- 1. Cliché/Common Elements  
This category would include those Cultural elements, which are commonly used by Designers to display the Cultural Identity of a place
- 2. Emerging Elements  
This category would include those Cultural elements, which have the potential to display the Cultural Identity of a place
- 3. Unconventional Elements  
This category would include those Cultural elements, which are unfamiliar and uncommonly used by designers to represent the culture of a place.

The participants were presented with the cards and were asked to categorize them into the defined categories. An interview was also conducted to obtain information regarding their logical reasoning behind selecting and segregating the cards.

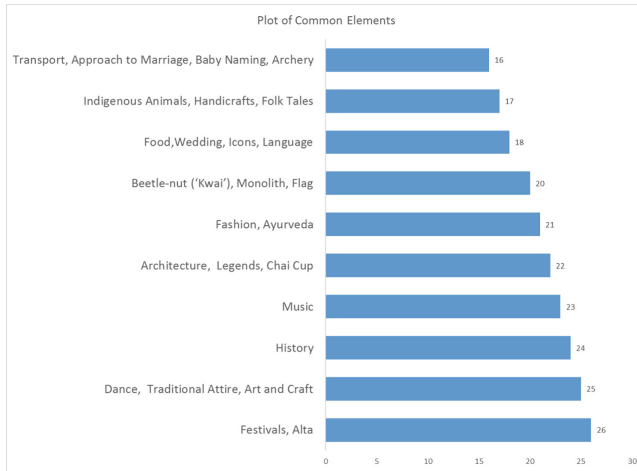
**3 Results and Discussions**

The following spider plot shows the distinct features obtained from tourists visiting the three states viz. Bengal, Kerala and Meghalaya (Fig. 3).



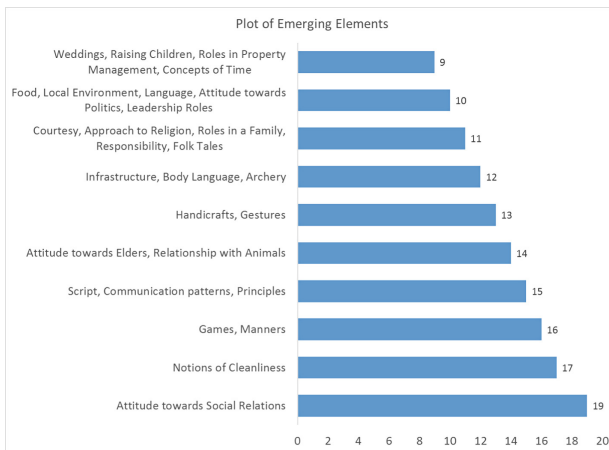
**Fig. 3.** Spider plot of the distinct features of each state

The data collected from the card sorting method was analyzed using cluster analysis and the data obtained from interview was analyzed using content analysis.



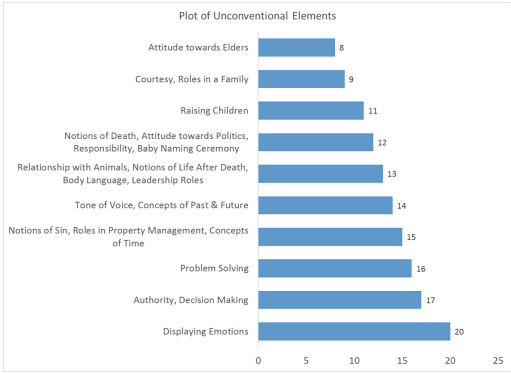
**Fig. 4.** Bar plot of top 10 common elements

The above plot in Fig. 4 shows the first 10 commonly represented cultural elements at tourist destinations. Out of the 30 participants, 26 participants chose festivals and 'Alta' to be the most commonly used representations of culture. Followed by Dance, Traditional Attire, Art, and Craft by 25 participants. History by 24 participants and Music by 23 participants (Fig. 5).



**Fig. 5.** Bar plot of top 10 emerging elements

Emerging Elements categorized by the participants as those that have not been extensively used by designers to represent the culture of a place but have the potential or are key elements that can display the culture (Fig. 6).



**Fig. 6.** Bar plot of top 10 unconventional elements

In the Unconventional Category 20 participants have chosen Displaying Emotion as unconventional or unfamiliar with regards to displaying the Culture. Authority and Decision making was chosen by 17 participants and 16 chose Problem Solving. From the interview with the participants, it was stated that though culture does have an influence on these elements, they are more personal and more individualistic and can differ from one person to the other. Hence, if one has to represent a culture using these elements there will be many factors or context that have to be specified.

For the analysis of the card sort cluster analysis was done using the SPSS software, as shown in the dendrogram in Fig. 7. The hierarchical cluster analysis is typically used to create a proximity matrix or a dendrogram, and it is the most common method used to analyze card sorting results.

The horizontal axis of the dendrogram represents the distance or dissimilarity between clusters. The vertical axis represents the objects and clusters. The dendrogram is fairly simple to interpret [17].

For this study, Ward’s Clustering method was used as it usually creates compact, even-sized clusters [18].

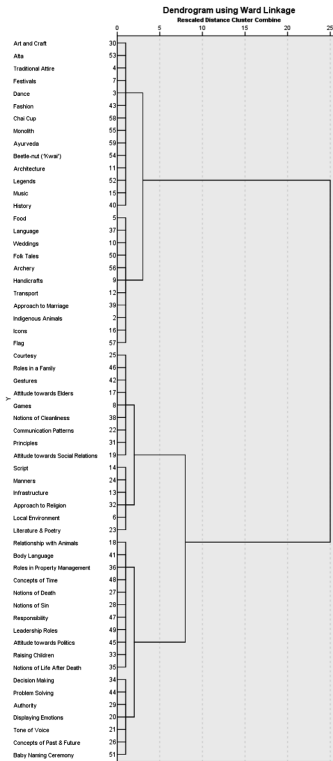
**Framework Design**

The clustered elements as shown by the dendrograms are visually presented in the chart below for clarity.

Categories derived from Phase III: Card Sorting of Cultural Representations and Interview (Cluster Analysis - Dendrograms using Ward Linkage)

- 1. **CE1**- Common Elements 1
- 2. **CE2**- Common Elements 2
- 3. **EE1**- Emerging Elements 1
- 4. **EE2**- Emerging Elements 2
- 5. **UE1**- Unconventional Elements 1
- 6. **UE2**- Unconventional Elements 2

A framework was devised from the hierarchal cluster analysis and content analysis that can help product designers identify notable cultural elements to incorporate in the



**Fig. 7.** Dendrogram of the clustered cultural elements

products. This framework is linked to the Cultural Representations Mapping shown in Fig. 8.

An explanation of the working and dimensions of framework is given below:

Product Attributes: DEE derived from Content Analysis (Fig. 9).

The product attribute viz. Distinctive, Essential and Elementary were derived from the content analysis. The designer can use one or combine more of these attributes into their products.

Cultural Attributes: The Cultural Attributes are derived from the cluster analysis.

After deciding the product attributes the designers can choose the cultural elements from Cultural Representations Mapping. A flowchart of the process is given in Fig. 10.

### Salient Features and Findings of the DEE Framework

- Application of the DEE Framework for designing the mementos or souvenirs, can help designers add a deeper cultural meaning
- The DEE framework can also be used for designing installations in a Cultural space
- It is observed that the framework can assist designers to think more in depth about the culture of a place



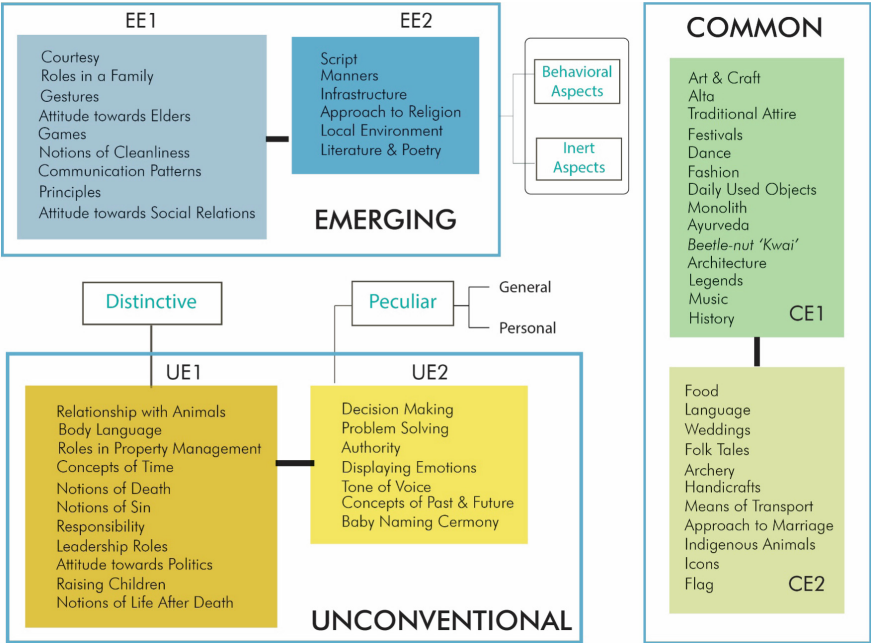


Fig. 8. Cultural representations mapping

DEE Guideline (Proposed Framework)

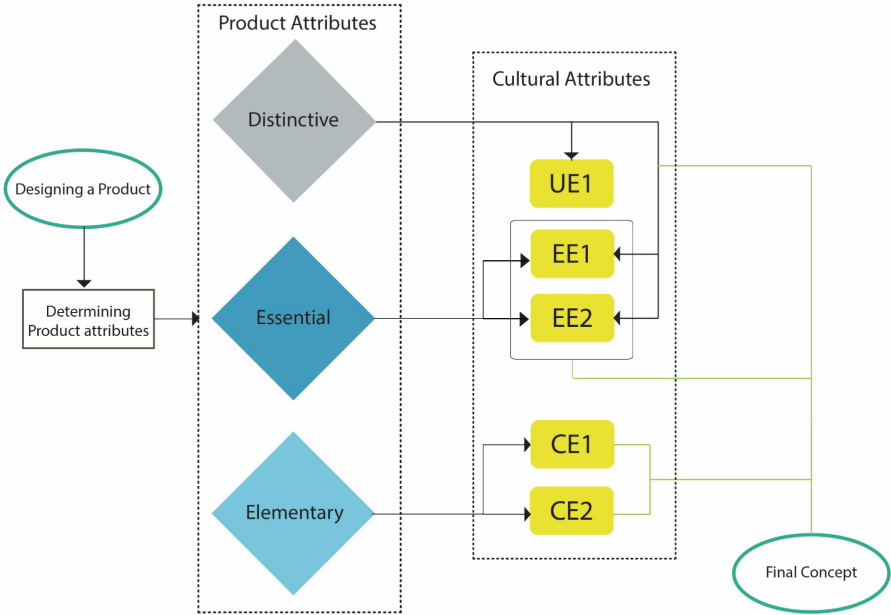
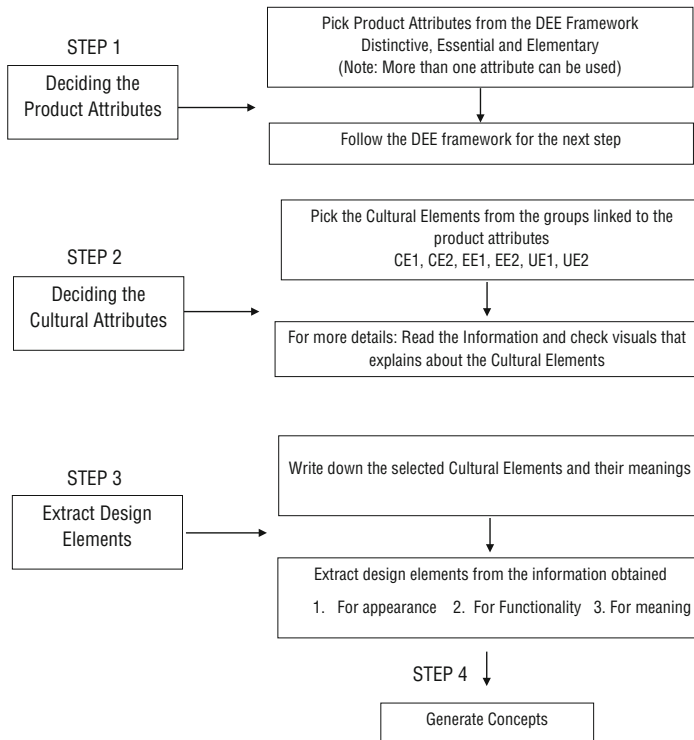


Fig. 9. Proposed framework (DEE)



**Fig. 10.** Flowchart of the process when using guideline (proposed framework)

- The framework also evokes memory on the part of the designer of the myths and rituals of the culture
- The framework is easy to use and the cultural elements are classified into themes of cultural attributes.

## 4 Conclusions

The above framework was given to design students to evaluate their understanding of the design process or flow. These students belong to different Cultural Backgrounds and have an educational background of Visual Design, Product Design and Interior Design. The following Limitations and Future Scope were observed:

### Limitations

While using the framework, it is easier for a designer belonging to a place to design cultural products using the cultural elements of their native place but it becomes difficult when designing products for other cultures unless a detail explanation of the culture is outlined.

## Future Scope

In terms of clarity, the framework can be re-worked by adding the meaning of each of the cultural elements for any chosen Culture to foster designing of cultural services or products more efficiently.

## References

1. Hall, C.M., Lew, A.A.: Understanding and Managing Tourism Impacts: An Integrated Approach, pp. 1–365 (2009)
2. Hall, E.: *Beyond Culture*. Anchor Books Doubleday, New York (1976)
3. Stebbins, R.A.: Cultural tourism as serious leisure. *Ann. Tour. Res.* **23**, 948–950 (1996)
4. Scott, A.J.: Cultural-products industries and urban economic development\_ prospects for growth and market contestation in global context. *Urban Aff. Rev.* **39**, 461–490 (2004)
5. Jensen, R.: *The Dream Society: How the Coming Shift from Information to Imagination Will Transform Your Business*. McGraw-Hill, New York (1999)
6. Wang, Y.H., Qin, S., Harrison, D.: Culture-inspired design principles, methods and tools in current products. In: *International Conference: Consilience and Innovation in Design*, Tokyo, Japan (2013)
7. Ravasi, D., Rindova, V., Dalpiaz, E.: The cultural side of value creation. *Strateg. Organ.* **10** (3), 231–239 (2012)
8. Demirbilek, O., Sener, B.: Product design, semantics and emotional response. *Ergonomics* **46**, 1347 (2003)
9. Celaschi, F., Celi, M., García, L.M.: The extended value of design: an advanced design perspective. *Des. Manag. J.* **6**(1), 6 (2011)
10. Moalosi, R., Popovic, V., Hickling-Hudson, A.: Culture-orientated product design. *International Association of Societies of Design Research*, The Hong Kong Polytechnic University (2007)
11. Moalosi, R., Popovic, V., Hickling-Hudson, A., Kumar, K.L.: Integrating culture within Botswana product design. *International Design Congress*, Yunlin, Taiwan (2005)
12. Luo, S., Dong, Y.: Role of cultural inspiration with different types in cultural product design activities. *Int. J. Technol. Des. Educ.* (2016)
13. Eckert, C.M., Stacey, M.K., Clarkson, P.J.: Algorithms and inspirations: creative reuse of design experience. In: *Proceedings of the Greenwich Symposium: Digital Creativity*, p. 1–10 (2000)
14. Spencer, D.: *Card Sorting Designing Usable Categories*. Rosenfield Media, Brooklyn (2009)
15. Roth, R.E., Finch, B.G., Blanford, J.I., Klippel, A., Robinson, A.C., MacEachren, A.M.: Card sorting for cartographic research and practice. *Cartogr. Geogr. Inf. Sci.* **38**, 89–99 (2011)
16. NCSS Statistical Software. [https://ncss-wpengine.netdna-ssl.com/wp-content/themes/ncss/pdf/Procedures/NCSS/Hierarchical\\_Clustering-Dendrograms.pdf](https://ncss-wpengine.netdna-ssl.com/wp-content/themes/ncss/pdf/Procedures/NCSS/Hierarchical_Clustering-Dendrograms.pdf). Accessed 14 Sept 2018
17. Szmrecsanyi, B.: *Grammatical Variation in British English Dialects: A Study in Corpus-Based Dialectometry*. Cambridge University Press, Cambridge (2012)



# Design Interventions of an Exergame for Fall Problem in Indian Older Adults

Nilakshi Yein<sup>1</sup> and Swati Pal<sup>2</sup>(✉)

<sup>1</sup> Department of Design, Indian Institute of Technology Guwahati,  
Guwahati 781039, Assam, India  
y.nilakshi@iitg.ac.in

<sup>2</sup> IDC School of Design, Indian Institute of Technology, Bombay,  
Mumbai 400076, Maharashtra, India  
swatipal@iitb.ac.in

**Abstract.** In the field of elderly - exergame research, there is limited information available in the Indian context. There is a need to explore how the Indian elderly respond towards such interventions to do the exercise, and if it is not positive what kind changes need to make it more context specific. A study is conducted among Indian elderly (three sets of pilot studies with twenty Indian elderly (age 60 years and above)) with an existing game (DDR) and a tailored exergame as a fall preventive measure. The aim of the study is to give a few design recommendations to design exergame for Indian elderly. The new stepping exergame design process includes the Technology Acceptance Decision Tree (TADT), Indian Anthropometric data. The design recommendations include the prescribed sets of exercise need to convert into a game goal, repeated movements to complete one goal to avoid confusions, self-paced game speed, game theme, and avatar in the Indian context, etc. The findings of the study will be helpful for the researchers in the field of exergame for the elderly while designing for Indian or similar context.

**Keywords:** Elderly fall · Exergame · Stepping exercise · Indian context

## 1 Introduction

Fall in the growing population of the elderly is a serious threat to their independent livelihood. In India alone, the elderly population will reach 17% by 2051 from 7.4% in 2011 [1, 2]. The aging population of this society deserves an active and independent livelihood. In India, nearly 20%–25% of elderly faced brain injury due to fall [3]. The loss of independence, as well as fear of further fall, making this a significant global health issue. Balance related exercises have widely benefited the elderly to avoid falling. The numerous studies (based on group exercise) have established exercise can significantly reduce the fear of fall [4]. The elderly are reluctant to perform traditional exercise due to various reasons like lack of interest, boredom, negative self-worth, not motivated to do exercise etc. [15, 16, 22]. In many developed countries exergames e.g., Dance Dane Revolution, Wii, etc. are used to address negative stereotypes and it also helps them in balance training. Researchers have defined exergames in different studies.

The exergames are interactive video games (VGs) which involve physical activity or exertion tracked as body movement [5]. In another study, it is defined as the VGs that require physical activities to play [6]. It can also be defined as the VGs that use sensing technologies and physical exercises termed in the literature as the Exergames (EXGs), which are now considered as a new educational tool in the health sciences [19].

Exergames are initially used by the younger generation of our society. Later in many developed countries, the older population also showed a huge interest in exergaming [23]. Exergames like Wii, DDR may shape balanced research in the elderly population in a positive direction. Few studies have shown EXGs can influence the elderly to do exercise [20]. The studies have shown both limitations and benefits of an exergame. The market available EXGs like Wii has a narrow board, due to which the elderly might fall while they are playing the game, that are not designed for the elderly [1, 9]. The games require a simple exertion of pressure on the board via the left or right leg/pressure on the top of the board while performing the game. Literature suggested further research on the impact of age-related game elements should be carried out for conclusive results [11, 12]. There is a need to gain more insight into how to use exergames for older adults as an exercise and rehabilitation tool [13].

EXGs like Kinect based or tablet-based games need the camera to capture the body movements [14], so it needs a little technical knowledge to install and or to use it. The previous study shows that although Indian elderly are trying to understand technology related solutions, these are not widely popular in Indian elderly due to the joint effect of the economic and social environment [21, 22]. In India cost of the product also plays an important role, along with that the feasibility and acceptance of such products needed further research [21, 22]. The EXGs which are widely popular in such countries, may not address or interest or it may not be affordable by the Indian elderly in a similar way. The Indian household environment for buying Kinect or availability of the internet and installing is not that convenient as the developed countries.

In few studies, a few theoretical guidelines are available based on the market existing products [11] but the literature also suggested that available EXGs are not basically designed for elderly [9], and as far our knowledge no extensive researches have discussed the elderly fall problem with EXGs specifically designed for the elderly user. Moreover, there is no readily available study that focuses to understand EXGs and Indian elderly as the user, or if any kind of changes is needed in the existing EXGs in the Indian context.

To address the above-mentioned issues a study has been designed that includes existing EXG (DDR), and a tailored EXG specifically designed for the elderly population and considering Indian scenario in mind. The study will give some insights of EXG experience by the Indian elderly and it will help the future researcher or designer to develop the EXGs, as an elderly fall preventive measure in the Indian or similar context.

## 2 Methodology

### 2.1 Participants and Selection Criteria of the Study

For the study participants of the age group of 60 years and above was selected who has volunteered for the study (defined as “Senior citizen” or “Elderly” by “National Policy on Older persons’ in January”, Government of India, 1999) [1]. This study is conducted three times with randomly selected sample from India (East and Northeast part). The total sample size,  $N = 20$  with 10 female and 10 male participants. The age of participants ranged from 60 years to 80 years old (standard deviation of 6.145 years, mean of 66.3 years). A researcher has briefed the participants with the study and their participatory consent was taken before the experiment.

### 2.2 Experiment and Interview Process

The participants are given time to get familiar with the EXGs according to their own pace. To ensure the safety of the participants while playing the EXGs a researcher always stood behind them. Participants played the EXGs for 30 min, followed by an interview. The interview is been carried out using semi-structured methods. Open-ended questions and direct observation methods have used for this study. Each pilot study was carried out in a common place where they can come for the experiment to make participant comfortable in the interview initially general questions are asked. The content of each interview lasted for almost an hour in length. Their views, comments, and reactions have been properly observed and transcribed. Participants interact with the EXG was also video recorded.

### 2.3 Exergame Design Process

The therapeutic EXG prototype is designed using the Technology Acceptance Tree. The designed EXG simulator is based on the Scratch engine, “Scratch 2 Offline Editor”, version: 458.0.1. Later story is designed in the version: 460. Makey Makey is acting as the switch which is attached to a pressure sensor for the interfacing mat shown in the Fig. 3.

**Design Method for Intervention in Exercise.** To identify the need of the end users, that is Indian elderly and to determine whether they likely to accept exergame, pilot studies are conducted in each stage. The study approach taken before designing the final prototype for the EXG tailed for Indian elderly is shown in Fig. 1.

**Designing Exergame.** *Technology Acceptance Decision Tree.* In the design of the Therapeutic exergame, fall preventive stepping exercises are considered. In the process different game concepts were developed. The Technology Acceptance Decision Tree (TADT) [7] is used before the selecting the game concepts.

One example of the process is shown in Fig. 2, using TADT with the concept (1) Inbuilt game activity (example considering a mole to catch, etc.) on the Floor/mat interface.

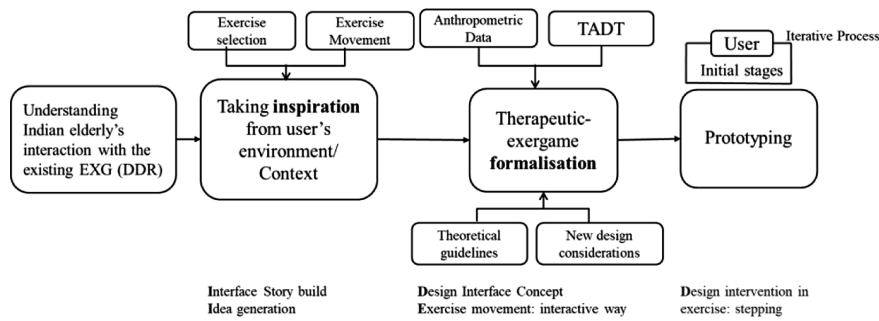


Fig. 1. Design approach for intervention in exercise

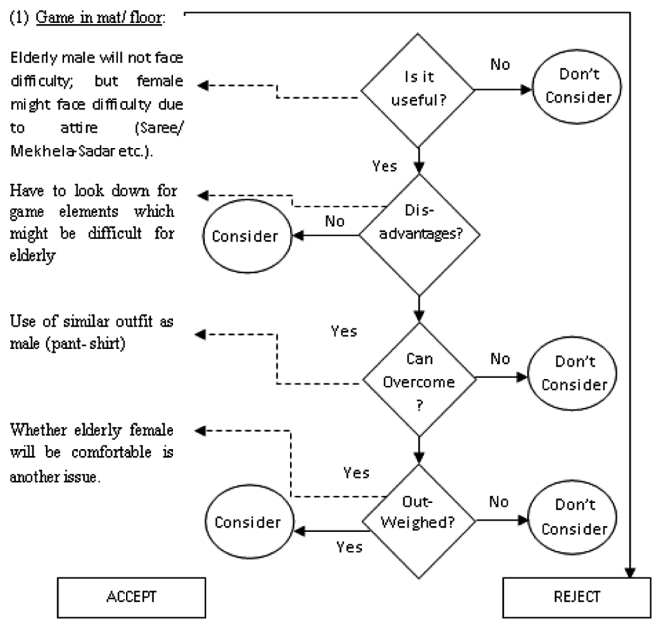
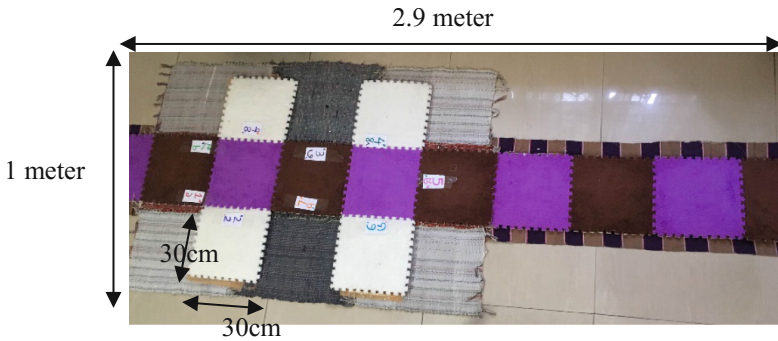


Fig. 2. Example: the use of Technology Acceptance Decision Tree in the game design concept selection.

*Exergame Interface.* The EXG interface is developed keeping elderly physical limitation and Indian anthropometric data in mind. For the first testing, hard paper sheet was used, later on, cloth and finally in a floor mat is designed. The dimensions of the mat for each capacitive pressure switch is 30 cm × 30 cm (step area). The dimensions of the stepping area on the mat are designed considering the foot length of the 95th percentile of the male is 27.4 cm and the foot breadth is 10.6 cm (female is 24.9 cm and 9.6 cm respectively) [8]. The floor mat has not made too large, giving room for ±6 cm length (considering male and female both), as elderly steps are slow and short, do not cover a long distance (observation).

The game theme for the (1) Simple standing with an open eye exercise is designed as fish catching game, named “Fish Catcher”. For the (2) Sidestepping exercise, game theme is designed as a step for a seed to grow into a tree, named “Plant a Tree”. Initially, developed in English language, in the final version it is developed in two languages (English and regional Indian language (Assamese)).



**Fig. 3.** Final prototype for EXG interface (mat) with dimensions

*Stepping Exercise with Game Story.* The EXG is tailored in a self-paced exercise mode with game stories that is related to the real-life situations of Indian elderly. The implication of self-paced exercises for exercise prescription, especially among overweight, sedentary adults, who are most in need of interventions to enhance adherence to exercise programs [10, 11]. Stepping exercises have a great impact on balance improvement [8, 9], and when personal interview was taken Elderly revealed that they perform their exercise in a self-paced manner.

The game movements (stepping) in the tailored EXG are similar to that of the prescribed sets of exercises by the medical experts and practitioners considering Indian elderly’s physical limitations and their real-life scenario. In the game concept development process, different ideas have been formulated. The outcome of the pilot study-I, was carefully considered while developing the game story along with the exercise movements. The game movements (stepping) are designed for prescribed stepping fall preventive balance exercise (FPBE), considering Indian elderly’s physical limitations and their real-life scenario. The stepping actions for FPBE included in these studies are (1) Simple standing with an open eye and, (2) Sidestep-over.

### 3 Findings, Design Modifications and Recommendations

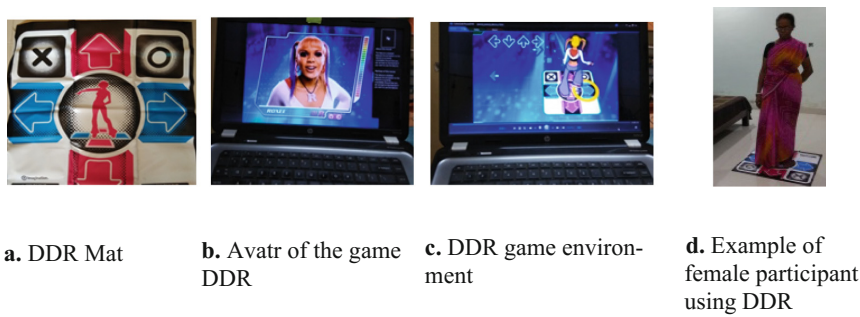
#### 3.1 Findings from the Pilot Studies

The direct observation method and analysis of the transcripts led to the identification of a number of factors that potentially affect elderly users’ experience of the exergame. This section will include the findings of all of the stages of the study.



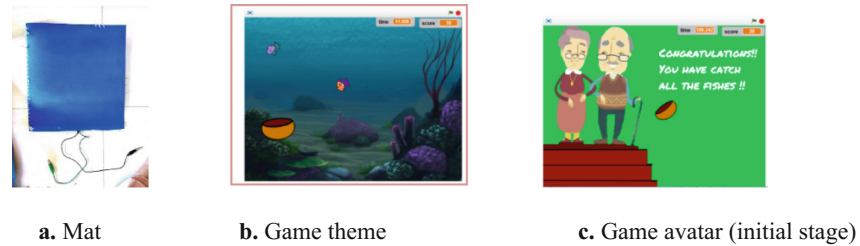
**Pilot Study (1<sup>st</sup>).** The DDR game has different soundtracks; the player can choose the track, on which the player can do the dance steps by following the avatar on the screen. On the screen in front of the player, arrows drift from the bottom of the screen to the target arrows on the top of the screen and participants need to synchronize each of their steps to correspond with the drifting arrow passing over the mat. Here someone has to monitor the steps for competition purpose.

The elderly felt EXG could be beneficial for them, although they mentioned that the game environment is not relatable to their daily living environment (Fig. 4c). In the feedback given by the participants, point out that the cost of DDR is high, and they have suggested to develop a more cost-efficient product. The elderly found the Avatar not relatable to them (Fig. 4b). For elderly women, the arrows on the mat were difficult to see, as all the female participants wore saree/mekhela - saddar (traditional attire) during the play (Fig. 4d). The game movements are too fast to cope. Elderly suggested slower/self-paced movement control in the game and showed interest to use the tailored EXG.



**Fig. 4.** Dance revolution

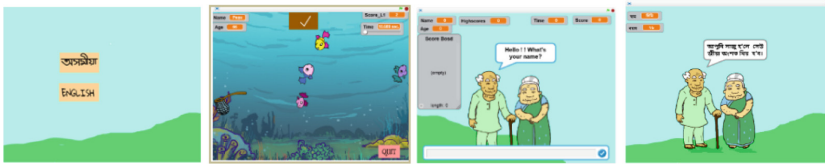
**Pilot study (2<sup>nd</sup>): Fish Catcher.** The fish catcher game environment consists of a tool (T) and fishes that moves in a predefined path. T moves to catch the fishes (Fig. 5b). The movement is dependent on the standing time of the user. As long as the user will stand on the mat as shown in Fig. 5a, the game will continue, else will stop. In the new designed EXG, if the elderly user chooses to quit the game there will not be any kind of negative feedback in the game.



**Fig. 5.** Game interface fish catcher at initial stage.

At the end of the experiment, researcher asked the participants to give their opinion about their experience with the EXG. It has been found from feedback that the elderly enjoyed the game theme (cartoon) and they have mentioned introducing an Indian elderly with a traditional attire as a game avatar instead of using an elderly with western outfits (Fig. 5c). The final prototype has designed keeping the finding of this study in mind.

**Pilot Study (3<sup>rd</sup>) - Modified Game: Fish Catcher and Plant a Tree.** The fish catcher game designing process is similar as mentioned in the previous section. The interface is designing based on the previous pilot study (Fig. 6) and the theoretical guidelines [11].



**Fig. 6.** Game interface with Assamese and English language with “fish catcher” game environment.

In the game “Plant a tree”, elderly has to step on the mat side-wise for 10 times (brown square area, in Fig. 8b). With each step, the seed will grow into a tree (Fig. 7).



**Fig. 7.** Game interface “Plant a tree” game environment in Assamese language.



**a.** Example: User in “fish catcher” game **b.** Example: User in “plant a tree” game

**Fig. 8.** Game interface with the mat



**Fig. 9.** Display of the game complete time for each participant after each session.

The study revealed that there is a difference in the duration to complete the standing exercise with and without the EXG. The average time difference in simple stand exercise with EXG was +22.8 s than that of manual one. The findings suggested when the elderly were using EXG they were more focused on the screen and not on the time duration. This is an important factor as elderly were doing the exercise with self-motivation.

In the designed EXG at end of each game, the duration of time play is displayed on the screen as a score board (Fig. 9), which is saved automatically. This is another important aspect. The doctors or physiotherapists use their knowledge and experience to assess elderly exercise improvement manually. The display of the quantitative data can be assessed by the user as well as the experts (doctor or physiotherapist) later on. It will help the elderly to keep their track for each session and help them to understand their exercise performance changes.

To minimise the complexity to set up the EXG the new EXG is designed with minimum wire connections, which is compatible with any laptop or desktop computer. The interface mat is designed as a portable product, which is light weight and takes less space. The present estimate cost of the product is Rs. 6000 which will include more exercises.

The feedback of the users unveiled a positive response with other factors like: the game avatar, the self-paced game movements, cost of the product, easy installation, and compact size etc.

**3.2 Design Modification**

The initial EXG testing in the pilot study, as mentioned in the previous section, and the results of the study leads to the necessity to modify the prototype. The following modifications are incorporated in the final tailored EXG.

- a. In the new theme, elderly with Indian wear are introduced as the avatar.
- b. The initial design “fish catcher” game had a definite path without any random/surprise movements, this made the game complete time same for every session. The observation showed the same predictable complete time made elderly less interested after 8 to 10 times use. So, a random time delay is given in the game, to make the end time unpredictable.

- c. In the initial stage, the game instruction was not continuously displayed on the screen. To lessen the cognitive load on elderly to remember the move visual instruction is incorporated (marked as “V” in Figs. 6 and 7).
- d. In the interactive floor mat, elderly can do different sets of prescribed stepping exercise (Fig. 3).

### 3.3 Design Recommendations

In the game design process few new design considerations have been incorporated, that can be used by the future researchers for designing EXGs for elderly fall in the Indian context.

- The elderly’s prescribed exercise sets can be converted into game goals.
- To avoid the frustration of fast/slow movements’ self-paced movements should be included to complete the game task.
- For elderly repeated step movements should be included to complete one goal or game task. This will help the elderly to remember the steps more easily and will reduce the cognitive load.
- Users attires should not restrict the users’ physical movements while playing.
- Relate exercise movement with game story.
- Instructions in written form visible through the game.
- The elderly should able to install EXG easily with minimum connections and compatible with all operating systems in laptops or computers. Easy installation and lesser complex connections will encourage elderly to use new technology more easily.
- Game goals are typically broken into small parts to boost elderly interest.
- The language of the game narration plays an important role to communicate to the users. To play the game language selection option should be included.

The maintenance and repair of the EXG should be readily available.

## 4 Discussion

Fall is a critical problem in the elderly, affecting their healthy lifestyle. Balance exercises can help to prevent falls in elderly. Although elderly does know about the positive benefits of exercise, but most of the elderly does not exercise at recommended levels. The factor that most of the elderly does not exercise at recommended levels [15]. The literature showed attitudes of the elderly influence the successful completeness with long-term exercise [15, 16]. There is an abundance of studies discussing the EXGs with elderly, and theoretical guidelines for designing EXGs for the elderly, the products used in the study are not specially designed for elderly and they are not appropriate for them [9, 11, 17, 18]. The elderly user’s perception on EXG is not under the scope of the present study. In Indian context, more study is needed in the field of technology related solution for elderly fall [21, 22]. The EXGs in the Indian context can be a novel way to approach these issues.

This can also increase the time span engaged by the elderly in the exercise in a more fun way than the traditional way of exercise and the quantitative output will help the elderly, as well as the experts to understand the users' improvements. The present study reveals that the Technology acceptance Decision Tree (TADT) can help to get the insight into the relevant issues that elderly considers before accepting a new technology: here the therapeutic EXGs. TADT can help to merge different aspects like the elderly physical (range of motion, game speed, movements)/contextual limitations that are comfortable with the attire, availability of the supporting system or space to install or operate the EXG, technology, etc. The game avatar, the speed of game movements, installation process, and the cost of the product, etc. are important aspects of EXG in the Indian context. In the future study the recommendations can be used in different fall preventive balance exercises in new games in contextually similar countries. The evaluation of the EXG can also include the assessment of the improvement in balance.

**Acknowledgements.** The authors thank the participants for their participation. Author also like to Subir Dey for the sketches used in the game interface.

## References

1. Jeyalakshmi, S., Chakrabarti, S., Nivedita, G.: Situation Analysis of the Elderly in India. Central Statistics Office, Ministry of Statistics & Programme Implementation. Government of India (2011)
2. Rajan, S.I.: Population ageing and health in India (2006)
3. Krishnaswamy, B., Usha, G.: Falls in Older People: National/Regional Review India. Madras Medical College and Government General Hospital, Chennai (2006)
4. Liu-Ambrose, T., Khan, K.M., Eng, J.J., Lord, S.R., McKay, H.A.: Balance confidence improves with resistance or agility training. *Gerontology* **50**(6), 373–382 (2004)
5. Padala, K.P., Padala, P.R., Lensing, S.Y., et al.: Efficacy of Wii-fit on static and dynamic balance in community dwelling older veterans: a randomized controlled pilot trial. *J. Aging Res.* 9 (2017). <https://doi.org/10.1155/2017/4653635>. Article ID 4653635
6. Nurkkala, V.-M., Kalermo, J., Endo, Y., Goto, M.: A pilot study to explore the possibilities of an interactive multipurpose exergaming simulator for senior activation. In: International Conference on Modeling, Simulation and Visualization Methods (2016). ISBN 1-60132-443-X
7. Fisk, A.D., Rogers, W.A., Charness, N., Czaja, S.J., Sharit, J.: Designing for Older Adults: Principles and Creative Human Factors Approaches. CRC Press, Boca Raton (2009)
8. Chakrabarti, D.: Indian Anthropometric Dimensions for Ergonomic Design Practice. National Institute of Design (1997). ISBN 81-86199-15-0
9. Brox, E., Luque, L.F., Evertsen, G.J., Hernández, J.E.G.: Exergames for elderly: social exergames to persuade seniors to increase physical activity. In: 5th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth), pp. 546–549. IEEE (2011)
10. Theng, Y., Dahlan, A.B., Akmal, M.L., Myint, T.Z.: An exploratory study on senior citizens perceptions of the Nintendo Wii: the case of Singapore. In: Proceedings of the 3rd International Convention on Rehabilitation Engineering & Assistive Technology, i-CREATE 2009. ACM, New York (2009). <https://doi.org/10.1145/1592700.1592712>

11. Gerling, K.M., Schild, J., Masuch, M.: Exergame design for elderly users: the case study of SilverBalance. In: *Proceedings of the 7th International Conference on Advances in Computer Entertainment Technology*, pp. 66–69. ACM, November 2010
12. Baez, M., Ibarra, F., Far, I.K., Ferron, M., Casati, F.: Online group-exercises for older adults of different physical abilities (2016)
13. Maroni, N.S.: Exergaming in older adults: use, user experiences, and the relationship between game elements and movement characteristics (2016)
14. Beaulieu-Boire, L., Belzile-Lachapelle, S., Blanchette, A., Desmarais, P.O., Lamontagne-Montminy, L., Tremblay, C., Tousignant, M.: Balance rehabilitation using Xbox Kinect among an elderly population: a pilot study. *J Nov Physiother.* **5**(02), 261 (2015)
15. Pappous, A., Cruz, F., De Leseleuc, E., Marcellini, A., Recours, R., Schmidt, J.: Attitudes of the elderly toward physical activity and exercise. Adaptation of the older person's attitudes toward physical activity and exercise questionnaire in Spain. *Stud. Phys. Cult. Tourism* **13** (1), 69–77 (2006)
16. Wankel, L.M.: Exercise adherence and leisure activity: patterns of involvement and interventions to facilitate regular activity. In: *Exercise Adherence: Its Impact on Public Health*, pp. 369–396 (1988)
17. Granic, I., Lobel, A., Engels, R.: The benefits of playing video games. *Am. Psychol.* (2013)
18. Anguera, J.A., Boccanfuso, J., Rintoul, J.L., et al.: Video game training enhances cognitive control in older adults. *Nature* **501**(7465), 97–101 (2013)
19. Vagheti, C.A.O., Monteiro-Junior, R.S., Finco, M.D., Reategui, E., da Costa Botelho, S.S.: Exergames experience in physical education: a review. *Phys. Cult. Sport Stud. Res.* **78**(1), 23–32 (2018)
20. Xu, X., Theng, Y.L., Li, J., Phat, P.T.: Investigating effects of exergames on exercise intentions among young-old and old-old. In: *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, pp. 2961–2968. ACM, May 2016
21. Yein, N., Pal, S.: Technological assistance for fall among aging population: a review. In: Chakrabarti, A., Chakrabarti, D. (eds.) *Research into Design for Communities*, Volume 1. ICoRD 2017. Smart Innovation, Systems and Technologies, vol 65. Springer, Singapore (2017). [https://doi.org/10.1007/978-981-10-3518-0\\_36](https://doi.org/10.1007/978-981-10-3518-0_36)
22. Yein, N., Pal, S.: Qualitative study on salient factors influencing Indian elderly's perception on fall and its related interventions. In: *8th International Conference on Applied Human Factors and Ergonomics (AHFE 2017)*, 17–21 July 2017, The Westin Bonaventure Hotel, Los Angeles, California, USA (2017). <https://doi.org/10.1007/978-3-319-60597-5>. [https://doi.org/10.1007/978-3-319-60597-5\\_11](https://doi.org/10.1007/978-3-319-60597-5_11)
23. Oh, Y., Yang, S.: Defining exergames & exergaming. In: *Proceedings of Meaningful Play*, pp. 1–17 (2010)



# A Re-look into the Information in Multimedia Design and Animation Theme Presentation

Manoj Majhi<sup>(✉)</sup> and Debkumar Chakrabarti

Department of Design, Indian Institute of Technology Guwahati,  
Guwahati 781039, Assam, India  
{manojmaj, dc}@iitg.ac.in

**Abstract.** Human factors and ergonomics involves the “fit” amongst the user, tools, and surroundings is to take into account the user’s abilities and limits that can be used to look for, to confirm that jobs, purposes, information, and the surroundings that can be the fit that a user can be provided with. An experience of hand rendering was used effectively, using the final frame of the hand render, to be used to design a moving visual. The frames used to design a moving visual through a stop-motion animation technique showing the abstract display of the refinement in the design. The design student learns the fineness of the technique to communicate imaginative exquisiteness. The procedure was used to bring the behind the scene technique forward, such that it is useful for users to assume the technique after inputs of their peers, such as to allow students’ to imagine and enrich to provide an experience.

**Keywords:** Multimedia · Animation · Stop-motion · Design · Education

## 1 Introduction

The context of effective multimedia communication can be interpreted in many different ways and as well as in many different fields likewise. Expression of themes through abstract imagination is done in many different ways. To allow this the effectiveness of the concepts of design can be easily comprehended. The essence of design can be imparted through the day to day activities, for which a set of experiments were carried out to let the students feel comfortable as well as confident in the pragmatic attempt, to learn the fundamentals of design effectively. The fundamentals can be put in simplified form through discovering design elements in various mediums of communication that are used commonly.

The students of design normally try to implement most of what their learning of the subject allows. It has been experienced that, there is a lag in following the technique if the learning techniques become lengthy. Students communicate their talent with their acquired knowledge and it has been observed that, if the learning techniques become lengthy, many-a-time they lose patience.

The next step of the trial was to check if by giving freedom in the usage of their desired mediums of communications to represent a social message gave them the motivation to learn the technique and could follow the procedure if they had missed it earlier or can be acquired from friends.

## **2 The Objective**

The objective was to allow the students' imagination to be enriched with the effective multimedia communications in multiple areas such as to provide an experience, through interactive imagination, from the various mediums of communication wide area for the students to explore so as to get the communications.

## **3 Experiments: Theme Based**

Everything that can be a means of information collection in the study, can be an effective study tool or a study instrument as observational forms, interview schedules, questionnaires and interview guides. The building of the study instrument is the primary practical step to carry out the study. The methodology to collect the data for the study as well as an instrument to collect the data needs to be put in place. For primary data of the study, a study instrument needs to be designed or select a tool that has already been tested.

## **4 Setting up the Experiment: Planning and Conducting Survey**

Everything that can be a means of information collection in the study, can be a study tool or a study instrument as observational forms, interview schedules, questionnaires and interview guides. The building of the study instrument is the primary rational step to carry out the study. The methodology to collect the data for the study as well as an instrument to collect the data needs to be put in place. For primary data of the study, a study instrument needs to be designed or select a tool that has already been tested.

This, in turn, brings more effectiveness to the scheme of the study of Blueprint of the chart of the concept of a construction. To depict the diagram made from the doodles of the dummy formulated which makes up for the outline of the paste-up of the perspective from the tracery of the tracing for the treatment of students, parts of students, a group of students, and other living things. It has a wide application in many different mediums of design.

## **5 The Context of Interactivity**

It can be interpreted in many different ways and in many different fields; likewise, the same is practicality of the experience, interactive imagination, communicated in many different ways by the students of multimedia design. To allow this segment, the effectiveness of the concepts of design that can be easily comprehended, the essence of design can be imparted through the day to day activities. A set of experiments were planned to let the students feel comfortable as well as confident in communications experience, of the interactive communication of the attempt to learn the fundamentals



of design effectively. The fundamentals can be put in simplified form through discovering design elements in the many mediums that are used commonly.

The students profile – JEE cleared students along with a successfully clearing an aptitude for design (Chakrabarti 2011) whose students are between the age groups of 16–18 years of age. The target students were 81% Male 19% Female.

A focus group is necessary for design, a focus group can be an effective method of qualitative study in which the target students are inquired about their understanding, views, assumptions as well as points of view of a design. The inquiry is given in an interactive session in which the students can feel free to interact with other members of the group. This procedure may be informal as well as formal, with a group of 5–10 students, smaller groups of 4–6 students may also be done.

These smaller groups can be called focus groups. These groups vary i.e., two-way focus groups in which one focus group observes the other and discusses the observations of the interactions and results. Dual moderator focus groups have two moderators, in which the first moderator makes sure of the session progresses seamlessly, and the other makes sure of the subject being taken into consideration. The challenging moderator focus group has two moderators as mentioned earlier. Take different sides of the topic that is in focus with debates being motivated. Respondent/client moderator group has one of the respondents being queried about to interact as the moderator provisionally.

An online focus group of new media is enabled to affect the interactivity effectively between the members of the group. The many areas in which the students planned to work in were in the areas of Smoking, Alcohol, Littering, Racism, Sex Education, Daily routine, Promotional, Music Video, and Social Causes Awareness.

## 6 Sample Size

To test the effectiveness of sketching without peer intervention and with peer intervention, communications experience in using creative imagination was used. In the design task of having to use interact with a natural medium of having to communicate a design concept was tried out. It gave favorable results and was taken forward by having to use the technique of seeing perceiving and sketching a design concept was practically tried out, an awareness test was arranged for the students. The students' profiles were, 21% of the students from Andhra Pradesh, 15% of the students from Assam, 13% from Madhya Pradesh, 13% from Rajasthan, 10% from Bihar, 10% from Uttar Pradesh, and 3% each from the states of Gujarat, Kerala, Maharashtra, Manipur, Punjab, Delhi of India.

## 7 Identification of Students' Segment and Respondent Profiling

Profiling can be standardized by the data accumulated of the students' segment that usually is analytical, geographic, and psychographic by utilizing a graphical representation of the relative strength of the distinguishing characteristic or quality of an

individual. It may not be possible to locate an uni-profile, as well as manageable types of students profiles which can be utilized to locate all the students of a selected segment. A limited number of profiles can be adapted to an intended majority of the students in each segment.

## 8 Administration of the Test for the Focus Group

A focus group test is not easy to predict the interpretation or response to the queries on a discussion guide, usually when the guide is not in the common language. For this a pilot test becomes critical. The primary copy of the discussion guide is not free of problems and pilot testing of the queries become important in the design of the discussion.

The test incorporates the query of the questions discussed for a crucial part of communities having similar and matching with the chosen group, to access the effectiveness of the queries. In a wider focus group study, the pilot testing may not be possible. In the case of inability to identify a suitable group from the community, the queries can be directed to specific individuals. As its essential use of the pilot testing has to be the identification of queries are easily evaluated as well as if the queries and their significance to interact effectively the imaginative experience, communication planned for the study.

## 9 Summary of Responses of Focus Group Study

The comprehensive study of the connection between the survey feedbacks can be displayed in more details as compared to the prior comparisons. A continuous attitudinal response in a focus group is done using the combined continuous attitudinal response technology with the survey study for the same. This method pairs two mediums allowing each medium to effectively use the communications interactive experience to assist the interactivity between the mediums.

The students were taken for the realism in the experience, the communicative imagination of allowing an effective method of design. Students enriched by such feedback were asked to give their understanding on their own production. At the end, their projects were put under peer group reviews as well as presented to others for common views placing in the exhibition hall at Department of Design.

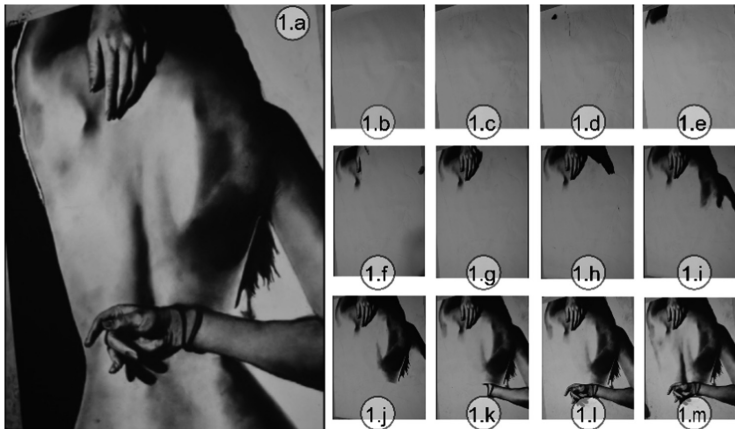
The students were given an hour to analyze a given physical object of a product design, an effectively such as to give the viewer a comprehension of the design.

The assignments were selected based on some social themes. Students were asked to list down as they interact with respect to the important social issues/messages in the present context and then the most important being chosen by peer group choice. In various realities in the experience, story planning and imaginative communication, tasks, the lacuna in the students understanding were singled out; is followed by learning by doing the principles (Gaiziunas et al. 2013).

The technique of hand rendering used effectively, by utilizing the final frame of the hand render used to design a moving visual. The frames hand rendered used to design was chosen by the users based upon the technique of the dynamic visual

communication through a stop-motion animation frames as emphasized in Figs. 1a and b–m showing the abstraction to display the aesthetics in the design. Student learnt the fineness of hand skill to be able to express the imaginative aesthetics. The story board format of visualisation used also seemed to help the users design effectively.

The story line could be modified if needed so as to produce excellence of



**Fig. 1.** **a.** The final frame of the hand-rendered aesthetic and abstract visualization in the static and the dynamic format. **b–m.** The key-frames of the development stages of the visualised animation.

assignments when peer group discusses and do it through a feedback refinement unfinished phenomenon. The study was used for effective multimedia communication to interactively communicate a design using a multimedia design for a conference. The paper was to understand the students' interaction from the communications experience in using interactive communication in the medium of text, effective medium to use the art or process of printing with type to highlight its sensitivity and fineness in media television as typography in motion.

## 10 Some Observations on the Methodology and Its Limitation

To get the students' perspective of the communication experience with the maximum and minimum effectiveness values of the interactivity of the mediums is crucial. To measure the values of the communications experience, interactive communications that are consistent with the medium of interest under consideration plays an important part in the study. To evaluate this effectiveness of the data towards being able to attain the goal, categorization of the data using the sorting techniques which are available in MS Excel and similar programs. The assignment done by students and the outcome is being presented below.

## 11 Conclusion

The importance of visual culture in the study of one of the mediums of multimedia communication - animation will be studied for its Interaction to effectively communicate the desired message to the target audience. This study will be analysed quantitatively and qualitatively to get the results in using a digitized Cel-Animation (Gavankar 2011) technique aesthetically to communicate an imaginative message effectively.

The abstract visualization assists for the students to imagine or think out of the box innovatively, this assists in bringing forward the new areas which may not have been thought of before. To enable the thought process, it is necessary for the students to think creatively for which an interactive environment needs to be utilized for the students to visualize. Many a time there is a disconnect with the visualization but at a later stage it can be effective, an imaginative visualization assist in the communications to become effective just as was visualized to imagine the interactive communicative need of a primitive man, while the visualization could imagine a remote controlled television set when sitting idle. It was effective as the students got a feel of the experience that could allow the imaginative visualization to become an effective design. The students also tried out effective communication methods to design for contexts; it has been discussed in the next section.

Theories in the theoretical model, phases and quantitative or qualitative techniques of the study standard, were utilized to comprehend the aesthetic as well as the abstract imagination of the students to design. The effective practices were observed and utilized to the required contexts, this was done such as the area of hand sketching (free hand as well as constrained) (2 groups results) creative ideation using techniques of communication - still images and moving images (2 groups results).

The outcome of the students' communication in using the experience, in imaginative and innovative along with the discussions with their peer groups in their assignments.

## References

- Chakrabarti, A.: Research into Design: Supporting Sustainable Product Development, p. 115. Research Publishing Services (2011)
- Gaiziunas, N.: Manager Moving Mountains: Return on Education: Excellent Employees, Brilliant Performance, Best Results Chapter 4 (2013)
- Gavankar, N.N.: The Desai Trio and the Movie Industry of India, p. 174. Author House (2011)

# Author Index

## A

Abreu, Manuel Adler, 263  
Adam, Dominique Leite, 254  
Ai, Xin, 275  
Almeida, Ana, 427  
Almeida, Catarina Machado, 597  
Almeida, Victor M., 220, 359  
Almendra, Rita, 370  
Alves, Jose Luís, 68  
Alves, Maria Aurileide Ferreira, 677  
Amaral, Mariana, 91  
Antunes, Sara, 370  
Aquino, Leonard T., 318  
Araneta, Daniel G., 318  
Arce-Lopera, Carlos, 514  
Ashdown, Susan P., 721  
Austria, Jeremiah V., 318  
Azevedo, Flávia, 742

## B

Boldt, Rachel S., 721  
Brandão, João Aranda, 597  
Brandão, João, 136, 383  
Brangier, Eric, 242

## C

Cabral, Teresa Olazabal, 79  
Cai, Mengjing, 502, 531, 551  
Carvalhais, José, 462  
Carvalho, Diana, 68  
Carvalho, Miguel A. F., 721  
Censon, Briant Angelo M., 318

Chakrabarti, Deb Kumar, 794, 816  
Chen, Xuemei, 296  
Chen, Yongquan, 177  
Chen, Yu, 683  
Chen, Ziding, 177  
Coimbra, Inês Farmhouse, 79  
Correia, Igor, 68  
Cruz, John Michael A., 318  
Cruz, Luciana, 742

## D

da Silva Oliveira, Aline, 656  
da Silva, Caelen Teger, 254  
da Silva, Fernando Moreira, 48, 91, 188, 287  
de Assunção Neves, Renata, 656  
De Guia, Wendel Jimver, 318  
Desouza, Gustavo, 15  
Deswal, Ajay, 769  
do Carmo Kattau Lopes, Maria, 609  
Dsingh, Ajita, 775  
Dursun, Melis, 628

## E

Esteves, Salomé, 404

## F

Falcão, Gonçalo, 677  
Fan, Xiaoli, 164, 296  
Fernandes, Ana Margarida, 485  
Fernandez, Patrick Henry S., 318  
Ferrão, Leonor, 35, 57  
Ferreira, Fernando B. N., 721

Filgueiras, Ernesto, [15](#)  
 Filho, Mario Saleiro, [563](#)  
 Francisco, Diane Denise, [110](#)

## G

Galvão, Inês, [436](#), [452](#)  
 Ginja, Luis Miguel, [621](#)  
 Giraldo, Jose, [514](#)  
 Graça, Nuno, [452](#)  
 Gregorio, Patricia Michaela C., [110](#)  
 Griffin, Linsey, [721](#)  
 Gu, Sen, [538](#)  
 Gu, Zhenyu, [753](#)

## H

Hakozaki, Fumitake, [494](#)  
 Han, Peng, [522](#)  
 Hong, Pu, [502](#), [531](#), [551](#)  
 Hu, Huimin, [164](#), [325](#), [502](#), [531](#), [551](#), [711](#)  
 Hu, Xiaoping, [147](#)  
 Huang, Cheng, [538](#)

## I

Imanghaliyeva, Amangul A., [665](#)

## J

Jiang, Rong, [753](#)  
 Jiang, Yuwei, [296](#)  
 Jiayu, Cheng, [494](#)  
 Jimenez Garcia, Juan, [514](#)  
 Joines, Sharon, [3](#)

## K

Kameno, Satoshi, [494](#)  
 Karadeniz, Aylin, [628](#)  
 Kaur, Amanpreet, [775](#)  
 Kharkongor, Wanrisa Bok, [794](#)  
 Kim, Byungsoo, [3](#)  
 Koszela-Kulińska, Joanna, [23](#)

## L

Laginha, Catarina, [188](#)  
 Lameira, Vanessa, [462](#)  
 Layug, Ninna Ysabel G., [110](#)  
 Lessa, Joana, [349](#)  
 Li, Qin, [122](#)  
 Li, Yinxia, [502](#), [531](#)  
 Liang, Zhang, [584](#)  
 Liu, Taijie, [325](#)  
 Lo, Chi Hang, [640](#)  
 Lobo, Theresa, [334](#)  
 Lopes, Arminda Guerra, [228](#)

Luh, Ding-Bang, [761](#)  
 Luo, Hong, [325](#), [531](#), [551](#)  
 Luo, Ling, [103](#), [502](#), [648](#), [711](#)

## M

Majhi, Manoj, [816](#)  
 Maldonado, Paulo, [57](#)  
 Mallare, Nikole Andrei B., [110](#)  
 Marache-Francisco, Cathie, [242](#)  
 Martin Sanromán, Juan Ramón, [91](#)  
 Mendes, Mónica, [228](#)  
 Mendonça, Pedro, [263](#)  
 Meng, Yanhua, [122](#)  
 Michalak, Dariusz, [305](#)  
 Michalski, Rafał, [23](#)  
 Montoya, Camilo, [514](#)  
 Moraes, Anna S. P., [721](#)  
 Moreno, Adriana, [228](#)  
 Moreno, Kent Xaivery L., [318](#)

## N

Neto, Maria João Pereira, [413](#)  
 Neves, João, [48](#), [188](#), [287](#)  
 Neves, Marco, [220](#), [359](#), [394](#), [404](#), [413](#)  
 Ng, Joshua M., [318](#)  
 Noriega, Paulo, [68](#), [207](#), [427](#), [436](#), [452](#), [462](#),  
[472](#)  
 Nunota, Ken, [494](#)

## O

Okimoto, Maria Lúcia Leite Ribeiro, [254](#)  
 Oliveira, Tiago, [68](#), [207](#), [462](#)

## P

Pal, Swati, [805](#)  
 Pan, Wenzhen, [275](#)  
 Paul, Arunita, [783](#)  
 Pestana, Ricardo Maia, [136](#), [383](#)  
 Ping, Zhang, [584](#)  
 Poças, Ana Rafaela, [394](#)  
 Porciuncula, Emmanuel Oliver D. C., [318](#)  
 Preto, Sandra, [571](#)

## R

Rafael, Sónia, [220](#), [359](#)  
 Ran, Linghua, [103](#), [122](#), [155](#), [325](#), [648](#)  
 Raposo, Daniel, [48](#), [91](#), [136](#), [188](#), [287](#)  
 Rebelo, Francisco, [68](#), [207](#), [427](#), [436](#), [452](#), [462](#),  
[472](#)  
 Reyes, Genhino Glenn D. C., [318](#)  
 Ribeiro, Rogério, [91](#)  
 Rijo, Cátia, [700](#)

Rolo, Elisabete, 609  
Romãozinho, Mónica, 733  
Rozmus, Magdalena, 305

**S**

Salmon, Paul, 665  
Salvador, Cristina, 692  
Salve, Urmi R., 783  
Santillan, Aroma M., 318  
Santos, Cristina, 413  
Sator, Nicole, 325  
Semedo, Daniel, 452  
Shen, Tong, 296  
Shen, Yongjia, 296  
Shiraishi, Mitsuaki, 494  
Siebert-Cole, Erika, 325  
Silva, Ana, 15  
Silva, José, 48, 188, 287  
Simeng, Yang, 584  
Singh, Ajita D., 769  
Siu, Kin Wai Michael, 640  
Smythe, Kelli C. A. S., 254  
Soares, Marcelo M., 656  
Song, Zhiqiang, 538  
Stanton, Neville A., 665  
Straßer, Peter, 325  
Su, Sheng, 538  
Sugiyama, Haruka, 494  
Sugiyama, Takuya, 446  
Sun, Guilei, 122  
Szewerda, Kamil, 305

**T**

Takahashi, Masaki, 494  
Thompson, Pauline, 665  
Tian, Qi, 155  
Tingyu, Liu, 584

Tokarczyk, Jarosław, 305  
Tokuda, Yoshihide, 494  
Töre-Yargın, Gülşen, 628  
Torres, Myrla Lopes, 57  
Trigueiros, Conceição, 563  
Trindade, Yanick, 472

**V**

Vilar, Elisângela, 452

**W**

Wang, Jie, 711  
Wang, Zhongting, 103, 325, 648  
Wong, Yi Lin, 640  
Wu, Haimei, 155, 502, 531, 551, 648

**Y**

Yein, Nilakshi, 805  
Yoshioka, Yohsuke, 446, 494  
Yuan, Shasha, 538

**Z**

Železnik, Gregor, 305  
Zhang, Liang, 103  
Zhang, Wei, 164  
Zhang, Xin, 325  
Zhang, Yumeng, 711  
Zhao, Cancan, 155  
Zhao, Chaoyi, 164, 296, 325, 711  
Zhao, Yu-Lin, 761  
Zhen, Renjun, 275  
Zhou, Xiaohan, 147  
Zhou, Zihan, 155  
Zhu, Zhijuan, 275  
Zou, Chuan-yu, 177  
Zou, Chuanyu, 648  
Żyrek, Leszek, 305