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Giuseppe Di Bucchianico *Editor*

Advances in Design for Inclusion

Proceedings of the AHFE 2019 International Conference on Design for Inclusion and the AHFE 2019 International Conference on Human Factors for Apparel and Textile Engineering, July 24–28, 2019, Washington D.C., USA

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Editor

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

Proceedings of the AHFE 2019 International Conference on Design for Inclusion and the AHFE 2019 International Conference on Human Factors for Apparel and Textile Engineering, held on July 24–28, 2019, in Washington D.C., USA

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Advances in Human Factors of Transportation	Neville Stanton

(continued)

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Advances in Artificial Intelligence, Software and Systems Engineering	Tareq Ahram
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Advances in Human Factors in Communication of Design	Amic G. Ho
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Preface

This book has two underlying messages, the emerging importance of the social issue of inclusion and human diversity in contemporary society and the increasing awareness that there is no such thing as a 'standard human being.' The first question has to do with inequality and social disparity as a necessary milestone toward economic revival, among other things, while a vital role in the strategies adopted by the European Union's Horizon2020 framework program is played by the ones that focus on strengthening equality, participation, and accessibility for all to goods, services and what Dahrendorf called 'life chances.' What this means is that the issue of social inclusion of diversity and for equality is firmly on political agendas all over the world, not least because of increasing awareness that new visions, new strategies, new tools and new approaches are needed, if we are to tackle the challenges arising from recent phenomena of economic and cultural globalization, demographic change; economic migration from poorer countries and an ageing population in wealthier countries, a phenomena that are destined to upset the entire planet's micro and macro-economic and social structures in years to come.

The second issue tackled in this book is more technical in nature, since the paradigm change from 'designing for standards' and 'inclusive products and service design' to the enlightened awareness that there are no such concepts to fit the standard human being, this has immediate, direct repercussions on the specialized dimension of designing. The realization is at last taking hold not only that those individuals are physically, psychologically and culturally 'diverse,' but they also have widely diversified skills, abilities, aspirations, and desires that make each one of us unique and not at all replicable. Since the diversity of individuals is the rule, not the exception, it makes sense to consider it as a resource, not as a limiting factor or a restriction on design, while equality between individuals, communities and peoples should be treated as fundamental strategic inputs to the sustainable development of contemporary society, where everybody should have the same opportunities to experience places, products and services. Numerous design approaches have been adopted to facilitate social and cultural inclusion in recent decades: Design for Disability, Universal Design, Inclusive Design, and Design for All. All of these philosophies, approaches, and methodologies aim to build value on

all aspects of human diversity, from psychophysical to cultural issues, and to offer equal opportunity to everyone in order to experience places, products, services and systems. With this in mind, this book sets out to forge a climate conducive to discussion and comparison between these approaches, without any prejudice in favor or against any one of them, but attempting to identify the elements they hold in common and to build each one's heritage of originality, because we are convinced that the true resource of Design for Inclusion may well be found in this very diversity of opinions.

In particular, this book describes the state of the art of recent research conducted in a variety of fields that share the focus on Design for Inclusion and was presented in the fourth international conference on Design for Inclusion (AHFE 2019, Washington D.C.). On this occasion, the numerous research papers presented were collected together into two different thematic areas, articulated in six sections of this book:

Part 1 Design for Inclusion
Section 1 Designing for Inclusion in Learning Experiences
Section 2 Industrial Design for Inclusion
Section 3 Designing for Inclusion in the Information Society
Section 4 Public Spaces, Building Environment and Communities
Section 5 Global Perspectives on People-Centered Design and Cultural Heritage

Part 2 Human Factors for Apparel and Textile Engineering
Section 6 Design for Inclusion for Apparel and Textile Design

Special thanks to Gianni Montagna and Cristina Carvalho from the Lisbon School of Architecture, CIAUD for their valuable contribution and for co-chairing the conference track on Human Factors for Apparel and Textile Engineering.

Each section contains research paper that has been reviewed by members of the International Editorial Board. Our sincere thanks and appreciation to the board members as listed below:

Design for Inclusion

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Contents

Designing for Inclusion in Learning Experiences

Inclusion in Danish Architectural Education and Design Practice 3
Masashi Kajita

Green for All. A Didactic Experience on Design for All Applied to Gardening Earthenware Objects 15
Giuseppe Di Bucchianico

Designing of Inclusive Learning Experiences: Preliminary Outcomes of a Pilot Project Tailored to SLD 22
Alessia Brischetto and Alessandra Rinaldi

Universal Signaling Based on the Articulation Between the Ergonomic Practices and the Perception of the Visually Impaired 35
Luís Rocha, Thaíla Santos Lima, and Lays Campos Brito

Industrial Design for Inclusion

Accessibility Evaluation of Automated Vending Machines 47
Nicholas Caporusso, Kingsley Udenze, Asibi Imaji, Yangyang Cui, Yanjun Li, and Spencer Romeiser

Human-Centered Design and Quality Function Deployment: Understanding Needs on a Multidisciplinary Automotive Research 57
Gian Andrea Giacobone and Giuseppe Mincolelli

A New Approach for an Inclusive Yacht Design 69
Paolo Ferrari

The Effect of Sliding Door Hardware Design on Opening Operation . . . 79
Satoshi Kose, Yoshiaki Goto, Ken Nunota, and Shinji Tanaka

Designing for Inclusion in the Information Society

Collaborative Quality Function Deployment. A Methodology for Enabling Co-design Research Practice 91
Giuseppe Mincolelli, Silvia Imbesi, and Matteo Zallio

Inclusive Design Methodology in Practice: Turning a Prison into an Inclusive Civic University 100
Jasmien Herssens

Defining a Shared Platform in China to Propose a Social, Cultural and Technological Bridge 110
Avril Accolla

Methods and Techniques Used in the Evaluation of Interfaces in Brazilian Studies Focusing on Visually Impaired People 117
Dominique Leite Adam, Maria Lúcia Leite Ribeiro Okimoto, Kelli C. A. S. Smythe, and Caelen Teger da Silva

Usability Analysis of the Payment Method with an Application of Digital Parking Meters with Younger and Older Users 129
Paula González-Torres, Ileana Chávez-Sánchez, Andrea Tejada-Gutiérrez, Claudia M. Fernández-Rivera, and Carlos Aceves-González

The Influence of Screen Brightness and Moving Speed of Visual Icons on Visual Acuity 140
Linghua Ran, Xin Wu, Hong Luo, Chaoyi Zhao, and Xin Zhang

Participatory Design with Older Adults: Exploring the Latent Needs of Young-Old and Middle-Old in Daily Living Using a Universal Design Approach 149
Alex Pui-yuk King

Public Spaces, Building Environment and Communities

A New Inclusive Housing Prototype 163
Francesco Spagnoli

Bioclimatic Design Approach for Low-Income Dwelling at Monte Sinahí, Guayaquil 176
Boris Forero, Jesús Hechavarría, and Robinson Vega

Codesign of Public Spaces for Intercultural Communication, Diversity and Inclusion 186
Alessandra Rinaldi, Leonardo Angelini, Omar Abou Khaled, Elena Mugellini, and Maurizio Caon

Development of an Anthropometric Protocol for Wheelchair Users: Guiding the Decision-Making for Designing Inclusive Spaces 196
Libertad Rizo-Corona, Adrián Leal-Pérez, John Rey-Galindo, Carlos Aceves-González, and Elvia González-Muñoz

Designing a Pilot System for Sustainable Villages for All 206
Avril Accolla

Assessing Accessibility and Safety Conditions in an Urban Environment: What Do Pedestrians Perceive? 215
Carlos Aceves-González, Libertad Rizo-Corona, Rosa Rosales-Cinco, John Rey-Galindo, Karthikeyan Ekambaram, and Maricela Ramos-Tachiquín

Global Perspectives on People-Centered Design and Cultural Heritage

Understanding Visual Information Processing for American vs. Saudi Arabian Users 229
Yahya Alqahtani, Joyram Chakraborty, Michael McGuire, and Jinjuan Heidi Feng

An Application for Mobile Systems Developed with the Community Involvement. An Open Source Mobile Application Project of a Perceptive City Map 239
Francesca Bozza

Inclusive Design Practices for Natural Parks. Products and Services for Experience-Focused Solutions in Places of High Naturalistic Value 251
Ivo Caruso, Vincenzo Cristallo, and Carlo Martino

User Interaction and Scenario-Based Experience Design for New Media Technology in Museum Spatial Experience 263
Jian Yu and Yongbin Wang

Inclusive Participation Design Methodologies for Digital Cultural Heritage 271
Giuseppe Mincolelli and Michele Marchi

User Attitudes Towards Wheelchairs: A Mexican Case Study with Special Focus on Vulnerable Wheelchair Users and Wheelchair Assistants 282
Paulina Manzano-Hernandez, Maria Giovanna Trotta, Carlos Aceves-Gonzalez, Alberto Rossa-Sierra, and Fabiola Cortes-Chavez

Inclusion of Children with Down Syndrome Through the Creation and Use of a "Learning Object" 292
Rita Assoreira Almendra and Mariana Elvas

Design of a Wheelchair for Low-Income Countries, the Second Stage of a Project 301
Alberto Rossa-Sierra, Fabiola Cortes-Chavez, David Vidana-Zavala, and Maria Giovanna Trotta Munno

Media Convergence in Information Transmission in Museum Space . . . 310
Yongbin Wang and Jian Yu

Design for Inclusion for Apparel and Textile Design

Formation of the 3D Virtual Models for Clothing Fit Assessment Applied in Human Factors 319
Hyunjung Lee and Su-Jeong Hwang Shin

Apparels for Comfort. Knitting for People 329
Gianni Montagna, Cristina Carvalho, and Carla Morais

Performative Approaches in Designing Costumes: Ergonomics in Immersion and Storytelling 337
Alexandra Cabral and Carlos Manuel Figueiredo

Reliability of Anthropometric Reference Data for Children's Product Design 350
Su-Jeong Hwang Shin and Mona Maher

Dynamic Wardrobe from a User's Perspective – A Previous Survey Study for Female Students 358
Carla Morais, Cristina Carvalho, and Gianni Montagna

Parametric Design for the Construction of a Corset Surface Based on Historical Female Bodies 365
Felipe Zapata-Roldan and Blanca Echavarria-Bustamante

Exploring Fashion Design Methods: Understanding Human Factors in New Society Contexts 372
Luís Ricardo Santos, Gianni Montagna, and Maria João Pereira Neto

Impact of a New Designed Automation Process in Textile Natural Fibers and Yarns Dying 382
Alexandra Ene, Carmen Mihai, Emilia Visileanu, and Cristian Jipa

Lean Manufacturing Model for the Reduction of Production Times and Reduction of the Returns of Defective Items in Textile Industry . . . 387
Yanira Andrade, Leslie Cardenas, Gino Viacava, Carlos Raymundo, and Francisco Dominguez

Ancient Handcraft Improved by New Material 399
Cristina Carvalho, Isabel Bieger, and Gianni Montagna

Solutions in Designing of the Composite Textile Structure Destined to Block, Intake and Storage of the Petroleum Residues Due to Natural Disasters 406
Carmen Mihai, Alexandra Ene, Emilia Visileanu, and Cristian Jipa

Changes in Physical and Technical Characteristics of Raw Materials in the Process of Making a Bra 411
Ana Filipe, Gianni Montagna, and Cristina Carvalho

Use of 3D Printing and Nano Materials in Fashion: From Revolution to Evolution 422
Javed Anjum Sheikh, Muhammad Faisal Waheed, Ahmad Mukhtar Khalid, and Ijaz A. Qureshi

Cognitive Behavior Difference Based on Sensory Analysis in Tactile Evaluation of Fabrics 430
Jun Zhang, Hui Tao, and Xuewei Jiang

Human Factor in Apparel and Fashion Exhibition Design 438
Catarina Carreto and Rui Carreto

Distribution of Clothing Pressure in Support Knee-High Socks and Its Evaluation 449
Tamaki Mitsuno, Aya Yamagishi, and Mayuko Takenaka

Woven Fabrics Specially Designed for Thermal Protection and System Recovery of Air Vehicles 457
Carmen Mihai and Alexandra Ene

A Pilot Study of a Hygienic Mask Sheet Pattern to Prevent Air Flow Through Gaps 462
Mika Morishima and Tamaki Mitsuno

Research on the Characteristics of Hand Shape in Different Countries 469
Jing Zhao, Fan Zhang, Gang Wu, Chao Zhao, Haitao Wang, and Xinyu Cao

Research on Human Factors Engineering for the Innovative Design of Work Clothes for Couriers 480
Longlin Luo and XiaoPing Hu

Biodigital Design and Functional Visualization of Multi-Class Personalized Compression Textiles for Ergonomic Fit 488
Rong Liu, Bo Xu, and Chongyang Ye

The Application and Development of Smart Clothing 500
Jia Lyu, Yue Sui, and Dongsheng Chen

A Classification of Care Apparel Characteristics for Disabled User Requirement 505
Qilong Feng

Author Index 515

Designing for Inclusion in Learning Experiences

Inclusion in Danish Architectural Education and Design Practice

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Abstract. In wishing to make our physical environment inclusive, this paper investigates the complexity and challenge of design process, focussing on the Danish distinction between architect and *bygningskonstruktør* (constructing architect) in both qualifications and practice. The paper looks at the division of the roles in relation to the knowledge acquired during their education; and discusses the kind of knowledge on inclusion they gain, mobilise and share during the actual design process. The findings from nine qualitative interviews highlight two key areas. Firstly, there is a need to develop shared knowledge on inclusion between architects and *bygningskonstruktører*; secondly, team structure and communication strategy needs to be critically reviewed and appropriated to optimise knowledge allocation and dissemination within a team and practice at large.

Keywords: Accessibility · Architectural education · Design process · Knowledge sharing · Spatial inclusion

1 Introduction

There is a growing emphasis on providing equal opportunities for all people regardless of age, ability and many more possible limitations. In November 2010, the European Commission adopted a disability strategy which addresses this challenge supporting the rights of disabled persons to full and equal participation in society [1]. In October 2013, the Danish government presented a new disability policy action plan which sets visions for an inclusive society characterised by diversity, equality and respect for the difference [2]. These followed on from the United Nations *Convention on the Rights of Persons with Disability* [3]. Article 9 of the Convention obligates State Parties to take appropriate measures to ensure that disabled people have access to facilities and services on an equal basis with others. Accessibility in architecture provides an essential foothold, upon which the independence, participation and enjoyment of people can be realised. Yet it is a slow process to make the built environment accessible and inclusive. This is not only because architects struggle to recognise and engage with diverse bodily variations and their complex relations to the built environment, but also, the perpetual existence of disabling environments elucidates the complexity of the actual design process and its associated challenges.

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In wishing to advance architecture as a means by which to improve future conditions, this paper addresses the challenges in the design process by focusing on the Danish distinction between architect and *bygningskonstruktør* (constructing architect) in both qualifications and practice. *Bygningskonstruktører* work with architects and other consultants in practice, focusing on construction details and technical specifications. The paper specifically looks at the division of roles in between the two professions, and questions how might this division relate to the *loss of accessibility* during the process of building and planning. How differently do they carry out their work in practice? And what are the consequences of the division of roles and responsibilities in practice? Furthermore, the paper investigates this separation of professions in relation to their knowledge acquired during their education. How differently have they been taught during their education? And how does the difference in education been embodied in their practices?

Empirically this paper is based on nine qualitative interviews conducted with Danish practicing architects and *bygningskonstruktører* who have experience of designing for inclusion. It was to get first-hand knowledge about the design process and their roles, as well as the type of knowledge on accessibility they use when designing. Their voices create a picture of the situation, which describes how projects were developed and executed in their everyday practice. To have a deeper understanding of how they gain knowledge on accessibility and inclusion, the curriculum of four leading schools in Denmark for architects and *bygningskonstruktører* were studied. The four institutions are: The Royal Danish Academy of Fine Arts, School of Architecture, Design and Conservation (KADK) and Aarhus School of Architecture (AAA) for architects, as well as Copenhagen school of Design and Technology (KEA) and Via University College (VIA) for *bygningskonstruktører.* The author represents KADK.

The analysis draws upon the theoretical distinction between context-dependent and context-independent knowledge of inclusion. This distinction is positioned within the critical discourse on the limited use of accessibility operated within the regulatory framework. The codification of the concept involves the generalisation of diverse human bodies and their relations to the built environment which further separates the lives of people from their contexts. The standardisation of architectural solutions with the potential of furthering stigma and social exclusion must be avoided. Accordingly, the paper discusses the knowledge on accessibility with a strong focus on the experience of users: how should designers – architects and *bygningskonstruktører* – gain, mobilise and share knowledge on disabled persons in order to produce inclusive architecture? The findings challenge this study in two perspectives: firstly, to develop a framework that internalises codified rules and standards, as well as knowledge on users into the creative process which can then be shared by both architects and *bygningskonstruktører*; and secondly, to continuously question the process and method of transferring and sharing knowledge between architects and *bygningskonstruktører.*

2 The Process of Building and Planning

The Danish construction industry is made up of a complex aggregation of professionals, specialists and suppliers. These different actors have different roles and involve themselves in different work stages. Amongst these actors involved, this paper focuses on architects and *bygningskonstruktører*; and looks at the separation of their tasks in relation

to the process of developing building projects. In what follows, schematic overviews of work stages for building and planning are described, based on *Service Descriptions for Building and Planning 2018* prepared by the Danish Association of Consulting Engineers and the Danish Association of Architectural Firms [4], and with reference to RIBA Plan of Works 2013 [5]. A general model, which organises the process of briefing, designing, constructing, operating, maintaining and using building projects into four phases, is presented in Fig. 1. The structure of projects can vary substantially from one development to another. The choice of project structure or of procurement route depends on numerous factors including the duration of project, cost certainty, flexibility, price competition and quality of design and workmanship required. Accordingly, the content of stages may differ or overlap to suit specific project requirements.

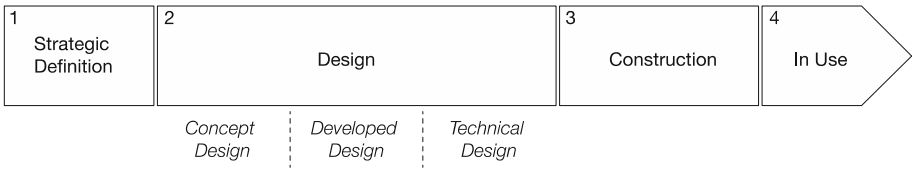


Fig. 1. An over view of generic work phases for building and planning

The first phase is strategic definition. This is the phase of appraisal and brief development. Consultancy typically starts from identifying client's business case, and later develops the project brief defining project objectives, project programme, project budget. Defined tasks in this phase also include clarifying the physical, social and legislative context around the project. The second phase is to develop design, where the project progresses from concept design stage, developed design stage to technical design stage. The concept design stage develops outline proposals for structural design, building services systems, outline specification and preliminary cost information in accordance with relevant project strategies and project programme. The developed design stage reaches to coordinated and updated proposals. It is the process of taking on and further developing the approved outline proposal to an extent that can provide sufficient information, describing all the main components of the building and how they fit together, for applying and obtaining statutory approval for building activities. Accordingly, planning applications are typically made using the output from this middle stage of the design phase. However, technical aspects may not yet have been fully developed and incorporated into the design at this stage of developed design.

The last stage of the design phase, the technical design stage, develops the final proposal that all architectural, structural and building service information, specialist subcontractor design and specifications are fully developed. This is typically the stage before the construction contract is tendered or construction begins. However increasingly, technical design may continue through the preparation of production information and tender documentation. It might even be extended to the construction phase, particularly when the technical design aspects are subcontracted to specialists. It should be noted that, during these stages of design development, the chosen procurement route defines when the planning application to be made, as well as specific tendering and

procurement activities. The third phase is for construction, where onsite construction and offsite manufacturing take place in accordance with the construction programme. Typical activities include administration and conclusion of building contract, the handover of building and the provision of *as-built* information. The last and fourth phase covers in-use service provisions and resource building. It deals with the operation and maintenance of buildings. Typical activities include reviewing of project performance and outcomes, undertaking post-occupancy evaluation and updating project information.

The above described the schematic overview of generic phases for building work. Specific tendering and procurement activities occur at different stages in the design phase in relation to the chosen procurement route. Accordingly, roles of architects and *bygningskonstruktører,* and the duration of their involvement in the process can vary from one project to another. In addition, with regard to accessibility, there is an increase of disabled users' and experts' involvements during the process, in order to understand their needs, to align those needs with the wishes of clients and other stakeholders, and to support decision-making processes. In this complex network of different actors, architects and *bygningskonstruktører* define their roles. Their roles and collaborations largely depend on office's management strategy, and yet their responsibilities are defined by their knowledge, skills and competences that have been developed during their professional education. And yet, this division of roles might create a gap within the communication network of different actors, contributing possibly to the *loss of accessibility* during the process of building and planning [6]. In the following, the paper describes how differently these two key actors in the field have been taught accessibility on their education; and how those different education frames their professional responsibilities; and further discusses the consequences, both positive and negative, of this division in practicing to produce inclusive built environments. However, before moving onto these discussions, both method and theoretical framework are outlined in following sections.

3 Method

Two sets of investigations were conducted. The first set of study looked into what and how accessibility and inclusion are taught to educate future architects and *bygningskonstruktører* at four institutions in Denmark. The Royal Danish Academy of Fine Arts, School of Architecture, Design and Conservation (KADK) and Aarhus School of Architecture (AAA) offer BA and MA programmes in architecture[1]. Copenhagen school of Design and Technology (KEA) and Via University College (VIA)[2] offer BA programme in Architectural Technology and Construction Management. The author represents KADK. The investigation includes the study of implemented curriculums

[1] There are only two schools of architecture in Denmark.

[2] There are six institutions for *bygningskonstruktører* in Denmark. These are: Københavns Erhvervsakademi (Copenhagen school of Design and Technology) in Copenhagen; Via University College in Horsens and Aarhus; EASJ - Erhvervsakademi Sjælland (Zealand Academy of Technologies and Business) in Næstved; UCN - Professionshøjskolen Nordjylland (University College of Northern Denmark) in Aalborg; UCL Erhvervsakademi og Professionshøjskole in Odense; and Erhvervsakademi Sydvest in Esbjerg.

and email correspondences and/or interviews for clarification with course responsible persons or programme leaders from these leading institutions in Denmark[3].

The second set was nine qualitative interviews conducted with five practicing architects[4] and four *bygningskonstruktører*[5] who have experience of designing for inclusion. These interviews were to gain first-hand knowledge about the design process and their professional roles, as well as the type of knowledge and information they use when designing accessible and inclusive architecture. The respondents are building architects and *bygningskonstruktører* who were educated at one of the above-mentioned institutions. Landscape architects were not included. To ensure that those architects and *bygningskonstruktører* are familiar with and know different aspects of accessibility, practices selected have considerable experiences in designing publicly accessible buildings such as sport and leisure buildings, cultural buildings, offices, educational institutions or health providing facilities where accessibility and inclusion matter. Those practices are AART Architects, Dorte Mandrup Architects, Force4 Architects, Holscher Nordberg Architecture and Planning and Schmidt Hammer Lassen Architects.

The interviews took a form of semi-structured qualitative interviews. Conversations were left as open-ended, however, within the framework of the pre-defined structure. First, the respondents were asked to explain how they carry out their works in practice, focusing on accessibility and inclusion. How different their roles and responsibilities can be? How does your office organise a team; and how do architects and *bygningskonstruktør* collaborate in a project? Then, the respondents were asked to relate their expertise to knowledge, skills and competences developed during their professional education. How differently these two key actors in the field have been taught; and how those different education frame their professional responsibilities? Lastly, they are asked to reflect on the division of their professional roles. What are positive and negative aspects of this division; and how could the situation be improved in order to produce inclusive built environments? The respondents were guided by those questions, and yet, they were encouraged to divert, tell their own stories and describe their experiences. These conversations were recorded and the quotations in this paper were transcribed and shortened by the author and were approved by the interviewees.

4 Knowledge Field in Designing Inclusive Architecture

What kind of knowledge do architects and *bygningskonstruktører* make use of when designing inclusive architecture? Danish scholar Kirkeby in her paper *Accessible Knowledge – Knowledge on Accessibility* emphasises the importance of context-

[3] Brigitte Geert Jensen from AAA, Claudio Spaziani Testa from KEA and Bo Sørensen from VIA.

[4] These architects are Kathrine Hegner Stærmose from AART Architects, Marianne Hansen from Dorte Mandrup Architects, Andreas Lauesen from Force4 Architects, Mikkel Nordberg from Holscher Nordberg Architecture and Planning, and René Nedergaard from Schmidt Hammer Lassen Architect.

[5] Helga Skovsted from AART Architects, Asbjørn Severin Lütken from Dorte Mandrup Architects, Anders Mortensen from Holscher Nordberg Architecture and Planning, and Kirsten Sennicksen from Schmidt Hammer Lassen Architect.

dependent knowledge in opposition to a general scientific ideal of context-independent knowledge [7]. Drawing on Flyvbjerg who refers to the concept of *phronesis* from Aristotle's description of *praxis* [8], Kirkeby articulates the essential roles of *phronesis* as context-dependent knowledge which enables the practitioner to make responsible choices [9]. In this paper, responsible choices are interpreted as choices for realising inclusive architecture and built environment. Kirkeby develops her arguments based on Aristotle's three types of knowledge – *episteme, techne and phronesis*. *Episteme* forms the body of ideas that is intellectually certain at any particular time and space. It is scientific knowledge gained through analytical rationality. *Techne* is knowledge related to the production of art and craft. It is a type of knowledge used in making and doing. It governs the application of technical knowledge and skills based on practical instrumental rationality. P*hronesis* is knowledge oriented toward action. It is pragmatic knowledge that places ethics centrally and helps persons to make reasonable decisions based on practical value-rationality [8–10].

While *episteme* is context-independent knowledge that concerns theoretical *know-why, techne* is context-dependent knowledge denotes technical *know-how*. *Phronesis* is context-dependent knowledge specific to each particular circumstance that cannot be reduced to knowledge of general truths [7]. When designing, quantifiable data sets and other rule-based knowledge such as building regulations and building standards are used. Those represent rationality and universality; and, therefore, are context-independent. On the contrary, context-dependent knowledge is a type of knowledge that people learn through their experience and used through the act of designing in reflective practice, as Schön (1983) describes – *reflection-in-action* [11]. It should be noted that these different kinds of knowledge are not to be seen as totally separated. Architects and *bygningskonstruktører* should freely mobilise knowledge while coordinating site, architectural, structural, building service, production and cost information in order to produce inclusive architecture. When designing, they must use accumulated knowledge from previous and current tasks, negotiating with a whole range of design parameters. And, user's experience – like every other aspect of design – should carefully be integrated into the design process as one of essential design generating parameters [12].

Another important distinction is made in-between the imagined space of designers and the lived space of users. This paper recognises that the experience of users that architects and *bygningskonstruktører* imagine when designing and the actual experience of users are never the same. The act of designing demands an ability of designers to imagine how others may use and experience designed buildings, products and services. And yet, no matter how actively one participates to make understanding of situations, the design process involves designers' personal interpretation of gained understandings. In addition, there is tendency of designers to conceptualise the human body as a biological object, which often has average dimensions and ideal proportions [13]. This abstraction suppresses the differences of which human bodies possess and simplifies the complexity of bodily interactions with objects, buildings and their surrounding environments. Accessibility requirements and related guidelines are based, to a large extent, on those standardised bodies. They objectify the body as primarily comprising of physical impairments in which a wheelchair becomes central to facilitate access and movement in and around buildings. Therefore, the roles of accessibility requirements and related guidelines in design process can continuously be questioned [14, 15].

The above-mentioned distinctions between context-dependent and context-independent knowledge, as well as the imagined space of designers and the lived space of users form an analytical model presented in Fig. 2. This model adopts Kirkeby's analytical model that describes the understanding of knowledge used in the making of architecture [7, 9, 10], and is further developed in order to describe a systematic understanding of knowledge learned and used in the production of inclusive architecture. The developed new model specially focuses on the aspect of use and users, and helps to understand how gained knowledge of users is translated into useful resources and mobilised in the design process. This focus on users reflects critical discourses on the codification of accessibility, and aligns with recent attentions towards people-centred practices that are integrated into architectural process which encourages members of project teams to adopt a practical approach to involving users throughout the different development phases of a project.

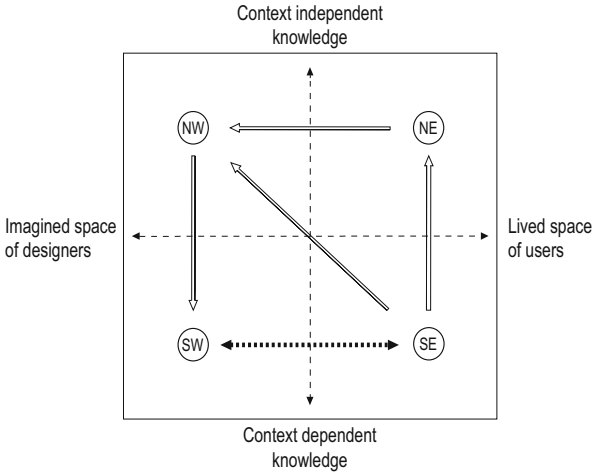


Fig. 2. A plane of knowledge for inclusion that architects and bygningskonstruktører make use of while building works are carried out.

South-east quadrant (SE) in the *plane of knowledge for inclusion* is an area where embodied experiences of individual users are situated. *North-east quadrant (NE)* is an area where users' experiences are translated into resources. This field corresponds with the rationality of science, representing in the type of knowledge such as a data sets that quantify human experience and behaviour. In the design process, designers operate in both fields of *North-west quadrant (NW)* and *south-west quadrant (SW). NW* is an area that available knowledge of users is translated and organised so that architects and designers can directly work with. These can be in the form of rules and guidelines; explicit answers to problem raising in the design process – what is the minimum width of doors for a person in a wheelchair to pass, for example. *SW* is the primal area where design methods and design thinking are employed in their creative process. In this field, architects and *bygningskonstruktører* coordinate gained knowledge but also develop new knowledge in the act of designing. The analysis made below draws on this *plane of knowledge for inclusion* presented in Fig. 2.

5 Findings and Analysis

The interviews with practitioners were carried out by following three main questions of; how differently do architects and *bygningskonstruktører* carry out their work in practice; how does this division of roles and responsibilities relate to their understanding of own profession in relation to professional education received; and what are the consequences, both positive and negative, of this division in practice in order to produce inclusive built environments? Correspondingly, materials from the interviews are organised into following subsections of: *Two Different Professions; Different Types of Knowledge on Accessibility;* and *Mobilising and Sharing Knowledge.*

5.1 Two Different Professions

Amongst practitioners, there is a strong recognition in professional differences between architects and *bygningskonstruktører.* Architects consider themselves – and are considered by *bygningskonstruktører* – as creative ones who look after formal and aesthetical aspects of design; whereas, *bygningskonstruktører* consider themselves – and are considered by architects – as technical ones. *Bygningskonstruktører* are often responsible for preparing and producing construction details and technical specification, which are coordinated with the cost information. As Asbjørn Severin Lütken, *bygningskonstruktør,* stated: "An architect gives a form to a building. Of course, the form changes given circumstances, considering how things are put together and making it possible to build. In the process, I can influence and set a project to a certain direction. But my job is not to create a form, instead, to make what architects have created or envisioned into a something buildable. I stay true to the form that architects pass on to me."

Architects involve themselves in projects from strategic definition phase to design phase; but typically focussing on the design phase. They are in charge of developing overall design of the project from concept development to the final proposal where all architectural, structural and building service information is coordinated. The professional roles of *bygningskonstruktører* also lie in the design phase. However, they typically join a project team in the developed design stage after outline proposals are approved; and take the project up to technical design stage where at the end of this stage, provided materials can form the basis for tendering, contracting and construction. However increasingly, they are involved through the preparation of production information and tender documentation, but also take a part at the concept design stage on consultancy basis. This earlier involvement of *bygningskonstruktører* typically increases as a project gets bigger in size, considering the complexity that the project might bring. *Bygningskonstruktører* handle technical information coordination and sharing, through a process such as BIM (building information modelling); and accessibility is considered as one type of such technical information that needs to be included in the process.

Furthermore, findings articulate that *bygningskonstruktører*'s involvement in a project changes over time. A team structure can change as Kirsten Sennicksen stated: "A project I am on now, which is in a technical design stage, we have ten persons in our team, and five of us are *bygningskonstruktører.* A year ago, in the developed design stage, we were two *bygningskonstruktører*". Responsibilities within a team might also shift. Marianne Hansen: "When *bygningskonstruktører* join a project in developed

design stage, they would likely take responsibility of 20%; and that will grow up to 60 to 70%". In some cases, *bygningskonstruktører* act as a project manager and take responsibility on coordinating with other consultants dealing with structural, service system and cost information. However, experienced architects are who typically manage projects. This is due to fact that the practices involved in this study prefer someone – ideally whole team members – to follow a project from the beginning to the end, in order to assure a seamless transition from a vision to a building. *Bygningskonstruktører* would often not be on early stages of the project. Hence, architects become project managers. This is underlined by their mutual understanding of: "aesthetic and form are expertise of architects, and the highest priority in the office", as stated Asbjørn Severin Lütken.

5.2 Different Types of Knowledge on Accessibility

Architects and *bygningskonstruktører* respect each other's skills and competences, and enjoy the collaborative aspects of their works, although they have very different approaches to accessibility. Interviewed architects consider that overall responsibility is on themselves, since accessibility is very much part of form making. However, this comment is always followed by a line such as "but later, *bygningskonstruktører* come into a project to make sure that a building lives up to minimum requirements specified on legal documents". Correspondingly, *bygningskonstruktører* believe that they are the one who takes care of accessibility – accessibility represented in the format of building regulations. This contrasts with how interviewed architects consider accessibility – accessibility as something opaque, relating to key words such as wheelchair, ramp, lift and circulation. However importantly, these different interpretations of accessibility create a hierarchy between two professions. As stated by one of architects, "*Bygningskonstruktører* know how to put details together by codes, but it may not be the way how we would like them to be. So, it might take a long time, doing *back and forth,* to get to the details that we want".

Both KEA and VIA offer education for *bygningskonstruktør as* BA programme in Architectural Technology and Construction Management, which has a duration of three and a half years and consists of seven semesters of a total of 210 ECTS. Their courses do not provide specific lectures or seminars on accessibility. And yet, accessibility is addressed within students' semester projects. Accessibility takes a part in the subject of design and building law, focusing on the Danish building regulations. Accessibility is understood and taught as one type of legal requirement which they as *bygningskonstruktør*er must comply with when designing. KADK and AAA offer education for architects at both levels of BA and MA programmes, which has a duration of five years in total and consists of ten semesters of 300 ECTS. KADK increasingly provides lectures and workshops on inclusion in some occasions. However, it is fair to state that there are not any coherent courses on accessibility and related legal matters across the school at this moment. This also applies to AAA. In both schools, different design teaching studios might address the theme voluntarily. However currently, there is no obligation nor control by the institutions on how and to which extent the issues of inclusion are addressed. Responding to this uneasy circumstance, KADK started to make positive changes in 2016, and is now in the process of integrating teaching on inclusion into its new overall structure.

These changes reflect not only on the lack of accessibility education, but also the critical view on codified rules that simplify the complexity of bodily interactions and represent lived life of persons in static and quantifiable ways [12, 13, 15]. However, KADK acknowledges the importance – and the limitation – of teaching rules and guidelines on accessibility and inclusion, because they provide essential points of reference for technical and functional solutions. Accordingly, KADK aims to balance between: (1) knowledge in *NW* of Fig. 2 – established design tools and information represented in building regulations; and (2) knowledge in *SE* – gained through people-centred practice that encourage designers to work directly with individuals. In *SW*, knowledge on *NW* and *SE* should be integrated. Design must progress through a reflective conversation with the situation where accumulated knowledge of designers from previous and current tasks as well as spatial experience of users, both systematised (*NW*) and embodied (*SE*), are integrated. In addition, KADK emphasises the importance of *reflection-in-action*, and promotes *leaning-while-designing*. This situatedness in contexts during knowledge production [8] and learning process [16, 17] gives an opportunity for architects to avoid objectifying the people, and therefore, to creating architecture that is more responsive to the manifold complexities of peoples' experience in situations.

5.3 Mobilizing and Sharing Knowledge

With regard to accessibility, *bygningskonstruktører* essentially use knowledge in *NW*. They consult the building regulations and other design guidelines, such as *Danish Standard DS3028*. This means that user's embodied experiences in *SE* come into *SW* via *NW*. Architects also use knowledge situated in *NW*; however predominantly through making use of *bygningskonstruktører's* knowledge on building regulations. *Bygningskonstruktører* become in-house consultants for architects who lead a team as masters of aesthetic and form-making. *Bygningskonstruktører* hold key knowledge on accessibility and are "the link between architects and rådgivende ingeniører (consulting engineers) and/or contractors", stated Asbjørn Severin Lütken. However, it must be reiterated that their knowledge on accessibility is technical information based on standardised body dimensions and proportions, of which exclusive use might lead design towards generic and *add-on* solutions [7, 13, 15].

Over the past 20 years, there has been an increase of involving users and other experts in the design process in order to gain valuable insights from them. The process can be formalised, especially when projects consider older and/or disabled persons as specific target groups. Such projects aim to involve these users and experts in periodic, so they participate in the project throughout. As an example, 1:1 mock-ups of different toilets were even made. A procedure was, and would often be, that users give feedback; then experts, clients and architects reflect these users' opinions and make decisions. In the process, architects take a leading role, coordinating with users and other expert groups. In this process, architects transfer knowledge of disabled users from *SE* into *SW*. It should be underlined that such user involvements provide deeper understanding of users' experience, as opposed to broad knowledge gained from statistics or other quantifiable data. Knowledge obtained in this way brings architects valuable insights; but less of comprehensive understanding of every aspects of a person's life. It produces understandings that are subject-dependent, and therefore can be deeply embedded into architects' creatively in practice: but not *bygningskonstruktørerer's*.

There is a strong hierarchy in two professions. Architects set a vision and make a form. This form-making is the highest importance of the practices studied in this paper. In this process, when possible or requested, architects engage with users directly. This movement of knowledge between *SE* and *SW* adds another layer of questions, which then inform the advancement of design. While architects develop the design, knowledge situated in *NW* is sought and integrated into solutions through a dialogue with *bygningskonstruktører.* This externalised process of consulting *bygningskonstruktører* provides an opportunity for both architects and *bygningskonstruktører* to critically assess and qualify information in *NW* while imagining how design could be. Kathrine Hegner Stærmose: "It is a collaboration. It goes back and forth all the time". This *back and forth* – a dialogue between architects who connect users, experts and a client, and *bygningskonstruktører* who communicate with other consulting engineers and contractors – is an essential key for producing accessible and inclusive architecture. And therefore, this division in their roles and the strong dependency to each other could create a gap of knowledge, when there is a lack of shared understandings or communication.

This challenges architects and *bygningskonstruktører* in two perspectives. The first, the common ground for knowledge on inclusion need to be established. *Bygningskonstruktører* oscillate between *SW* and *NW*. Architects firmly dwell in *SW*; and yet move between *SW* and *SE.* In *SW*, architects and *bygningskonstruktører* put together carried knowledge from their previous tasks and accumulated knowledge from their current tasks. In order to enhance collaboration between those with different skills and competences, they should share the foundation of knowledge. They both need to know the rationale behind technical information based on the systematised experiences of users; and be informed by the embodied experience of users. This challenge should primarily be addressed in educational institutions. However, learning process of inclusion must continue while practicing. They gain knowledge while developing the project; and they develop design while developing new knowledge. This aspect of continuous learning leads to the second perspective. The team structure and communication strategy need to be critically reviewed and frequently appropriated in order to optimise knowledge allocation and dissemination within a teams and office. Kirsten Sennicksen: "This *ping-pong* of knowledge allows us to come up with solutions that regulations might not be able to solve. Our office has gained experience in last 19 years. We become better at handling issues, and understand the importance of having this *ping-pong* to make architecture more inclusive." Yet, can the experience of architects and *bygningskonstruktører* be the only solution for better knowledge allocation and sharing?

6 Conclusions

The paper has presented how architects and *bygningskonstruktører* collaborate in practice, using different types of knowledge on inclusion. They receive different education on accessibility which define their respective roles and responsibilities. Based on the *plane of knowledge for inclusion* developed from the distinctions between context-dependent and context-independent knowledge, as well as the imagined space of designers and the lived space of users, the paper systematically analysed how knowledge on inclusion is gained, mobilised and shared during the actual design process. The

first conclusion to be drawn from this study is that there is a need for developing the common ground for knowledge on inclusion between architects and *bygningskonstruktører*: legislative framework, statutory requirements and the rationale behind specific requirements, specific and complex needs of users. The second conclusion to be drawn from this study is that the team structure and communication strategy need to be critically appropriated in order to optimise knowledge sharing within a team and practice at large. Rules and standards, as well as people-centred techniques are useful tools; but are not decisive. Hence, the achievement of inclusive environments depends largely on the capability of architects and *bygningskonstruktører* who gain and share knowledge on inclusion effectively. Situate themselves in the primal field of creation of *SW,* they must reach out – as individuals but also as a team – to *NW* and *SE,* as well as *NE* if necessarily: moving far and wide trough the *plane of knowledge for inclusion*.

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Green for All. A Didactic Experience on Design for All Applied to Gardening Earthenware Objects

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Abstract. The Design for All approach, enhancing human diversity, promotes the spread of a social conscience oriented towards inclusion. This seems particularly useful for the training of young designers, because it obliges them to consider the complex system of constraints and opportunities arising from the extreme variability of the design targets, that more and more contemporary society requires to design activity. Here are described the development and results of a teaching experience, entitled "Green for all", developed at the University of Chieti-Pescara, in which students designed a product for gardening, referring to specific and original use contexts, through the DfA approach. Starting from the dimensional and productive restriction of earthenware, the projects had the purpose to favor the cultivation of ornamental plants or domestic spices even in contexts of original use (in the kitchen, in the bathroom, in the office, but also on the desk, in gym or on the train).

Keywords: Design for All · Gardening · Earthenware products

1 Introduction

In parallel and in response to the latest global socio-demographic phenomena, they have seen a rapid development and diffusion also different design approaches related to the more general definition of "Design for Inclusion", also applicable to productive sectors and new user contexts, such as gardening, especially when it is related to new healthy therapies for the psyche and the human body.

1.1 The New Socio-demographic Horizons

The main demographic challenge of contemporary society, especially for industrialized economies, is represented by the aging of the population. The global population of 9 billion expected for 2050[1] will be set up for about 2 billion from "over 65"[2].

[1] UNITED NATIONS, DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS, POPULATION DIVISION, World Population Prospects. The 2008 Revision, New York, 2009, 9.

[2] R. LEE, The Demographic Transition: Three Centuries of Fundamental Change, in Journal of Economic Perspectives, 2003, vol. 17, n. 4, 3.

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In particular, the same source estimates that in Europe and in China in 2050 the "over 65" will reach 30% of the population, while in Japan the "over 80" will represent even 40% of the population. This phenomenon is the result of two factors: on the one hand, the increase in life expectancy, which will rise from the current 65 years, as a world average, to 74 years in 2050 (in Italy, the first country in Europe, is already 82 years); on the other, the parallel decrease in the average world fertility rate, which will drop from the current 2.7% to 2% in 2050. The first consequence will be a drastic reduction of people of working age and therefore the need to revise the traditional welfare systems to support a growing "old" society. The second consequence will be the increase in pathologies, even partially invalidating, linked precisely to the aging of the population (chronic-degenerative diseases and mental illnesses, reduction of sensory capacities, reduced mobility, etc.). In fact, most observers expect a society marked by disability for the next decades: a great increase in non-self-sufficiency, with all the economic, social security, welfare and anthropological consequences that this entails.

Another social phenomenon that, for different reasons, instead invests across contemporary society in all its age groups is the lack of social relations, which, for the weaker sections of the population, is transformed into social isolation, which at in turn it can lead to serious consequences also on the cognitive level and physical health. To give an example, a study that examined 479 thousand individuals between 40 and 69 years, shows how healthy but lonely people, without a family, friendship or social network, seem to have statistically a greater risk of cardiac events such as heart myocardium attack and ictus [1].

On the other hand, policies of social inclusion start from the assumption that the condition of social hardship does not only concern the forms of social deprivation and suffering, such as economic or material poverty, but also the shortcomings with respect to family and social ties, housing systems, networks of support services and social integration, as well as training and forms of work or cultural marginalization[3].

Aging, disability, isolation and social suffering: these are therefore some of the most significant phenomena that characterize contemporary society and which will presumably increase in intensity in the coming decades.

1.2 The Horticultural Therapy

Horticultural therapy is one of the healthiest therapies for the psyche and the body.

It is a set of floriculture and horticulture activities, which aim to improve the physical and psychological conditions both of individuals and of entire communities.

Taking care of land, gardening, cultivating plants and vegetables is a great stimulus for treatment, socialization and self-esteem. Attending a tactile and olfactively different environment from the everyday is a way to accelerate healing, or simply allows you to increase your perception of yourself, enhance your skills, shift the focus from your person to an object in need of care, with significant emotional, social and physical benefits. The plants therefore can help in many cases, from stress to old age, from addictions to disability, from depression to psychopathology.

[3] United Nations Development Programme, 2011.

The earliest references to the use of plant cultivation as therapy for people with disabilities were found in an Irish monastery and date back to 1300, while in the late 1700s, Benjamin Rush, father of American psychiatry, wrote that working the land had a beneficial effect on mental health [2]. It is necessary to underline the differences that exist between the gardening activities and the Horticultural therapy that, even if are referred only to a question of points of view, seems to be important. In fact, while gardening can improve the well-being of the community or groups of people living in the same environment and share different interests, Horticultural therapy deals with interactions between human beings and plants in a much more intimate way: its primary objective is to promote the individual health of patients while the plants become, in this way, only a "by-product" of the rehabilitation process. Its peculiarity is that it can be applied in a wide range of contexts: at home, in public or private gardens, in green spaces or in plants for the cultivation of plants connected to hospitals, rehabilitation clinics and hospices.

1.3 Design for All for an Inclusive Gardening

Starting from these assumptions, we understand how there can be a close relationship between the therapeutic approach to gardening and the issues of social inclusion.

In order to promote social inclusion, the idea that all people, regardless of age, sex, culture, physical and psycho-sensorial capacities, must have the same opportunities to develop a dignified life and to decide and satisfy themselves desires and aspirations: it is a challenge that, without a new way of thinking and making a project, it is not possible to face and solve.

In addition, gardening, and more generally, taking care of a plant, as well as requiring specific skills, sometimes also requires the need to perform tasks and gestures that are sometimes extremely technical and attentive.

One of the design approaches developed to respond creatively to this dual challenge is Design for All (DfA), which is the "design of human diversity, social inclusion and equality" (EIDD Stockholm Declaration, 2004). It proposes a holistic and innovative approach to the project, which considers the differences between individuals as an important resource for economic and social development, rather than as a "problem" or a "limitation" for the project. In particular, it is opportune to dwell on some key concepts through which the design approach of the DfA can help to generate truly inclusive solutions.

The first concept concerns the theme of the diversity of people that is seen as a resource rather than a problem. In fact, the assumption that the whole population is made up of deeply and radically different individuals - from the biological, cultural, social, demographic, ethnic, pathological, experiential aspects, etc. - is considered a positive value of society and a resource for improving the quality of life. Through appropriate design methodologies the DfA tries to prevent these differences from turning into disabilities, designing products and services that are able to respond as much as possible to the diversity of human needs. Human diversity, if properly managed, respected and valued, can lead to a greater wealth of the whole of what makes some *ad hoc* production coupled with a pervasive, inattentive and generic production [3].

The second concept concerns the theme of the participation of people and their involvement in the design process. The DfA approach tries to involve, both directly and simply through the observation of behaviors and attitudes, the greatest number of people involved in the design process.

The inclusive society, therefore, is also the place where to see the diversity of people in a new way, that is as a resource and not a problem. And it is also the place where all people can actively take part in the processes of transformation and construction of reality in different aspects: they can not only be considered as people who must be satisfied in their needs (target design), but also as people who can contribute in an active and unique way, through participation, collaboration and co-creation (design tool).

In this perspective, applying some principles of Design for All to the project of equipment and tools for gardening, if on the one hand it promotes the spread of practices of Horticultural Therapy, on the other hand it allows to extend the relationship of individuals with plants also to new and unexplored contexts, through the development of new products useful for the cultivation of plants.

2 Objectives

The principle of conscious participation and awareness on the issues of inclusion, on which the Design for All approach is based, is the basis of the "Green for All" didactic experience presented in these pages, developed in the Department of Architecture at the University of Chieti-Pescara.

The initiative started from the idea that green care can be an effective tool to raise awareness of environmental issues, as well as, in some cases, a real instrument of therapy and rehabilitation through the care and management of the green, in the cultivation of flowers, vegetables and other plants.

By extending these benefits to the categories of users not strictly related to disability and starting from the assumption that everyone can benefit from an intimate and direct relationship with the plants, the design laboratory has solicited the students to deal with the theme of design for all, through the project of an artifact for gardening.

Starting from the dimensional and productive bond of the terracotta, the projects have had the purpose to favor the cultivation of ornamental plants or spices of domestic use even in unpublished contexts (in the kitchen, in the bathroom, in the office, but also on the desk, in the gym or in train), and also with original and unconventional use modalities. A selection of these projects forms the basis for the realization of a collection of prototypes, useful for hypothesizing a collection for a traveling exhibition.

3 Method

The "Green for All" design laboratory, through the direct involvement of a complex system of actors, has been a pretext for raising awareness on the issues of diversity among individuals, equal opportunities to enjoy everyday experiences in an autonomous and comfortable way, favoring in this way social and cultural inclusion, according to the Design for All approach.

Therefore, from didactic experience, through different phases the initiative has all the characteristics to be transformed into a multidimensional promotion event, with moments of reflection and discussion within the working group alternating with moments of public exposure of the partial results obtained.

3.1 Critical Reflection and the Definition of the Briefs

In the Department of Architecture at the University of Chieti-Pescara some teachings related to Industrial Design have been dealing with the issues associated with design for inclusion for several years. In particular, the teaching of Product Design 2 of the Bachelor in "Design", starting from the basics of ergonomics applied to the industrial products, focuses mainly on the innovative approach of Design for All, both with lectures and collective reflections and debates, both through the identification of a specific design issue.

Recently, the field of application of design experimentation has been repeatedly identified in the types of products related to the domestic gardening sector, with the aim of developing inclusive product ideas for the care and cultivation of ornamental plants, spices and vegetables, whose use autonomous, comfortable and pleasant, it is extended to the widest variety of individuals with diversified needs and abilities. The only constraint was that the products should refer to the technology of terracotta, and therefore that the projects made specific reference to the formal and productive constraints of the pressing and turning of the clay, with a precise dimensional constraint for each element that does not exceed 30 cm of maximum size.

The brief was developed in groups by the students, starting from the identification of specific and unusual contexts of use and from the description of the respective limit user targets with respect to the chosen activities: this in order to inspire also original strategies and methods of use of the new products.

Some specialist contributions on the themes of home gardening and of the production process of terracotta, together with specific contributions on Design for All issues, have encouraged the students' collective critical reflection. Subsequently they were engaged in groups in the definition of specific design briefs. This starting from the direct observation of users grappling with the use of products for gardening and of users acting in contexts unrelated to the usual ones of home gardening.

3.2 Development of the Concepts Towards the Construction of Prototypes

On the basis of the briefs defined, each student subsequently independently developed a concept proposal, which had to refer strictly to the formal and productive constraints of terracotta.

The concepts defined in this way immediately highlighted the potential of the design process related to inclusion: the students verified how innovative product concepts can be developed to meet specific needs, determined by the needs expressed by multi-user, especially in relation to new contexts and use.

Thus product concepts have been developed, which are also interesting in their simple denominations: pocket flowerpots, kitchen wall-hung pot, mortar for cultivation and processing of spices, umbrellas-cushion vase, height adjustable pot, "a garden on the legs" for users in wheelchairs, spinning top pot (Figs. 1 and 2), etc.



Fig. 1. The "Spinning top pot" concept

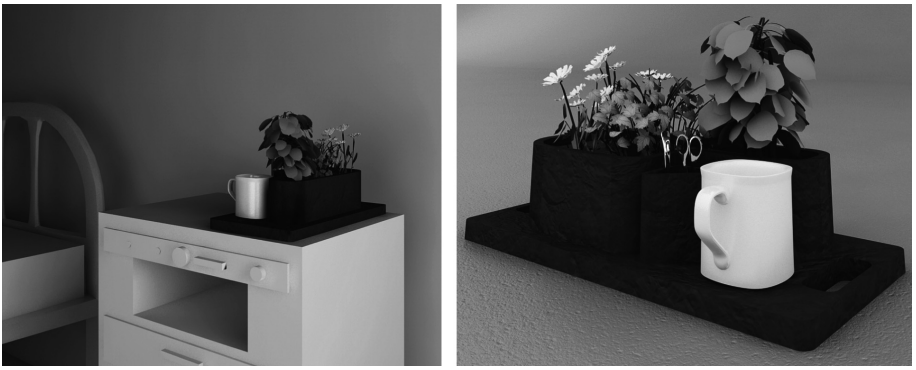


Fig. 2. The "Garden for bedside table" concept

A group of private subjects has recently shown interest in the educational initiative. The hope is that it happens as in a previous similar initiative, entitled "Everyone at the table!" [4], in which some private individuals and public institutions have made available facilities, professionalism and equipment for the concrete realization of prototypes. On the other hand, the extension of the project towards the realization of physical prototypes, allows the diffusion of the "Design for All" approach to a wide and diversified public, not limited therefore only to "insiders" able to interpret the project technical drawings. This also through the organization of public events which can foster a broad reflection and widespread awareness on the issues of social inclusion and human diversity.

4 Conclusions

The orchard or the garden are effective and extraordinary setting for testing the principles of inclusive design. This is through the possibility of autonomously using places, systems and products for the cultivation and care of plants, and the comparison and enhancement of the differences between the different crops (and their cultures).

In this the Design for All, with its attention to the "design process", appears to be the most promising and effective approach to experiment and promote social inclusion and equality between individuals, peoples and different tastes, also through the daily activities related to the care of domestic plants.

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Designing of Inclusive Learning Experiences: Preliminary Outcomes of a Pilot Project Tailored to SLD

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Abstract. Thanks to the knowledge related to Ergonomics in Design and Inclusive Design, the present work aims at finding and providing an opened and integrated approach to the disciplines of cognitive psychology, pedagogy and human-computer interaction by presenting field experiments on learning and case studies. The latter show novel co-design practices through the use of Human-Centered Design and Inclusive Design methods, which were pointed out by means of experiments conducted in collaboration with professionals, end users and people with Specific Learning Disabilities. Through the presentation of a pilot project dedicated to the SLDs, the final output of the work was to illustrate a developed inclusive learning platform and its operating rules. Moreover, the research highlighted the need for systems based on social networking, supporting not only accessibility but also autonomy, socialization and the ability to collectively build new meanings.

Keywords: Inclusive Design · Human Centered design · ICT · Social inclusion · Web accessibility · Learning

1 Introduction

Learning in the digital age means having user-friendly and interactive systems capable of creating a series of new relationships between man and technology. In this regard, the Design is called to face, more and more strongly, with different disciplines, from the engineering-informatics to the humanistic-social ones. Therefore, it is necessary to adopt a bottom-up multidisciplinary approach, within which the design field interfaces with increasingly complex design dimensions. In recent years, computer accessibility and aspects regarding the use, distribution and visualization of contents, not only informative but also educational, became issues of great importance within the technology market, particularly within the Educational Technologies sector.

The survey of the Italian National Institute of Statistics (ISTAT), dating back to 2004–2005, reported a percentage of people with disabilities for an absolute value of about 2,600,000 individuals. The latest unofficial estimates have raised this figure to three million. In 2009–10 there were 15,884 students with disabilities enrolled in the University, a figure that has now tripled compared to ten years before. With regard to

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Specific Learning Disabilities (SLDs), the statistical service of the Ministry of Education, University and Research (MIUR) provides relevant data for the 2014/2015 and 2015/2016 academic years. These data are organized by Region and school system according to the various levels, defined as pre-primary (3 to 5/6 years), primary (usually from 6 years to 11), middle school (age 11–14) and high school (from 14 to 19 years of age). In Italy, the statistical data for the academic year 2014/2015 state an average percentage of students with SLD of 2.1%. Excluding from the calculation the SLD diagnoses attributed to pre-primary school and its population, the percentage is 2.5%. The highest SLD values seem to be recorded in the middle school years. Comparing these results with those of the academic year 2015/2016, which has a predominant value of SLD certifications of 3.0%, an absolute increase of 0.5% emerges compared to the value recorded the previous year [1]. These alarming data are growing both in Italy and internationally. To face with this issue, within the framework of Educational Technologies, assistive and adaptive systems, including a broad range of technological devices (hardware, furniture, computer screens, software and so on), are usually employed to enable anyone to interact with more easily and effectively, regardless of any impairment or disabilities. Similarly, Learning Management System (blended Learning, E-learning, ecc.), born as electronic educational technologies, are largely used nowadays as networking environments to promote the integration and guide learning through flexible architectures based on current standards of web accessibility, platforms and content format [2]. However, it is noteworthy that the main limitation of these systems is ascribed to accessibility. This causes social exclusion, as it makes more difficult the access to information of people with different types of impairments. Despite the significant efforts, the accessibility of e-learning and web platforms and the use of assistive technologies are issues not entirely addressed yet. With this in mind, the present work studies how Design and related operational methodologies may support the process of analysis and development of complex digital products, which should be as much as possible inclusive. In particular, the preliminary outcomes of a pilot project tailored to SLDs, carried out in collaboration with experts and the C.R.E.D. center are presented. The main objective of the research was to design and develop a platform for inclusive learning dedicated to students over 11 years old. Summarizing, the work is therefore finalized to:

- assess the actual inclusive potential of technologies, in particular by analyzing systems designed for SLDs;
- technical aspects related to accessibility and use of contents;
- interaction styles (variability, transcoding, convergence, multimedia, hypertext);
- teaching and pedagogical aspects (organization, creation and sharing of teaching materials);
- didactic and pedagogical aspects for disables (universal access to information, organization of the study, didactic strategies, motivation);
- how to motivate and foster socialization (i.e. User Experience);
- design alternative scenarios.

2 Methodology

The design workflow was focused on the Human-Centered perspective, according to indications reported on the ISO standard (ISO 9241-210: 2010) [3]. The latter defines criteria for user-oriented design in systems based on human-machine interaction. The main criteria concern the clear knowledge of needs, tasks and contexts of use; the involvement of users in the design and development phases; the multidisciplinarity of skills and perspectives; the centrality of the evaluation phase; the iterative design process that provides for continuous steps and revisions ranging from consultation with users, to the analysis of needs, to the (re)definition of system requirements. In order to make available to users (People) who will use the system in specific contexts (Contexts) to perform certain activities (Activities) through appropriate technologies (Technologies), reference has been made to the PACT model (People, Activities, Contexts, Technologies) proposed by Benyon (2010) [4]. To explore all four categories of PACT, the research was structured in three macro-phases:

- Phase 1: Preliminary analysis and Understanding
- Phase 2: Evaluation phase
- Phase 3: Design and Envisoment

The first phase was dedicated to critically reviewing the reference literature and technical standards in order to get preliminary information about the educational sector, learning models and related technologies. It was also taken into account how and when Assistive Technologies (AT) should be used. Aspects related to the effectiveness and inclusive potential of learning technologies were subsequently investigated for evaluating the contribution of a combined approach between Inclusive Design (ID) and Universal Design for Learning (UDL) [5]. At the same time, the existing web accessibility standards and guideline (WCAG) [6, 7] and standards ISO[1] were analyzed and possible integrations with UDL approach evaluated. During the Understanding phase, qualitative procedures and tools were adopted to collect data on users' needs, but also to build a framework of habits and perceptions in terms of technologies. Usually the work of phase 1 precedes the experimental section (phase 2), since in the guidelines and good practices illustrated we find the necessary requirements to design a platform for inclusive learning. The methods applied were User Observation, Interviews and Focus Groups [8, 9]. The object of the evaluation was a hybrid platform developed by the research team through an Adobe XD interface simulator. The decision to create a platform for the simulation of activity was aimed at recreating all the best features identified in phase 1 and to verify the actual possibility, from the design point of view, to apply the technical standards of reference. Phase 2 was planned on the basis of the following objectives: (1) define the reference framework of the most widely used compensatory and dispensatory tools, (2) evaluate the instructional support that these

[1] It addresses software accessibility and usability (see also ISO 9241-110, ISO 9241-11 to ISO 9241-17, ISO 14915 and ISO 13407). Regarding AT: ISO/IEC TR 13066-3:2012 Information technology - Interoperability with assistive technology (AT) - Part 3: accessibility application programming interface (API).

tools are able to offer and their effective degree of inclusion, (3) measure the user experience and investigate organizational and motivational aspects of users (teacher-student-family), (4) define possible design scenarios.

The work activity of the last phase is an ongoing step. Preliminary functionalities for the development of a web platform will be discussed on the basis of the data collected in phase 2.

3 Results and Discussion

3.1 Preliminary Analysis

Currently on the market there are different types of products for SLD, some of these products are dedicated to specific categories of users, denoting a lack of tools effectively transversal. Looking at all that concerns the technological supports intended for subjects with SLD, it is possible to distinguish three categories of systems: compensatory, dispensatory and those used for the evaluation of the SLD degree. In our analysis we have taken more account of the first two. Compensatory systems aim to compensate for deficits due to SLD. In this category we find applications for both computers and mobile devices. Many of them consist of screen readers, software that, mainly in the field of dyslexia, through speech synthesis or with expedients to properly highlight words, assist the reading and suggest the correct decoding of the text. For example, in Italy there is "EdiTouch", a tablet that is proposed as a collection of the main compensatory tools for SDLs, such as an e-book reader, a calculator and a software for creating mental maps. Another Italian product is represented by the software created by Anastasis, which are computer programs mainly dedicated to the creation of mind maps, speech synthesis and support for study. The dispensing systems involve tools for dispensing some performances (reading aloud, taking notes), the possibility of organizing the study (personalized time of realization of the activities) and evaluation (the form is not evaluated but only the content).

These tools are not always available, some of them need to be paid and/or addressed to operating systems such as Windows. In a for all perspective, the possibility of the web to exploit the basic browsers is the most usable dimension and would also offer the possibility to monitor and implement the system over time. The same concept would also serve to improve the adaptability of AT (always and in any case necessary). Another feature found in the web is the ability to connect multimedia (such as YouTube platforms, and/or EVO, Fliker, SlideShare, Scratch by MIT, etc.) to the platform through the import or sharing of content. It was also found the ability of the web to promote socialization as well as to develop cooperative teaching materials. In terms of accessibility, the web also offers many indications at a regulatory level than the software market, which at the moment, especially in Italy, is poorly based on the study of accessibility in the broad sense.

In particular, ICT and network services have long been considered as an opportunity for growth and methodological-disciplinary reflection within educational and training environments. The substratum of ICT allows to significantly transform the articulation of productivity in a way that is no longer solely individual but cooperative

and collaborative. To define pros and cons related to the adoption of ICT, it was made reference to the survey carried out by INVALSI [10]. Below are some aspects considered relevant:

- possibility to create customized teaching materials also for pupils with severe disabilities;
- the increase in self-esteem;
- respond to the need for flexible and shared tools;
- customization of contents to facilitate learning;
- motivation to improve the speed of writing autonomy;
- the work shared between teachers and experts from the school and from the university.

The use of ICT for disability carriers in educational environments simultaneously affects educational-methodological and technical issues regarding the selection of devices to be used. ICT, for its characteristics, would seem to have strength for at least three aspects including "motivation, strictness, adaptability." The use of computer, thanks to its flexibility, allows the customization of specific training processes, playing a key role on learning styles and abilities of each individual [11].

As far as the project dimension is concerned, we have witnessed the development of new disciplinary areas and project approaches with respect to the themes of inclusive learning over the years. These mainly refer to the field of Instructional Design and Universal Design for Learning (CAST). In particular, they refer to sectors such as the User Interface (UI), interaction design and User Experience, which are contributing to the growth of this disciplinary sector in qualitative terms [12]. While usability assessment methods allow us to measure the actual level of accessibility, HCD and UX methods can provide us with qualitative parameters on emotions and pleasantness (strategic aspect with regard to the educational dimension). Inclusive design and, above all, in the field of information technology and education, Universal Design, are today treated as disciplines of Instructional Design. Within the field of educational technologies, the UD (Universal Web Design Principles and guideline) approach and the educational studies of the Universal Design for Learning (UDL) emerge more clearly [5]. The UDL approach, combining the principles of UD and neuroscience-related research on different ways of learning, formulates the following principles (CAST, 2011):

- support models of recognition learning and at the same time provide multiple and flexible methods of content presentation;
- supporting strategic learning through flexible methods of expression and training;
- support affective learning and provide multiple and flexible options to stimulate engagement.

The UDL provides an interesting perspective and a solid foundation allowing to state that it is possible to pass from the concept of "special adaptation" focused on disability to universal design (for all), by valorizing individual differences and taking advantage of the potential of inclusive technologies [13, 14].

Identified in the UDL a viable base of operations to define strategies for planning and structuring learning in accessible way, it is noteworthy that WCAG, Universal Web

Design Principles and guide line and UDL have in common the attention to customize how to display the information, the availability of alternatives to the audio and visual content through the use of different media (even in support of understanding), the readability and comprehensibility of texts and compatibility with assistive technologies.

These aspects were verified and considered in the development phase of the platform for the simulation of activities and by the functions of phase 2.

3.2 Evaluation Phase

In the evaluation phase, web platforms for supporting learning at school and at home were analyzed. The sample of users considered foresaw the involvement of users aged 11 to 13 years and teachers involved in formal and informal training. As this is an experimental research, the aim of this work has been to define an intervention strategy implemented over time, which is expected to be extended to schools and universities. The sample analyzed concerned 5 teachers and 25 students (70% of these SLD).

Step 1: Preliminary Accessibility Review (Expert Evaluation): Checking conformance to guideline and Standards (UD, UDL and WCAG, ISO). In this phase, direct observation sessions were carried out with the involvement of a small sample of users and with the support of experts. In this way it was possible to make a preliminary analysis of the most popular platforms for reading and understanding the text. In particular, through the Task Analysis (TA) [15], the interactions on the teacher's side and then on the student's side were modeled. Once the architecture and functionalities of the platforms had been defined, Nielsen's Usability heuristics, Sheinderman's 8 golden principles of goods interface design were applied [5, 9–16]. The objective of this phase was to validate the correspondence and potentiality of the UDL guidelines and the technical and operational standards identified in phase 1 and to define the objectives of the following phases.

Step 2: User-Based Evaluation: Methods applied were Interviews and Focus Groups. Object of the evaluation at this stage was a hybrid platform developed through a simulator of Adobe XD interfaces. The choice of recreating a simulator was made to outline all the best features identified in phase 1 and the actual possibility from the design point to apply the technical standards of reference.

The aspects observed with respect to the process of organizing the teaching and monitoring of the path by the teachers were: (a) organization of the contents and planning of the training course, (b) creation and sharing of the teaching material, (c) monitoring and personalized support.

The aspects that were observed with respect to the students' learning process were as follows: (d) Access to the information to be studied, (e) understanding of the text, (f) re-elaboration of the information, (g) storage, (h) retrieval of the contents.

To evaluate these aspects a platform that allowed to simulate the functionalities present in Udl Editors, UDIO of the CAST was designed. It also includes open source compensatory tools with functions for speech synthesis Clip Claxon, LeggiXme and Balabolka, for text decoding (Memory for images and words by C.R.E.D and Super-Quaderno di Anastasis, LeggiXme_Jr_SP etc.), mental and conceptual map processing

tools (Super Maps, Cooperativa Anastasis, Super Maps EVO, C-Map Tools) and for lesson creation (Facile Facile web platform by C.R.E.D). Figure 1 illustrates some of the functions of the platform created.

The hybrid platform has been tested through direct observation sessions, and each session included the support of experts. The test sessions were structured following the same flow of activities.

Subsequently, on the basis of the data emerging from the evaluation sessions, 2 Focus Groups were organized, one aimed at the teaching dimension and the other at the students. Semi-structured interviews were carried out within the Focus Groups. In particular, this article contains the considerations that emerged and the design requirements identified and discussed with the teachers and experts involved in the survey.

(d) Access to the Information to be Studied: 40% of the observed users read the text several times highlighting a difficulty in the legibility of the font. The presence of textual indexes highlighted and subdivided in a coherent and repeated way in the screens (the title, the images, the subtitles, the words highlighted) have emerged as fundamental. The ability to select the level of difficulty was seen as negative before the test of almost all users observed. Although at the end of the session they reported that they had taken advantage of the possibility of being able to select difficulty levels; 25% said that this feature stimulated them to improve. Voice synthesis is 70% a strategic element and a support to understanding, the same for the dictionary. The dictionary should be revised because the size of the text and external links (Wiki, Translator, etc.) have not been perceived as exhaustive.

Design Ideas: Introduce topic without reading the entire text, possibility to customize the font (OpenDyslexic, Dyslexie, Read Me!, Bianconero, EasyReading) and the line spacing. Introduce the possibility to select text and activate speech synthesis in a more dynamic way through an enhanced tool. Possibility to integrate the notes taken in class to the text being studied. Insertion of verification tools in the form of gaming (scaffolding and tutoring system). This would allow the exchange and sharing of the study experience with others or with a tutor. Create the possibility of integrating content with extra material created by the student.

(e) Text Comprehension: For an LSD student, understanding a text read on its own is often very complex. This can be explained by the fact that, considering the problems in the reading process, all his attention is channelled into reading correctly, leaving out the meaning of the text. The observations made by the teachers and experts were as follows:

- the possibility of dividing the text into smaller parts, giving the possibility of analyzing one part at a time of the text;
- presence of the priming, i.e. providing questions to be read before proceeding to the reading of the text, in order to focus their attention on the salient points;
- possibility to insert and/or identify the key words first in the question and then in the text;
- possibility to highlight the keywords in the text during the reading.

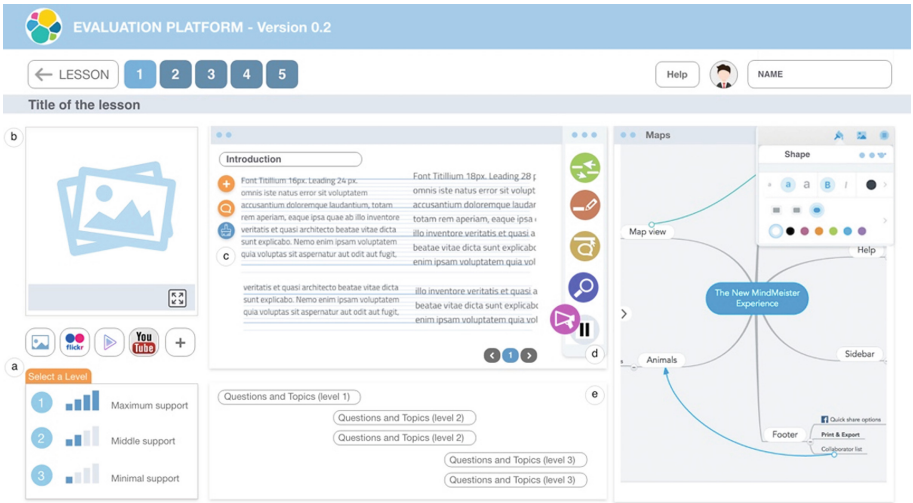


Fig. 1. Screen shot of the hybrid platform - student version 2.0: (a) Selection of the levels of support to the reading (b) Multimedia resources (c) Link window to select support levels and text line spacing (d) Text HELP Toolbar (e) Table of Contents.

Remarks: This phase has been linked to the evaluation phase involving teachers (a). The teacher expressed the need (as on Facile Facile) to create the contents himself and not find all the topics already packaged. This presupposes that the platform is conceived on the one hand for the teacher and on the other for the student. The teacher side, in addition to the usual registration phases, should allow the teacher to insert all the chosen elements necessary for the construction of the teaching units. This is especially strategic for the pedagogical aspect and to follow the student throughout his learning path. Consequently, a significant aspect is the possibility to include learning verification functions.

Design Ideas: Create a structured teaching area that allows you to organize the teaching units by topics and objectives. The architecture section of the functions must be connected to the student section, the teacher follows a format and obligatory operational phases. Consider the possibility of creating a register of the activities carried out by the student and the possibility of activating customized tutoring tools. Stimulate collaboration and sharing of material developed by individual teachers through a shared space.

(f) Re-elaboration of Information: Content reworking is fundamental for learning, and completes understanding by preparing for memorization. The deeper the processing of the information received, the easier it is to store and retrieve it. There are many ways to elaborate what you study, that is to reorganize and manipulate the contents of a text, and what certainly gives more results for a DSA is the construction of a conceptual map, that is a scheme, that visually organizes all that is to be studied and memorized. The dimension of the graphic representation of the contents has been tested, in which the key words previously highlighted are inserted, linked together by

arrows and enriched by images to facilitate visual memory. The maps were made by the student (this aspect is fundamental) and not already provided by the teacher or the system, precisely because it is the graphic representation that allows the cognitive stimulation of the student. From the focus group activities it emerged that each user has developed his own personal version in the organization of the contents. The users highlighted the need to develop the map on paper before making it on the platform. This aspect opens a reflection on the aspects related to the manipulation and tangibility of learning that should be considered during the development of the system.

Design Ideas: Possibility to create maps simultaneously and provide the possibility to import paper maps convertible into interactive digital format. Today, there are products that in this direction could increase the link between technology and disadvantage (see: Osmo™, Sifteo Cube). If you access the platform via tablet, you can use the drawing tool through digital pensil.

(f) Re-elaboration of Information: Content reworking is fundamental for learning, and completes understanding by preparing for memorization. The deeper the processing of the information received, the easier it is to store and retrieve it. Here are many ways to process, reorganize and manipulate the contents of a text, and what certainly gives the most results for a SLD is the construction of a conceptual map, that is, a scheme, that visually organizes everything that is to be studied and stored. The dimension of the graphic representation of the contents has been tested. The key words previously highlighted are inserted, linked together by arrows and enriched by images to facilitate visual memory. The maps were made by the student (this aspect is fundamental) and not already provided by the teacher or the system. It is the graphic representation that allows the cognitive stimulation of the student. From the focus group activities emerged that each user has developed his own personal version in the organization of the contents. The users highlighted the need to develop the map on paper before making it on the platform. This opens a reflection on the aspects related to the manipulation and tangibility of learning that should be considered during the development of the system.

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(g) Storage: The analyzed users requested to view the information acquired in the previous sections within all the tabs. Users also had difficulty remembering certain words or topics. The navigability for horizontal tabs was more functional than the vertical scrolling of traditional web pages as well as the ability to deepen the content through the viewing or listening to multimedia material.

Design Ideas: To offer a simple reiteration of the information sought during navigation. Support the association between the information to be remembered and familiar elements through the activation of symbols and/or photographic material and/or the possibility of highlighting portions of text or image in an alternative way, compared to

the functions hypothesized in point (e). Possibility to organize the information on the basis of those previously stored. To make possible the transformation of a complex information into a simpler one through a keyword in order to generate a process of meta-cognition.

(h) Recovery of Contents: Once users have created their own concept map and therefore started the memorization process, it has not been possible to verify in an exhaustive way the learning, especially if the user does not have the possibility to expose it to others or recover it from the memory. Some students said that they are used to repeating out loud the contents of their map or the text they have read. Repeating the subject they learned to someone else was also useful for getting feedback about their ability to expose themselves.

Design Ideas: Evaluate the possibility of recording your own voice and hearing it again to encourage self-correction within the platform with the possibility of being able to listen to it again, or to make video calls with your friend or school friend.

Note: If the user has difficulty in repeating what he has represented in the map, this means that the map is not adequate to support him in learning and then in exposure; consequently, it will be necessary to make some changes that the student himself will have to make to understand which concepts are missing, which keywords can help him and which links can facilitate the memorization of the speech.

In addition to the above, other considerations emerged, which were fundamental for the development of the pilot platform. These included the need to include tools and functionalities for the organization and management of time, which was found to be critical for SLD students. Moreover, some hardware tools such as the PC keyboard were more difficult to use than touch devices. This opened up an interesting question and the need to investigate more on the interaction modes. Multimedia material and hypertext revealed to be strategic for SLDs, although a current and ordered layout is necessary to prevent cognitive crowding. This is a determining aspect in the phase of content creation by the teacher. Compensatory tools have not been effective if not used consciously. Automation practices must therefore be preceded, the tool is effective only if it takes the abstract form of a communicative bridge, built in a conscious way.

The systems of self-correction and verification of learning favor meta-cognition, at the same time it is necessary to pay attention to how this agents are administered (the user does not like to be corrected by an adult or by a teacher). The subject understands why he is wrong, and through it the sense of what he is doing is amplified (significant learning). Therefore, it is in this phase that the conscious and non-automatic use of the instrument allows to generate strategies in the name of autonomy. The subject thus has control of what he does and consequently experiences modes of learning until the identification of the preferred practice.

The use of collaborative platforms allows to operate in an inclusive perspective. Any student, regardless of their condition, can learn in a dynamic and collaborative way thanks to others.

In conclusion, the aspects related to the design dimension of the teacher-side content have been the subject of the preliminary design phase, while those of the student-side learning support will be explained in the next paragraph.

3.3 Phase 3: Design and Envisoment

On the basis of the data collected in phase 2, a web platform is currently being developed with a horizontal layout for supporting and sharing learning. The objective of the preliminary project was to develop a conceptual version that allows to evaluate from a technical and graphic point of view the project ideas that emerged in phase 2. The platform will aim to support the following functionalities:

- Organization by degrees of learning support (maximum, moderate, minimal) selectable and modifiable at any time by the user
- Presence of pedagogical agents who support readers in understanding the text through contextualized explanations, operational suggestions and guided questions. These are supposed to be customized by the student through the development of features: Create your own Avatar.
- Presence of text-to-speech technology. Through this tool it will be possible to activate on request the translation of foreign language words. This tool will be provided through audio and text formats to facilitate correct pronunciation allowing for in-depth analysis of words and phrases with direct searches on the Google engine;
- Presence of reading supports such as synthesis and images
- Presence of indications on the correct ways to achieve a careful and effective reading at the level of understanding and appropriation. The strategies proposed consist in predicting, asking questions, visualizing and summarizing the contents of a narrative;
- Tools for creating interactive maps. It will be tested the possibility of importing maps made through digital media that allow you to store the gestures of the drawing - tablet/scanner
- Presence of feedback on several levels to promote self-correction and to encourage problem solving
- Insertion of content manipulation tools. Predict, ask questions, view and summarize content.
- Presence of external links for in-depth analysis (teacher side and student side)
- Integrated comprehension support tools, including a multi-media glossary that can be linked directly from the text for more difficult terms
- Collaborative section activated by a specific icon and activated by choice connected to a section that provides for the exchange and collection of processed materials, rather than dialogue through the chat
- teaching area that allows you to organize the teaching units by topics and objectives. The function architecture section must be connected to the student section, the teacher follows a similar format and operational steps for all. This is to avoid the creation of uneven teaching material.

The platform is currently under development and, as mentioned in paragraph 2, the beta platform will be re-tested and implemented on the basis of the criticalities that will emerge during the evaluation phase.

4 Conclusion

The aim of this experimentation was to define, through the development of a hybrid pilot platform, the functionalities that favor the autonomy process and the problem solving strategies in learning. The experimentation has shown that doing "problem solving" means developing a critical sense (also through others). Active interaction with teaching material within a web container favors these practices and is a positive aspect from the pedagogical point of view. In this sense, the most significant tools are those for the development of concept maps that allow to rework concepts by strengthening key aspects, voice reproducers, tools for the organization and structuring of content and programs of temporal organization. Within this framework, the experimentation allowed to identify strategic aspects in order to support SLDs in the learning process, with a broader approach that addresses all regardless of their capabilities. The future objective of this work will be to extend the observations to the dimension of visual, auditory and cognitive disabilities. In perspective for all, the success of this experimentation will lie in its ability to be compatible with assistive technologies as well as supporting all teachers and students, regardless of their condition.

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Universal Signaling Based on the Articulation Between the Ergonomic Practices and the Perception of the Visually Impaired

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Abstract. Every signaling system involves a range of issues of communication, visual perception, semiotics, pictograms, signage, writing, among others, in order to guide and inform, offering the necessary accessibility conditions for anyone, regardless of their condition. The present work proposes to continue to rethink the construction of inclusive educational environments from the integrated reflection of research related to ergonomics, participatory practices in design and sensory experiences that allow the development of alternatives for a universal signaling system centered on the user, including the visually impaired user, of the São Luís - Monte Castelo Campus of the Federal Institute of Maranhão.

Priority to understand the experience lived by the visually impaired in a theoretically open environment for all was the starting point to see the difficulties faced by this public. However, the user's participation in the process consolidates the opening of new paths that achieve the most significant results. Thus, considering the participation of the visually impaired user with the intention of proposing improvements in existing methodologies or in the process of creating the solution gains more and more strength as a strategy to promote intelligent and accessible environments.

Keywords: Accessibility · Inclusion · Ergonomics · Signage · Universal design

1 Introduction

Throughout the world there has been an increase in the number of people who need the help of some resource to develop their daily activities due to some difficulty or sensory incapacity. The deficiencies are affecting individuals, while, unequally, research and possible solutions and technologies are also advancing in order to balance this gap.

Brazil, with almost 519 years, grew under strong social, cultural and economic influence of the European countries, its formation and construction were conceived and constructed from the adaptation of the material and socioeconomic conditions, disregarding the necessities of the deficient minority of the time.

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Time has passed and the world has opened up to think and design things that can be used interchangeably by society, regardless of their condition. It took many years for the country to open its eyes to see social needs. When this happened, laws and standards were created to guarantee the rights of those with disabilities. Today, ensuring that these guarantees are met is a goal to be achieved.

Gradually the disabled, have been seeking to exercise their rights of care, accessibility and autonomy. For this to happen, there needs to be a change in behavior and especially in the construction and adaptation of projects, with a more human thinking in conceptions.

In this way, design has been gaining strength because it is a tool capable of repairing failures and injustices by balancing solutions that can involve people's needs to the peculiar aspects that involve social and environmental issues. Both participatory design and universal design work so that your products and services meet as many people as possible, that is, with the participation and use of all. For the visually impaired, the design aims to contribute to the elimination of barriers that impede the access of the handicapped, thus allowing a significant improvement in the well-being and the quality of lives of all.

2 Understanding Disability

Deficiency is part of nature, like other animals, the human being is also prone to have problems that can cause impediments in their interaction with the environment.

Thus, disability is any partial or permanent handicap or incapacity, which limits the individual to develop his activities in its fullness.

This definition of disability has always been based on the medical and individual aspects of the people, which are related to the medical model. Since the 1970s, the way in which disabled people are seen has changed, mainly due to the growing number of people who have become part of the disabled group. In order to have more arguments about human conditions and to propose solutions that reduce the segregation of these people, the United Nations began to investigate these aspects and began to adopt another model that is based on the condition of the individual, from a structural and social perspective, "In which people are seen as disabled by society and not due to their bodies" [11], thus beginning the transition to a new model, the social, adopting the CIF, International Classification of Functionality, Disability and Health.

ICF, adopted as the conceptual model for this global report on disability, comprises functionality and disability as a dynamic interaction between health problems and contextual factors, both personal and environmental. Promoted as a "biological-psychic-social model," the report represents a viable compromise between medical and social models. Disability is a comprehensive term for impairments, limitations to perform, and restrictions to participate in certain activities, which encompasses the negative aspects of the interaction between an individual (with a health problem) and the contextual factors of that individual (environmental and personal factors) [11].

This model now treats the diversity of disability as complex, so that people are no longer part of the traditional generalized group of sensory problems and disabilities, which includes hearing, visual, mental and motor deficiencies, being part of a group

whose disability is defined by the relation of their problems involving environmental and personal factors, the latter involving "differences in terms of gender, age, socio-economic status, sexuality, ethnicity, or cultural heritage" [11].

The Brazilian State, through Decree Number 3.298 of 1999 [2], considers the disabled and incapable, all those with loss or abnormality of physiological, anatomical or psychological functions, and those that due to some event have not been able to restore the autonomy in the performance of their activities and because of this they need the help of adaptations, equipment or special resources. The Brazilian Federal Constitution of 1988 recognizes the condition and the rights of the disabled, and advances in the creation of other laws that since then have been extending these fundamental guarantees.

Law Number 13.146 of 2015 [3] establishes the inclusion of the disabled person of any nature and has full participation in society, in order to allow equal and unconditional access to spaces and buildings, equipment, furniture, information systems and technologies, as well as services and facilities of a collective nature, whether public or private.

3 Visual Impairment

According to data from the OMS [11], about 40 million people with vision problems worldwide, in Brazil, according to data from the World Health Organization, are deficient visually impaired. last Census [9], the number of people with vision problems reaches approximately 36 million, representing 3.5% of the population (Fig. 1).

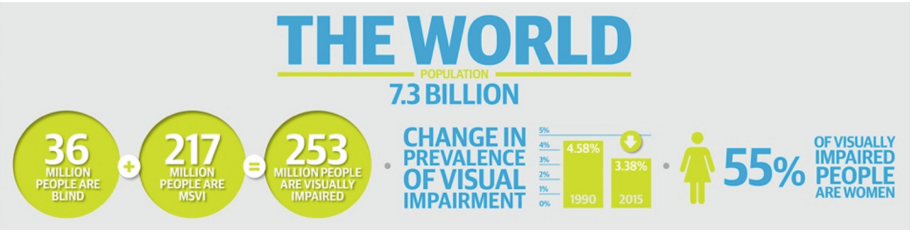


Fig. 1. Data from the international agency for the prevention of blindness.

Visual impairment consists in reducing the level of visual acuity, that is, the visual system, which reacts through stimuli, has the function of converting light energy into neural activity with meanings recognizable by the human being, cannot work correctly, soon, the formation of the images are totally or partially compromised.

According to the International Agency for the Prevention of Blindness [8], problems with the visual system can occur congenital or acquired. The most common causes of visual impairment are due to problems related to cataract, glaucoma, age-related macular degeneration, retinopathies, optic neuropathies and amblyopia, and according to Carletto [6], are presented in several types:

Tubular vision - the individual sees only what is directly in front of him and nothing that is next to him, while others see objects as a puzzle missing one or two

pieces; Low vision - the person sees very little, but still they are able to use the vision for the planning and execution of a task; Blindness - when there is no perception of light causing the individual to see absolutely nothing.

Knowing the levels of visual capacity is essential, above all, because the visually impaired individual tends to discover new means and use the other senses to fill the absence of vision, so that they can relate to the environment and carry out their activities.

4 Participative Design

In the last decades, design has undergone several transformations regarding its performance, when it is no longer focused on the project activities with a high degree of complexity, applied to manufacturing and consumption on a large scale, to become a constantly evolving activity, from of the improvement of their practices, which have expanded to the most diverse areas, yet the needs of the human being, have become their center of interest in all these practices.

One of these evolutions was social insertion in its practices, as a way of seeking collaboration for the understanding and resolution of the most varied and complex problems.

Collaboration has a fundamental role in enabling the relationship of different groups with a common interest, having positive effects on the performance and communication of those involved, as well as contributing to the success of the project.

In this sense the participatory design in its planning, it relates to several integrated areas, such as interaction design, interface and product design, architecture and information technology, all of which are user centered.

This integration brings together a great deal of knowledge, opinions and ideas that are going to be discussed and evaluated, within a planning process. Interpreting this information will aid in the usability of a system. In line with this view, Du et al. [7], considers that participatory design adds indissociable elements: argumentation, evolution, association and fusion. The argument involves the examination of all the information and positive and negative opinions to which the project refers; the evolution refers to stoning and refinement of the proposals offered; already the association is when an idea or proposition encourages the other idea, thus conceiving a new one; and finally the merger is the possibility of unification of proposals that are similar.

According to Camargo and Fazani [4] "participatory design assumes that people are always participating, even if unofficially, because the adaptations they make to use their tools are also creative actions, that is, the use is not considered mere consumption". This engagement, which must be democratic in nature, fosters the construction and alignment of perspectives that lead to the construction of solutions.

5 Universal Design

Since its inception, design has always had a clear purpose, "to put order in the mess of the industrial world" [5]. However, the deep transformations that occurred in all social, political, economic and cultural scenarios have meant that within the process of design

evolution, it also added to its organism the need to offer more human values, as well as to make its solutions, products for everyone.

Recently, at the center of the discussions, design begins to assume this role of designing things, but things that meet not only needs, but also that can be used by any individual, regardless of their conditions, skills, culture and whatever be their differential for the others. This is how universal design gains notoriety by adding to its solutions elements that extend the possibility of use to most people and can still simplify the life of all of them.

In this way the universal design, it aims at designing objects, equipment and structures of the physical environment intended for use by the majority of people, without recourse to adapted or specialized projects, and its objective is to simplify the life of all, whatever the age, stature or capacity, making the products, structures, communication/information and the built environment usable by as many people as possible, at low cost or without extra costs, so that all people and not only those with special needs, even temporary ones, can fully integrate into an inclusive society [10].

Contrary to popular belief, universal design does not converge with unnecessary actions that are intended to serve specific audiences, such as solutions that target only people with disabilities or an age group. That's why they are basic principles of universal design:

Equality in the possibility of use: comparable use, for people with different abilities;
Flexible: adaptable to a wide range of preferences and abilities;
Simple and intuitive: easy to understand for any audience;
Effective information gathering: communicates effectively the necessary information;
Safe: error tolerant and minimizes the risk of unwanted actions;
Minimized physical effort: requires little physical effort;
Comprehensive: Provides appropriate size and space for access and use.

Thinking about a universal project often does not necessarily involve major interventions, first of all there must be empathy, sensitivity and small attitudes that aim to improve things for everyone. The universal design exists so that things and places are prepared for any individual, be it architectural, functional, or informational questions.

6 The Development of the Project

For the beginning of this project, we sought theoretical basis in articles, laws, legislation and other materials that could feed our repertoire of information, with the purpose of enabling the analysis of a given environment, with respect to an inclusive environment.

Based on the idea that a public teaching environment should be as accessible as possible and always ready to receive any individual, information surveys were carried out at the Federal Institute of Maranhão - Campus São Luís Monte Castelo, seeking to observe the main aspects related to the existence or not of a system of visual communication and accessibility conditions offered, with the aim of offering contributions that can minimize the daily barriers, be they architectural or communication. Assuring thus, the autonomy of the people, and especially those with disabilities, giving them the

opportunity to commune with an egalitarian environment. In this way, we focused on experiencing the challenges and difficulties experienced by people with visual impairment.

To do this, a mapping of three main routes used by a blind student was carried out, starting from his arrival on the campus, until his move towards the classroom, library and cafeteria.

For those who use public transportation, whatever the bus line, it is possible to disembark a few meters from the main entrance of the Campus São Luís Monte Castelo, and in this first contact, it is possible to perceive the lack of tactile signaling that directs to its dependencies. Even for those who see it is possible to find some sign, sign or any type of inscription in the surroundings and the facade that identifies the place. However, there is a wide entrance structure, which, although not fully adapted to the ergonomic accessibility standards, allows the entry of handicapped people to move quietly. This initial structure has a ramp with handrail and body guard, which due to its steep slope, should have at least one segment or rest area, following the orientation of the Brazilian Association of Technical Standards – ABNT (Fig. 2).



Fig. 2. View of campus areas. Source: Authors. January 2019.

This standard, NBR 9050 [1], says that only ramps can be considered if the tread surface has a slope of 5% or more. And according to the same standard, for a ramp to be accessible, maximum slope limits, slopes that need to be overcome and the maximum number of segments are set. The value determined for the slope represents the relation between its height and length, represented as a percentage, as it is possible to observe the values arranged in the following Table 1:

Table 1. Calculation of incline ramps. [1].

Maximum slopes of each ramp segment h (meters)	Permissible slope on each ramp segment i (%)	Maximum number of ramp segments
1,50	5,00 (1:20)	Without limit
1,00	5,00 (1:20) $< i \leq$ 6,25 (1:16)	Without limit
0,80	6,25 (1:16) $< i \leq$ 8,33 (1:12)	15

In practice a ramp would be as in the image below (Fig. 3):

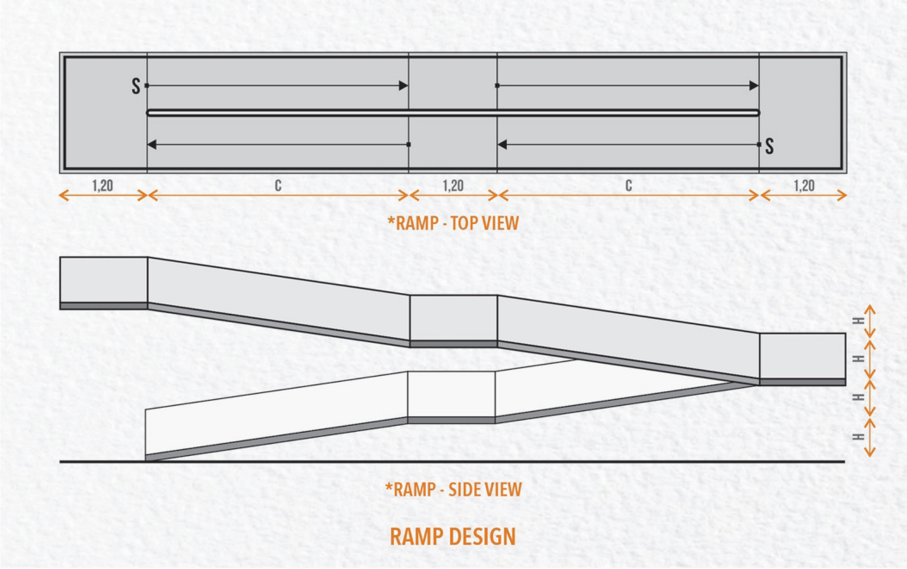


Fig. 3. Ramp design. [12].

Following the course towards the classroom, we come across long corridors, without any type of signage, are ways with insufficient widths for side-by-side passage of a person and a wheelchair, besides possessing several obstacles, buckets and garbage baskets, drinkers, traps for rodents, among others, that can cause some accident for people with disabilities. For arrivals in some rooms, the accesses through the corridors lead to staircases that further hinder the path of the visually impaired student.

In the reverse direction, going to the library and cafeteria, it is not possible to carry out a shortcut on the way, as do the sighted students, since the ramps of access to another level are punctual, and take an even more complicated path.

In many of the rooms observed in the trajectories covered, there were some signs, some paper, others adhesive and some even using more rigid materials, however, all of them are out of the accessibility standards, do not have any of the prerequisites of a signaling, who will say an inclusive communication, that has sensorial resources.

There were also some observations related to other environments, such as the campus restaurant, which even has plates, a table with information on prices and products offered, an ordering desk and shopping receipts, but none of this information is presented in Braille or in the standard communicational communication. The Theater also has only a small plaque, without Braille. Locomotion conditions for disabled people inside the theater are not favorable and seating arrangement makes it even more difficult. In relation to the use of the bathrooms there is also no information and the environment is not able to meet the needs of a student with reduced mobility or wheelchair, and as for access to the upper floor of the theater, it is also difficult to

access for those who have visual difficulties and others deficient because they have only stairs, with uneven stairs and different heights, which makes the route dangerous.

As it is a project that is in progress is still being carried out the diagnosis of other environments and in parallel the initial study of a signaling proposal that enables a disabled to have autonomy to reach any campus environment.

7 Final Considerations

We know that inclusion and accessibility are important prerogatives for any location or environment, as well as all the things they offer. Although this research is in progress and does not yet have the final results, it is possible to understand the seriousness of the situation regarding the lack of these two basic prerogatives that permeate the values of universal design.

So far, this research has been able to raise and verify the architectural and information deficiencies that exist in the construction of the Campus São Luís Monte Castelo.

The project will now be in the development phase of solutions, which, based on guiding foundations in universal design and participatory design, will seek to understand the vision of various user groups, including: students, teachers, community, people with and without with a view to developing solutions that effectively fulfill the task of communicating and helping people.

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Industrial Design for Inclusion

Accessibility Evaluation of Automated Vending Machines

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Abstract. Electronic vending machines are a wide-spread system for delivering and accessing goods: the possibility of operating in a completely automated fashion and independently from business hours makes them extremely convenient for serving public and private locations. However, they fail their purpose in serving individuals with special needs: their lack of accessibility prevents users who are blind or have severe visual impairments from autonomously purchasing products. In this paper, we focus on the ergonomics of electronic vending machines and their automatic payment systems: we discuss their human factors and, specifically, usability to individuals who have severe low vision. Furthermore, we present a user experience analysis of their components and we detail the results of a study that evaluated the performance of different common types of commercially-available vending machines in the three steps of a purchase, that is, product selection, payment, and collection. Our results demonstrate that poor design, lack of tactile information, and absence of non-visual feedback have a significant impact on accessibility and prevent most customers who are blind from being able to independently select, pay, and collect a product.

Keywords: Accessibility · Blindness · eVending · Automated payment systems · Americans with Disability Act

1 Introduction

Electronic Vending machines (eVending) are a convenient method for delivering and accessing different types of goods in public locations as well as in private facilities that cannot be served otherwise, and outside office hours. Modern eVending features a variety of categories of products, such as, tickets for public transportation, electronic gadgets, books, and food and beverage. With specific regard to the latter, other than comforting customers, vending machines provide them with additional choices that include more affordable options. The success of the eVending industry is demonstrated by recent market reports, which estimate that currently there are 4.6 million automated devices in operation, in the United States alone, with an annual spending of 7 billion US dollars in food and beverage, alone [1]. Also, industry reports show a growing trend in all the diverse sectors. Moreover, the increasing adoption of eVending benefits from

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and facilitates the introduction of cashless technology: according to recent statistics, vending machines that offer an electronic payment system represent 30% of the existing market [1].

Primarily, studies about eVending devices focused on the type and quality of food offered, on the habits of consumers, and on how to improve interaction by connecting vending machines to Internet-based services. However, human factors received less attention, and there are very few studies that investigate the usability of eVending systems. Specifically, there is a lack of understanding of the accessibility principles that enable people with disabilities to independently buy food and drinks from vending machines. Despite the numerous challenges in supporting interaction for people who are blind [2, 3], addressing and supporting accessibility is an often-overlooked aspect. The Americans with Disabilities Act (ADA) established in 2012, outlines design guidelines and details federal regulations for rendering eVending devices usable and accessible, as well as defining penalties for violations [4]. Nevertheless, ADA rules primarily address physical accessibility for people with limited mobility (e.g., wheelchair users), only, and do not consider sensory conditions, such as, blindness or severe low vision. Unfortunately, a recent article [5] reports that the Supreme Court and the U. S. Department of Justice declared that vending machines are not public accommodations under the Americans with Disabilities Act.

In this paper, we introduce a study that investigated accessibility in the most common types of automated vending machines, with specific regard to people who are blind or have significant visual impairments. We discuss the results of an accessibility assessment of the individual components of eVending devices. Moreover, we detail an experiment in which we studied the usability performance of two different types of automated vending machines in serving a group of people who experienced them as if they were blind.

2 Related Work

In the last decade, the topic of accessibility, with specific regard to individuals who are blind, received increasing attention and has been introduced as a major theme in the design of public and private spaces [6], products and appliances [7], and software [8]. Recently, the lack of accessibility in kiosks [9], eVending, and other types of self-service devices, has been considered by the research community, though there is an ongoing legal debate on whether accessibility of automated vending machines should be regulated [10]. The authors of [11] question Title III of the Americans with Disabilities Act and describes the legal pitfalls that can lead to non-compliance in the design of websites as well as self-service vending machines.

Previous studies discussed methods for supporting individuals who are blind or visually-impaired in several tasks [12], using wearable devices [13], touch- or sign-based communication [14], or implementing Braille [15]. Nevertheless, most of research resulted in new technology. Conversely, others focused on analyzing and improving accessibility of existing devices: the work of [16] investigated the use of touchscreens and other types of input devices that utilize capacitive sensors, demonstrating the impact of systems that do not provide any tactile feedback on the usability

of self-service kiosks. Indeed, lack of accessibility in devices for enabling equitable use of public transportation has the largest impact on the blind community [17–19]. Therefore, many are addressing support to mobility from different perspectives, such as, leveraging smartphones or increasing the presence of auditory and tactile feedback. Nevertheless, their applicability still requires further investigation. In this paper, we present the result of an experimental study that aimed at increasing awareness on the impact of poor accessibility in eVending. Moreover, we demonstrate the problem and describe simple and resource-effective fixes that, despite negligible investments, might lead to significant social return.

3 Experimental Study

We designed a preliminary experimental study to evaluate the accessibility of vending machines to people who are blind. The objective was to discover if currently available systems can be effectively used by blind people in each of the steps of a purchase, that is, product selection, payment, and product collection. Additionally, by doing this, we also aimed at evaluating the accessibility of automatic payment systems to individuals who are blind. The experimental study was realized in the library of a state university. We chose a public space because our goal was to evaluate the use of eVending in a real-life scenario that an individual with visual impairments might encounter.

3.1 Protocol

The experimental task consisted in completing the purchase of a product. The task was repeated twice with each of the vending machines: first, they realized it while being blindfolded to simulate the circumstances of being blind; then, they were asked to repeat it without any impairment, to simulate acquisition from a control group. The order of eVending was selected at random. The experimental task was divided into three sub-tasks, that is, product selection, payment, and collection. They were recorded, timed, and analyzed separately. Subjects had a 60-s time limit to complete each sub-task, which was considered as unsuccessful after 1 min.

Sub-task 1: Selection. Subjects were verbally instructed to select a specific product: for machine A, they were asked to purchase the drink at the very bottom left; for device B, they had to select product having code 609. In addition to standardizing the protocol and removing confounding variables, this was to simulate the situation in which they already used the eVending and knew which product to select.

Sub-task 2: Payment. Participants were verbally asked to complete a payment for the selected item. Regardless of the type of vending machine and product selection, product price was set at 1.75 US dollars to standardize the protocol and avoid confounding variables. This sub-task was further divided in two pieces: payment with credit card and with cash. The objective of this task was to realize which automated payment method and system might prove to be easier for a visually impaired person to operate. Before the beginning of each activity in this sub-task, participants were provided with a credit card or with 2 dollars in notes and 1 dollar in coins.

Sub-task 3: Collection. In this activity, participants were verbally asked to collect the product from the dispenser. A sample item was placed in the collection container before the beginning of the sub-task. This was to provide subjects with the same type of auditory feedback they would receive if the product was released after they actually purchased it.

Before the experiment, participants were provided with informed consent form and instructions. Subjects were not allowed to touch the vending machine until the timer started. Experimental data were recorded using a camera and a paper-based experiment worksheet. After completing all the experimental tasks, participants were asked to fill out a questionnaire that collected their accessibility evaluation of each of the vending machines.

3.2 Equipment

For this study, we utilized two types of eVending: one serving drinks (A) and one snacks (B). They are shown in Fig. 1. They were chosen because their components had very different design, with regard to product selection and payment. Specifically, machine A, which offered 12 products, featured a large, embossed press-button for each drink. On the contrary, machine B utilized a flat, touch-sensitive keypad to enable users to access a greater choice of products (approximately 50) by entering their code.

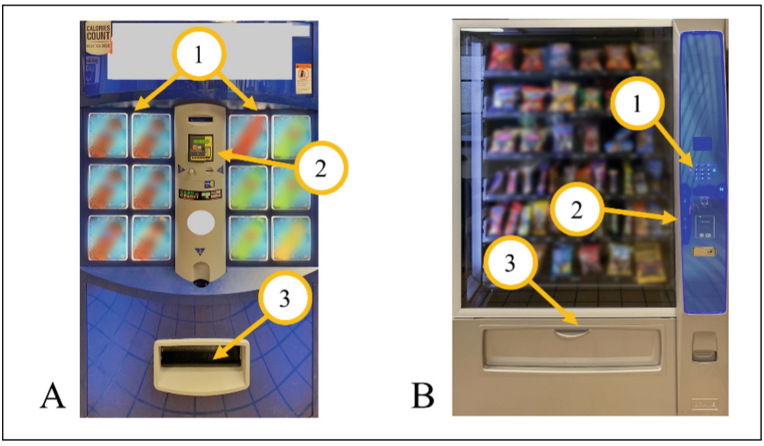


Fig. 1. The eVending utilized for the experimental study. We utilized two standard vending machines for beverages (A) and snacks (B) offering payment with both cash and credit card. Also, machine B implemented contactless payment. The numbers illustrate the different configuration of the devices in regard to: (1) product selection, (2) payment, and (3) product collection.

Furthermore, the payment system of eVending A consisted of an external unit that incorporated a vertical slot for swiping credit cards and a horizontal opening for cash; the opening for coins was located separately, on the bottom of the payment unit.

Conversely, machine B featured 3 adjacent openings: a large vertical inset for credit cards, a horizontal slot for cash and a small vertical opening for coins. Both machines implemented released the product in a container located at the bottom: machine A had a simple opening whereas the compartment of machine B was protected by a sliding door. They are shown in Fig. 2.

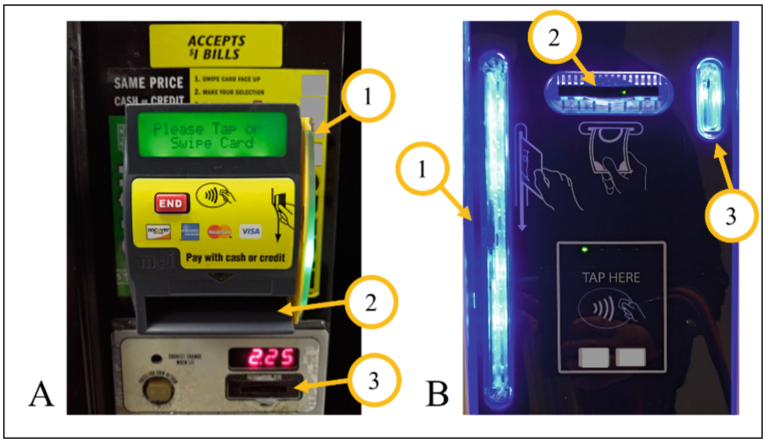


Fig. 2. The automated payment systems for eVending A (left) and B (right). The devices had different configurations. The numbers indicate the different design of the components for (1) swiping credit cards and inserting notes (2) and coins (3).

3.3 Participants

A total of 15 participants were recruited in this experimental study (12 females and 3 males); 12 (80%) aged 18–24, 2 (13.33%) were in the 25–34 bracket, and 1 (6.66%) aged 35–44. As this was a preliminary study, we did not specifically involve individuals with blindness: subjects did not have any visual impairment and their vision was generally good, though it was not assessed with any optometry test.

Participants' familiarity with vending machines was evaluated before the experiment using a self-assessment tool in which respondents described the frequency of use of eVending and their preferred method of payment.

4 Results and Discussion

Our results show that very few subjects were able to complete the experimental tasks when they were blindfolded, despite the presence of the experimental staff, who suggested which product to buy, told participants the price of the item, and prevented actions that could impact the task, such as, inserting the credit card in the slot for notes. Furthermore, subjects would fail every sub-task without this type of guidance. Regardless of the simplified and supervised setting, participants were not successful in finalizing product selection using the touch-sensitive keypad incorporated in machine

B, due to accidental input, lack of auditory or tactile feedback, and to the impossibility of recognizing individual buttons. As a result, in a real-life scenario, they would not be able to move the purchase forward. Table 1 summarizes the experimental result, with specific regard to the success rate (SR) in each task: very few subjects succeeded in paying with credit card, leading to an aggregate success ratio of 17%, on average. In this regard, the design of the payment device is key: the slots for credit card and cash are similar in shape and structure, there are very few details that help distinguishing them, and no measures prevent users from inserting the payment method in the wrong slot. On the contrary, participants were relatively successful in product collection.

Table 1. Timing (T) and success rate (SR) in the experimental sub-tasks using machine A and B. The table shows results for subjects when they were blindfolded (BF) and without any impairment (NBF). Success rate is not shown for the latter as all subjects were able to complete the task.

Sub-task	A/BF T	A/BF SR	A/NBF T	B/BF T	B/BF SR	B/NBF T
Selection	30.32 ± 17.57	92.86%	2.36 ± 1.88	60 ± 0	0%	5.95 ± 3.7
Payment - card	59.19 ± 3.03	7.14%	13.04 ± 12.58	51.87 ± 16.7	28.57%	12.31 ± 9.07
Payment - cash	51.01 ± 13.22	33.33%	11.85 ± 4.86	44.97 ± 13.97	64.28%	17.27 ± 12.8
Collection	16.5 ± 16.07	92.86%	2.91 ± 0.66	22.68 ± 17.94	85.71%	6.79 ± 8.5

The total time for accomplishing the experimental task is described in Fig. 3. On average, subjects experienced a 4-fold increase in purchase time when they were blindfolded. However, as none of the experimental subjects could complete product selection with machine B, the time associated with this sub-task was 60 s.

Nevertheless, in a real-life scenario, individuals who are blind would not be able to select a product and, consequently, move the purchase process forward. Also, the lack of any type of non-visual feedback prevented participants from understanding if the machine was working, if they selected the right product, the cost of the selected item, if they inserted the cash or card correctly, and if there was any issue with the purchase.

In addition to quantitative data acquired during the experiment, we asked participants to complete a survey that featured items on a 5-point Likert scale. Figure 4 shows the overall usability of machine A and B, indicated as perceived frustration and accessibility. Several subjects ranked eVending as accessible, despite their frustration and even if they were not able to complete some of the experimental tasks. This might be due to a lack of familiarity with the concept of accessibility: our future work will address this aspect.

Moreover, users were asked to report the accessibility of machine A and B in each sub-task, considering the experience they had while being blindfolded (see Fig. 5). Overall the accessibility of both devices was considered less than acceptable. Despite product collection had a good outcome, respondents identified selection and payment

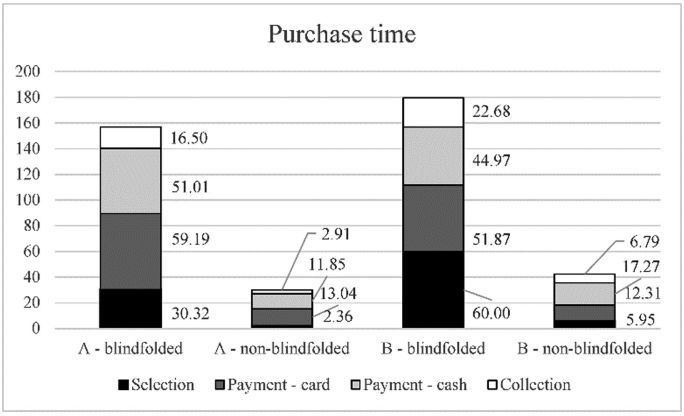


Fig. 3. Time (in seconds) for completing the different steps of a purchase, that is, selection, payment with cash or credit card, and collection. Although customers use only payment method, data are shown in an aggregated form as they describe how design affects each phase.

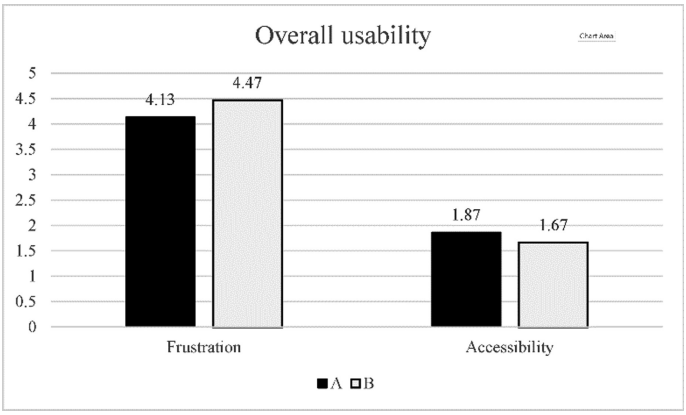


Fig. 4. Overall usability experienced by experimental subjects and displayed as frustration and perceived accessibility. Most of the users felt very frustrated with both machines, and they scored the devices as not being accessible. Unsuccessful product selection was the main reason why eVending B ranked the worst, though both devices scored very low in usability.

as inaccessible. This is supported by other experimental data, which showed high failure rate in these tasks.

Cash was considered a more accessible payment system than credit card. This is mainly due to the lack of tactile indications that help locate and distinguish where to and in which side and direction to insert the card. Also, the design of the slots for inserting cash and credit cards is ambiguous, and in several instances the experiment required the intervention of the assistants, who prevented subjects from inserting the payment system in the wrong slot. We found no significant correlation between

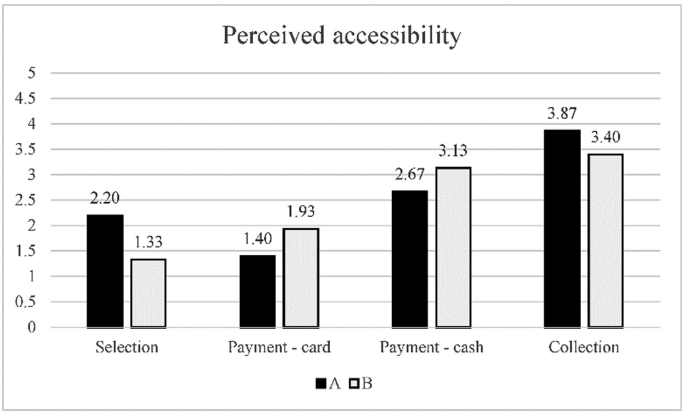


Fig. 5. Detail of perceived accessibility in each of the experimental tasks. Product selection with machine B was the lowest ranked because it was impossible for blindfolded subjects to operate the touch-sensitive keypad due to lack of tactile features and spurious input. Payment with credit card was perceived as the hardest, whereas subjects were able to use cash and coins to complete the purchase. Nevertheless, using either method was indicated as hard. Conversely, product collection was perceived as the most accessible sub-task, though the presence of the sliding door on machine B impacted the user experience.

previous experience with vending machines and perceived or calculated accessibility; moreover, participants' preferred method of payment had no impact on their ability to complete a purchase using cash or credit card.

At the end of the experiment, most of the subjects spontaneously shared their feedback about aspects that could be improved to render the eVending systems more accessible. Specifically, the majority indicated lack of auditory feedback and absence of tactile information as the main issues. Interestingly, addressing the items reported by participants would result in a negligible cost for manufacturers.

5 Conclusion

Automated vending machines are an established technology that experienced a significant growth in the last decades and its diffusion is capillary in public and private spaces. Nevertheless, their accessibility has been addressed only partially: although the sighted use this technology without major limitations and ADA defined implementation criteria for enabling people with limited mobility (i.e., using a wheelchair) to operate them, they are still not accessible to individuals who are blind; also, as regulations do not enforce any accessibility guidelines in regard to blindness, their needs are not taken into consideration. Moreover, there are very few studies on the accessibility of vending machines, kiosks, automated dispensing systems, and devices that serve more fundamental needs (i.e., mobility and personal care).

In this paper, we focused on the accessibility of eVending. Specifically, we were interested in evaluating if people who are blind can independently operate them and

successfully complete a purchase. To this end, we realized a study that involved two of the most common types of eVending offering snacks and beverage. Specifically, we realized a quantitative analysis of each task involved in the use of eVending systems, that is, selection, payment with cash- and card-based systems, and collection. Our preliminary study involved 15 participants only. Despite the small sample might limit the applicability of our results, this paper is one of the first attempts to investigate accessibility of vending machines for people who are blind. From our findings, we can conclude that the majority of eVending systems lack features that are crucial for enabling individuals who are blind to independently select, pay for, and collect a product. Current automated vending machines do not support people who are blind at all: although our data show only a 4-fold increase in the time required to blindfolded subjects to complete a purchase, this result was obtained in a setting where participants were guided in every step of the process, that is, which product to select, and the amount to be paid. However, subjects would not be able to even select a product without indications from an assistant. Moreover, our study demonstrates that the adoption of novel technology, such as, touchscreens, which might improve the look and feel of a device, involves the overlooked risk of rendering them less accessible.

Although this study focused on eVending that dispense food and beverage the results are applicable to almost all other types of vending machines as well as to kiosks providing information. In our future work, we will expand our sample and we will involve individuals who are blind, so that we can achieve more accurate results. Furthermore, based on the outcome of our study and on feedback from participants, we will work with appropriate populations on developing design guidelines that allow vendors to incorporate inclusion in their design strategy, or at least to improve the accessibility of their current devices by introducing minimal, low-cost refactoring.

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Human-Centered Design and Quality Function Deployment: Understanding Needs on a Multidisciplinary Automotive Research

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Abstract. The paper reports the activities of a specific design research integrated into multidisciplinary automotive project funded by Emilia Romagna region, Italy. The main goal of the overall project is to design the concept of a high-performance vehicle. In particular, this contribution presents a qualitative user analysis that has been carried out specifically to design the vehicle interface. This work lays on a methodology that points out the importance of inclusive and human-centered design approaches that are used throughout the automotive product development. The Quality Function Deployment (QFD), namely an inclusive decision-making tool, has been utilized into the product planning process in order to obtain measurable design parameters for improving the quality of the expected project through a correlation with the user needs. The outputs derived by QFD tool are used as a strategy to develop a possible design solution for the vehicle interface.

Keywords: Human-center design · Quality Function Deployment · User needs analysis · Automotive product development · Interaction design

1 Introduction

The category of high-performance cars is a particular segment, in which engineering and technical aspects of the vehicle are maximized to provide extreme performances. Given that the sport cars are primary designed either for track or race use, often the product development process prefers to minimize or partially exclude from the project, characteristics of comfort or usability, in favor of technical and mechanical improvements. However, on a different point of view, those parameters are fundamental parts of the total experience that a product provides to its users during its use [1]. In that particular context of automotive, the cited elements are very important to improve, at the same time, human abilities and physical-cognitive performance of all the people who constantly interact with the vehicle, for driving, but also for setting and maintaining its technical parameters in optimal conditions.

Designing an automotive product is very complicated undertaking because it requires many resources and coordinated engineering processes. Due to the difficulty of managing the development of automotive products, there is a possibility to create also a

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real gap between the level of satisfaction desired by the users and the management utilized by the engineering processes to achieve the requested quality [2]. In this case, for realizing a successful product, the vehicle definition has the necessity to be based on the needs of its final users, in order to improve not only its mechanical properties, but also every physical and psychological aspect elicited by the interaction with the vehicle, which determines the qualitative level of the total product experiences [3].

But often the main problems to produce wrong results come directly from the failure to understand user needs, but also to translate them into technical specifications for designing the vehicle and to validate them, if the final product coincides to the customer expectations [2]. To avoid negative outcomes, it is important to identify user prospective and its main requirements through a research analysis primary focused on users. Every need is immediately recognized, understood and subsequently processed into the automotive development process at an early stage. In this way, clearly defined data from this practice become useful parameters to define the acceptability of the final product and important inputs to the expected concept vehicle.

2 Objectives

Following the consideration touched in the introduction, the paper reports a design research process that is carried out in the field of automotive, in particular focusing on sport car segment[1].

This contribution regards the activities of a specific design research integrated into multidisciplinary project called Automotive Academy: a learning by doing project for innovation engineering automotive, which is financed with public funds by Emilia-Romagna Region, Italy. The peculiarity of this project lays on a collaborative network that involves four universities – University of Modena and Reggio Emilia (which is the coordinator), University of Ferrara, University of Parma and University of Bologna – and many research centers located on the territory.

The main goal of the entire project is to develop several engineering and design solutions in different areas of study that can be applied for developing the future concept of a sustainable sport car. The final vehicle expects to combine, at the same time, engineering solutions that provide high performance with the technology of the hybrid drivetrain. Working on many aspects of the automobile (as weight, aerodynamic shape, propulsion and consumption), the scope of the project is to increase the sustainability of the sport car improving its energy efficiency, in order to reduce its level of carbon emission without compromise its performance. In addition, the research puts the

[1] In automotive industry, every country or region assumes a particular regulatory framework that is used to classify multiple categories of vehicle. In this specific project, the main framework that is taken into consideration is provided by European Commission. The utilization of car segmentation is important to define in which market area a particular vehicle want to be inserted, because it is subjected to technical and administrative regulations that authorize the type-approval and placing on the market. In this case, according to both European segmentation and the specific vehicle attributes – that characterise the entire automobile in terms of driving experience and design forms – the concept vehicle of this research is inserted is S-segment, namely the sport coupés segment.

attention on people needs and for this reason it is aimed to define also functional and ergonomic aspects of both driver package and vehicle interface, in order to provide to the final users, the expected User Experience (in terms of safety, comfort usability and sensation).

Each partner contributes with its specific research in five different areas related to: design methodologies; hybrid powertrain; vehicle body; smart materials; drive-by-wire instruments. This specific research is inserted on the first area regarding design methodologies and it is focused on inclusive and human-centered design approaches. Its aim is to delineate the design guidelines of the vehicle that will be used specifically to define many exterior and interior elements of the final concept. In particular, this contribution presents a research process that will be utilized specifically to design the vehicle interface.

3 Methodology

For this research it has been decided to configure the entire process through the application of a design methodology whit an inclusive character. It is Human-Centered Design (HCD), an approach that puts human needs, capabilities, and behavior first, then designs expected solutions to accommodate those needs, capabilities, and ways of behaving [1].

For a respectable success of the research, this method starts with a good understanding – through observation and direct interviews – of the main users and their needs that the design is intended to meet. Then it processes gathered data to find new possible solutions that can satisfy many unaware problems encountered by people during the interaction with the product. To translate raw information into design outputs and technical specifications for designing the concept vehicle, the overall research uses also an inclusive tool called Quality Function Deployment (QFD). It is a powerful decision-making tool for creating a system of cooperation among different expert divisions (such as decision makers, designers, engineers, etc.) within design process [4].

QFD is based on a bi-dimensional mathematical matrix that represents graphically the correlation between the most important user needs and the product characteristics that are more significant to develop suitable solutions for solving the main problems of people [5]. QFD provides a qualitative product planning process that is used to obtain measurable design parameters, in order to improve the quality of the expected final result. The outputs derived by this tool are used as a strategy to develop a possible design solution for the vehicle interface.

4 User Analysis

According to the goals of the project, the research has identified the main target to which the final concept vehicle – in particular the vehicle interface – is addressed to. In this case, for a good result of the analysis, it is important to recognize different typologies of user who have either direct or indirect relations with the concept vehicle

throughout its entire life cycle [6]. The main categories of user identified during the activities of this research analysis are essentially four. Each category has another sub-categories and some of them may be overlapped between them:

- D - Driver: It is the principal typology of user that is directly related to the concept vehicle throughout the usage phase of the product. This category is composed by people who drive the car and interact whit its functions in a period of time much longer that the other classes. Each person can have a different level of driving experience. The relation with the vehicle occurs within the interior package during driving, especially with its vehicle interface. The sub-categories identified for this category are: Owner; Amateur driver; Professional driver; Race driving instructor.
- T - Technician: The members of this category are mainly expert people with a great engineering know-how and many technical and practical skills that are used to set up the vehicle and its performance, in base of the necessities requested by the first category. They accompany and assist drivers in the pit lane during race events. The relation whit the vehicle mainly happens with the engineering elements and technical parameters of the vehicle. The sub-categories identified for this category are: Team manager/director; Race engineer; Mechanic; Tire specialist.
- O - Operator: This category is composed by people who interact with the vehicle in some phases of its life cycle such as production, assembly, distribution. They are mostly employments of the company that realize the vehicle. As the second category, the member of this class are related to the vehicle through a technical point of view, but unlikely the technicians, they are not specialized and their work is essentially linked to manual labor. The relation with the vehicle occurs with its mechanical components during production processes. The sub-categories identified for this category are: Manufacturer; Installer; Truck driver; Repairer.
- S - Decision Maker (Stakeholder): The members of this category are directly and indirectly linked to the vehicle during the early phases of the life cycle of the project. This class corresponds to the decision makers of the company, which manage the entire vehicle development program under its all technical, economic and organizational aspects. Some of the needs derive from marketing analyses, in order to increase the quality of the product compared to its competitors. The relation with the vehicle is connected to the design phase. The sub-categories identified for this category are: Program manager; Commercial director; Technical director; Chief aerodynamicist; Chief designer; R&D officer.

5 Analysis of Needs

As mentioned in the chapter of methodology, the analysis process has been carried out through many direct interviews with the various typologies of user and many observations in the context where people are doing activities. One of the most important activities of needs analysis – reported in this paper – has been carried out at a motorsport event, which it has been taken in exams to acquire as much information as possible about concrete necessities and problems of users (Fig. 1).



Fig. 1. Technician at work while he is analyzing data log of the KTM X-Bow. The vehicle is one of the case studies selected for this research. The image comes from the analysis of needs related to the vehicle interface, held from 27th to 29th of September 2018 at MWC - Misano World Circuit, Misano (Province of Rimini), Italy.

The activity of data gathering was performed within the event organized by KTM company called X-Bow-Battle, during the Italian stage. The event lasted three days from the 27th to 29th of September 2018 and it was held at MWC (Misano World Circuit), Misano (Province of Rimini), Italy. KTM's event has been chosen as a significant step to acquire information because the motor company (in particular its car model) is one of the case studies that have been taken into account to design the expected vehicle and their users are the same of this research.

Given the event was very thigh to the vehicle target, the research activities have allowed to acquire the most important needs, which have been significant to continue the following design activities of this research. Raw data derived from the analysis activities have been evaluated and translated into short sentences that express the needs of users. Every expression of need has been undergone to an abstraction process, namely every phrase has been represented with few simple words that can express only moods, whishes and feelings of users, eliminating any indication about technical characteristics of the product [7]. Indeed, in order to make the phrases as much useful as possible, it is always important to express each problem or expectation of people without anticipate possible design solutions, as they could compromise or affect decision-making choices that will be taken for designing the final project [8].

At the end of data processing, the investigation has gathered more of 200 needs, distributed on each category of user. According to the final goal of this research presented in this paper, the analysis has specifically selected and extrapolated from database, only the main needs related to the vehicle interface. They are:

- D. 054 - I would want to keep me eyes on the road
- D. 069 - I would not want to obstruct the visibility of information
- D. 077 - I would want to see only the essential vehicle information
- D. 079 - I would want to have great readability in all environmental conditions
- D. 068 - I would want to know when the race finish
- D. 074 - I would always want to know the state of vehicle system
- D. 086 - I would want to know if I'm losing time laps
- D. 126 - I would want to shift gear at the right moment
- D, T. 134 - I would want to check the vehicle parameters before a driving section
- D, T. 136 - I would want to track the vehicle on circuit
- T. 157 - I would want to monitor vehicle parameters remotely
- T. 159 - I would want to analyze driving data easily
- D. 007 - I would not want to remove my hands on steering wheel
- D. 060 - I would want to change functions in base of my preferences
- D,T. 135 - I would want to speak with my team on-board
- D. 056 - I would not want to decrease my driving attention
- D. 064 - I would not want to change driving functions accidentally
- D. 081 - I would not want to be stressed by information workload
- D. 082 - I would want to be warned in time in case of malfunctions
- D. 058 - I would want to adjust parameters during driving
- D. 061 - I would want to have a specific driving style based on context
- D. 067 - I would want to be entertained during my trips
- T. 158 - I would want to set up the vehicle tools for race
- D. 083 - I would want to learn from my driving mistakes
- D. 084 - I would want to know every characteristic of the circuit

The list of phrases has been used to create the QFD matrix about the design strategy of the vehicle interface. As noted in the list, the main needs related to the goal of this activity come from driver and technician categories, as they are the two categories that interact with the interface more frequently that the others.

6 Correlation Matrix

This chapter presents the QFD matrix of the vehicle interface. It combines user needs with technical parameters of the product, which can be managed for increasing the overall quality of the expected project. The results of this index are very important for the design phase, because it gives many directions on how the expected project can be designed, by assigning priority to the characteristics with higher score.

6.1 Evaluation System

Each need has received a value in numbers that corresponds to its level of importance. The values are: 5 = indispensable; 4 = very important; 3 = important; 2 = preferable; 1 = negligible. Since the selected sentences may be all important for the final result of the research, during weight assignation, it is indispensable compare that needs to each other in such a way that the rating can be as much distributed as possible. This consideration helps the research to identify concretely what needs are more important that others, without assigning the same weight to all. Instead, each technical attribute has another scale of rating that corresponds to the level of correspondence and relationship with a specific need. The values for this second rating are: 9 = strong relation; 3 = medium relation; 1 = weak relation; 0 = no relation.

The multiplication between the two values (weight of need and relationship between need and technical requirement) shows the effective relevance of a specific technical attribute with a certain need. Then, to understand the total weight of a specific parameter within the entire QFD matrix, it is possible to sum all the values allocated in its own column together. Below each column there is the final level of relevance of each product requirement. During design phase, the values with higher score will be more considered as essential elements to develop the final project. All values are reported both in absolute weight and in relative weight (percentage). The use of color saturation helps designers and engineers to better recognize the most important relations between needs and product specifications.

6.2 Product Parameters

Technical attributes that are utilized for realizing the QFD matrix has been chosen to increase the quality expected by users about the vehicle interface. Driving is a complex, multitask activity [9], consisting of interactions between the driver, the vehicle and the environment [10] and requiring the successful integration and coordination of the driver's cognitive, physical, sensory, and psychomotor skills [11]. Indeed, the aim of these parameters is to provide the adequate driving experience – conforming to the necessities that can be encountered in race contexts – in order to maximize physical-cognitive resources of driver and consequently guarantee to it an acceptable situation awareness [12]. The product elements of the QFD matrix has been identified to improve vehicle interactions taking into account some of usability's general criteria, which are associated to the User Experience. They are: error prevention (low error rate); efficiency (high level of productivity); satisfaction (pleasant to use); learnability (easy to learn rapidly); memorability (easy to remember); flexibility (adaptable to different users) [13, 14]. Moreover, some attributes have been selected in relation with the Hutchins, Hollan e Norman's model of direct manipulation [15], in order to recognize the elements that can facilitate understanding and steps execution of a specific task in Human-Computer Interaction [1].

Technical attributes that concern *viewing distance*, *dashboard form factor*, *dashboard area*, *screen resolution*, *brightness and contrast*, are related mainly to the relation between the driver's field of view and the physical area of the vehicle

dashboard. They are necessary to guarantee the execution of different task while continuously monitoring the driving scene [16] (Figs. 2 and 3).

Product characteristics regarding *menu depth*, *font/icon size*, *space of intersection*, *number of information*, *number of options*, *colors*, *border radius ratio* and *personalization* are addressed to the layout of the interface and they are considered because some aspects may affect many visual principles – for example *gestalt* rules, layout grid, basic visual hierarchy, Hick's law or Fitts's law[2] [17, 18] – which are used to increase the entire comprehension of the vehicle interface.

The elements of *frequency of use*, *operation distance*, *operation time*, *operation steps* and *error rate* are connected to some parameters that compose specific tasks, which are fundamental to reach a predetermined goal in a correct way [19].

Technical parameters concerning *input area*, *contour depth difference*, *roughness*, *fingertip force*, *feedback response* and *feedback intensity* are related to both the input elements of the vehicle dashboard and the feedback quality that the interface must guarantee to the driver without producing any type of error.

At the end, the product attributes corresponding *memory*, *number of input* and *number of output* are related to electronic and productive characteristics that are used to define the technical sheet of the final project. In this phase, it is important to report that the QFD is focused on the technical parameters addressed to increasing the quality of User Experience and not to the contents of vehicle interface. The values that must be displayed on dashboard will be selected in an other design research.

7 Results and Discussion

QFD tool has allowed to gather qualitative and quantitative information about the real needs of users. The matrix offers a synoptic view – in a representative form – the most important product characteristics that must be taken in consideration for developing the vehicle interface in next design development.

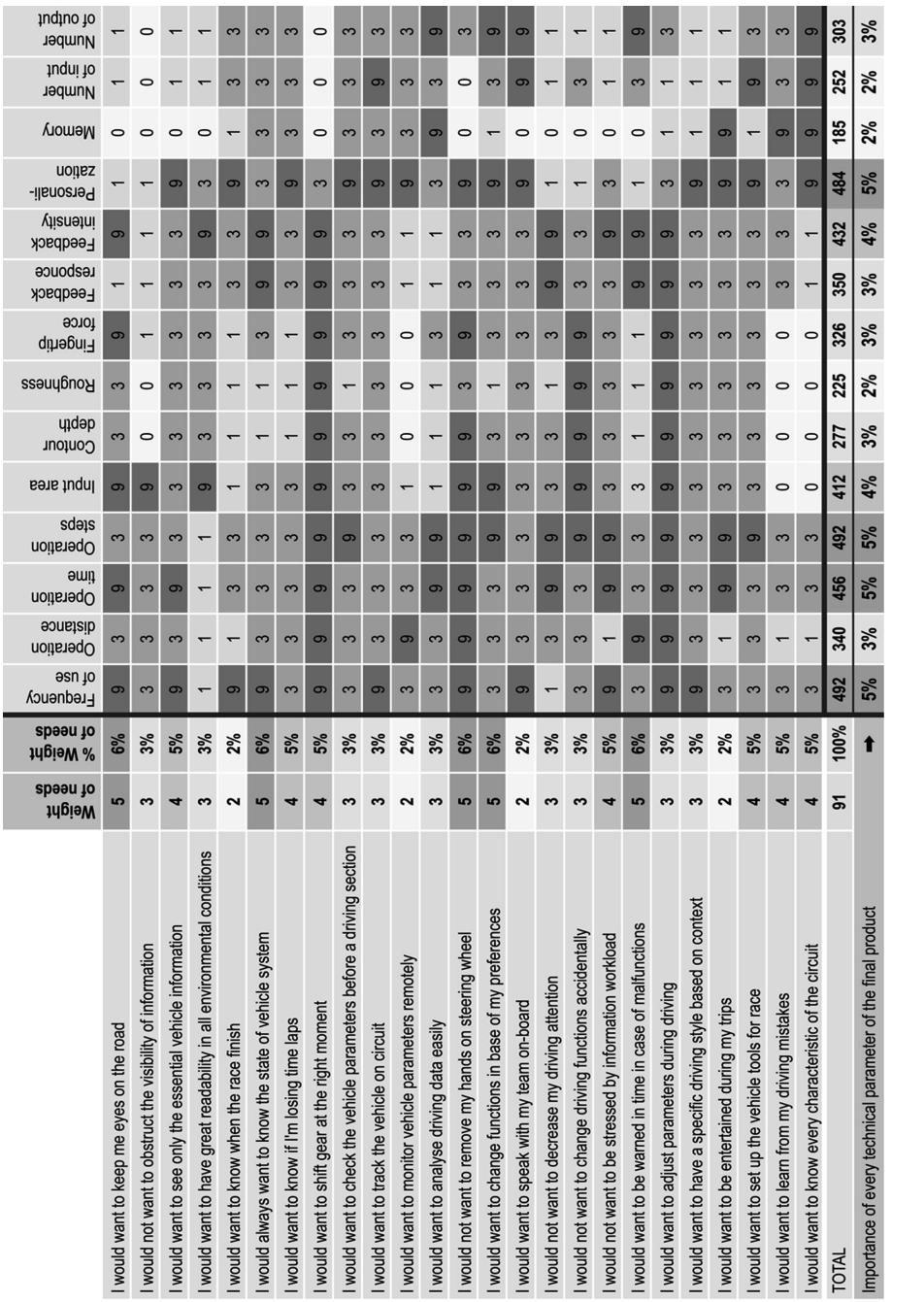
The close reading of QFD matrix shows that the data for improving the vehicle interface are slightly more concentrated on the quality of operations and their task flow – both provided by the system or performed by the driver – than the others aspects related to readability of information. Indeed, more relevant values (5%) are posed on *frequency of use*, *operation time* and *operation steps*, which are necessary to do a specific task on the system. It means that the project must avoid intrusive and complicated functions that can require a long task flow or a high cognitive workload from driver. On the contrary, it is important to design immediate and easy operations that can be rapidly activated only when it is necessary. In this case, synthetizing operations allows the system to reduce errors during the activities of a particular task.

The QFD matrix shows also that other important values are addressed to *number of information*, namely the parameter that regulates both the correct distribution and the

[2] Hick's Law, says that the time it takes for users to make decisions is determined by the number of possible choices they have. Fitts's Law simply states that the time it takes to move from a starting position to a final target is determined by two things: the distance to the target and the size of the target.

	Weight of needs	% Weight of needs	Viewing distance	Dashboard form factor	Dashboard area	Screen resolution	Brightness	Contrast	Menu depth	Font/Icon size	Space of Intersection	Number of information	Number of options	Error rate	Colours	Border radius
I would want to keep me eyes on the road	5	6%	3	9	9	9	3	9	9	3	3	9	3	3	3	3
I would not want to obstruct the visibility of information	3	3%	9	3	3	9	3	3	1	1	9	1	1	3	3	1
I would want to see only the essential vehicle information	4	5%	3	3	9	9	3	3	9	3	9	9	9	9	9	3
I would want to have great readability in all environmental conditions	3	3%	3	3	9	9	9	9	3	9	9	3	3	3	3	3
I would want to know when the race finish	2	2%	3	1	3	3	3	3	9	9	3	9	1	3	3	1
I would always want to know the state of vehicle system	5	6%	3	1	3	9	3	3	3	3	3	3	3	9	3	3
I would want to know if I'm losing time laps	4	5%	3	1	3	3	3	3	1	9	3	3	3	3	3	3
I would want to shift gear at the right moment	4	5%	3	1	3	3	3	9	1	9	9	9	3	9	3	1
I would want to check the vehicle parameters before a driving section	3	3%	1	1	3	3	3	3	9	3	3	9	9	3	3	3
I would want to track the vehicle on circuit	3	3%	1	1	1	3	1	1	3	3	3	3	3	1	1	1
I would want to monitor vehicle parameters remotely	2	2%	0	0	0	0	0	0	3	0	0	0	0	0	0	0
I would want to analyse driving data easily	3	3%	1	1	1	3	3	3	9	3	9	3	3	1	1	1
I would not want to remove my hands on steering wheel	5	6%	3	9	3	3	3	9	3	3	3	3	9	3	3	9
I would want to change functions in base of my preferences	5	6%	3	1	9	9	1	3	9	3	3	9	9	3	9	9
I would want to speak with my team on-board	2	2%	1	1	1	1	1	3	3	1	1	3	3	3	1	1
I would not want to decrease my driving attention	3	3%	1	3	3	9	3	9	1	3	3	3	3	3	3	1
I would not want to change driving functions accidentally	3	3%	1	9	3	3	3	9	3	3	3	9	9	9	9	9
I would not want to be stressed by information workload	4	5%	1	3	9	3	1	9	3	3	3	9	9	9	9	3
I would want to be warned in time in case of malfunctions	5	6%	3	3	3	9	3	9	9	9	9	3	3	9	9	3
I would want to adjust parameters during driving	3	3%	3	9	3	3	3	3	3	3	3	9	9	3	3	3
I would want to have a specific driving style based on context	3	3%	1	1	1	1	1	1	9	3	3	3	3	3	3	3
I would want to be entertained during my trips	2	2%	1	3	9	3	3	3	9	3	3	3	3	9	1	1
I would want to set up the vehicle tools for race	4	5%	1	3	9	3	3	3	9	3	3	9	9	3	3	3
I would want to learn from my driving mistakes	4	5%	1	1	1	1	1	1	3	3	3	3	1	3	1	1
I would want to know every characteristic of the circuit	4	5%	1	1	1	1	1	1	3	3	3	3	3	3	1	1
TOTAL	91	100%	200	270	382	430	226	422	452	356	386	492	426	408	348	276
Importance of every technical parameter of the final product		➡	2%	3%	4%	4%	2%	4%	4%	4%	4%	5%	4%	4%	3%	3%

Fig. 2. QFD matrix for developing the vehicle interface. First part.



	Weight of needs	% Weight of needs	Frequency of use	Operation distance	Operation time	Operation steps	Input area	Contour depth	Roughness	Fingertip force	Feedback response	Feedback intensity	Personali-zation	Memory	Number of input	Number of output
I would want to keep me eyes on the road	5	6%	9	3	9	3	9	3	3	9	1	9	1	0	1	1
I would not want to obstruct the visibility of information	3	3%	3	3	3	3	9	0	0	1	1	1	1	0	0	0
I would want to see only the essential vehicle information	4	5%	9	3	9	3	3	3	3	3	3	3	9	0	1	1
I would want to have great readability in all environmental conditions	3	3%	1	1	1	1	9	3	3	3	3	9	3	0	1	1
I would want to know when the race finish	2	2%	9	1	3	3	1	1	1	1	3	3	9	1	3	3
I would always want to know the state of vehicle system	5	6%	9	3	3	3	3	1	1	3	9	9	3	3	3	3
I would want to know if I'm losing time laps	4	5%	3	3	3	3	3	1	1	1	3	3	9	3	3	3
I would want to shift gear at the right moment	4	5%	9	9	9	9	9	9	9	9	9	9	3	0	0	0
I would want to check the vehicle parameters before a driving section	3	3%	3	3	3	9	3	3	1	3	3	3	9	3	3	3
I would want to track the vehicle on circuit	3	3%	9	3	3	3	3	3	3	3	3	3	9	3	9	3
I would want to monitor vehicle parameters remotely	2	2%	3	9	3	3	1	0	0	0	1	1	9	3	3	3
I would want to analyse driving data easily	3	3%	3	3	9	9	1	1	1	3	1	1	3	9	3	9
I would not want to remove my hands on steering wheel	5	6%	9	9	9	9	9	9	3	9	3	3	9	0	0	3
I would want to change functions in base of my preferences	5	6%	3	3	3	9	9	3	1	3	3	3	9	1	3	9
I would want to speak with my team on-board	2	2%	9	3	3	3	3	3	3	3	3	3	9	0	9	9
I would not want to decrease my driving attention	3	3%	1	3	9	9	3	3	1	3	9	9	1	0	1	1
I would not want to change driving functions accidentally	3	3%	3	3	3	9	9	9	9	9	3	3	1	0	3	1
I would not want to be stressed by information workload	4	5%	9	1	9	9	3	3	3	3	3	9	3	0	1	1
I would want to be warned in time in case of malfunctions	5	6%	3	9	3	3	3	1	1	1	9	9	1	0	3	9
I would want to adjust parameters during driving	3	3%	9	9	9	9	9	9	9	9	9	9	3	1	1	3
I would want to have a specific driving style based on context	3	3%	9	3	3	3	3	3	3	3	3	3	9	1	1	1
I would want to be entertained during my trips	2	2%	3	1	9	9	3	3	3	3	3	3	9	9	1	1
I would want to set up the vehicle tools for race	4	5%	3	3	3	9	3	3	3	3	3	3	9	1	9	3
I would want to learn from my driving mistakes	4	5%	3	1	3	3	0	0	0	0	3	3	3	9	3	3
I would want to know every characteristic of the circuit	4	5%	3	1	3	3	0	0	0	0	1	1	9	9	9	9
TOTAL	91	100%	492	340	456	492	412	277	225	326	350	432	484	185	252	303
Importance of every technical parameter of the final product		⬆	5%	3%	5%	5%	4%	3%	2%	3%	3%	4%	5%	2%	2%	3%

Fig. 3. QFD matrix for developing the vehicle interface. Second part.

clear visualization of data on the screen. Since the particular race context requires specific configurations to operate on the system rapidly, this specific requirement needs to organize the vehicle interface in an intelligible manner, in such a way that the driver is able to detect and understand information with a few glances. To improve the efficacy of the system, it is also possible to work on the information architecture, as it can give the correct hierarchy to the entire system and consequently display only values or commands that are considered more utilizable for the driver. In fact, the importance of this element is very connected to the first technical parameters, because a good setup of visual data – combined with an immediate task flow of operations – can provide less steps or less time to perform an action. The relevance of information architecture is also highlighted and reinforced by the quite high values (4%) of the attribute *menu depth*.

An other important parameter on which the research must focus the attention is on *personalization*, because the driver needs flexibility on driving functions, in order to use only the information or commands that are considered more significant for comfortable and usable driving experience. Again, the project must provide a functional configuration to personalize the contents of the vehicle interface through an adaptable layout and flexible information architecture. A good setup of this parameter can positively influence the other important characteristics, in order to provide efficient commands to users, based on their needs.

In conclusion, the combination of Human-Centered Design approach with the QFD tool has proven to be effective tools to increase the quality of a design research at the early stages, combining the analysis of a creative process together with the technical aspects of the automotive development process. The results coming from QFD matrix provide a detailed and measurable assessment about user needs, which often report subjective points of view. In addition, the assessments will be utilized as a strategic tool to define concretely the vehicle interface, working on the technical characteristics of the product, in order to satisfy user expectations. Therefore, the most important elements will have a greater influence on the decision-making process of design phase.

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A New Approach for an Inclusive Yacht Design

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Abstract. The paper focuses on the definition of a new approach for the design of accessible sailing yachts that takes into account not only the physical problems of users affected by permanent and temporary motor disabilities, but also the presence of architectural barriers on most boats built to date. Through an analysis of the current state of the art of modern sailing yachts is possible to determine a series of cases in which the user, depending on his physical limits, may encounter problems while boarding or using external and internal spaces. The research aims to define the most suitable solutions, in order to create a reference standard in the field of nautical design for accessibility. The research leads to the drafting of a technical instrument useful to promote accessibility and inclusion on board.

Keywords: Design · Yachts · Disability · Accessibility · Inclusion · Ergonomics

1 Introduction

Recent studies, conducted by the OECD [1], show that the world population will be getting older and therefore characterized by different types of disability. For this reason, it is essential that designers focus their attention on projects that meet the needs of all, developing specific design approaches, especially in the context of inclusive disciplines. Inclusive design today is addressed to every human being and it is therefore useful to quote a famous statement by Paul Hogan, EIDD-DfA Europe President Emeritus: "Good design enables, bad design disables [2] ", to underline how much, even objects that arise from a purely aesthetic process, must deal with particular attention to accessibility. Despite its recent introduction, the concepts of Design for All have been widely introduced in most fields of application. Currently, a large public practices recreational activities, which were once considered the prerogative of most prosperous classes, and even individuals with different disabilities are more and more active users. In particular, sailing is one of those activities. In the last few years, some pleasure boats have been modified to favor the inclusion, giving the possibility to form mixed crews with men and women, young and old, able and disabled together. This type of experimentation, even if not widespread, gives an idea of the potential of this new design approach, which would allow to produce boats able to satisfy different types of users simultaneously, creating inclusion, integration and opening new commercial scenarios. This document focuses on the definition of a new approach that takes

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into consideration the architectural barriers present on every pleasure boat actually produced and tries to find possible solutions suitable for any type of user.

2 Problems and Possible Solutions to Improve the Accessibility of Sailing Yachts

The design of pleasure boats from 33 to 78 feet has, to date, limited to the development of sailing yachts that are almost identical to each other and practically inaccessible both above and below deck (Fig. 1).

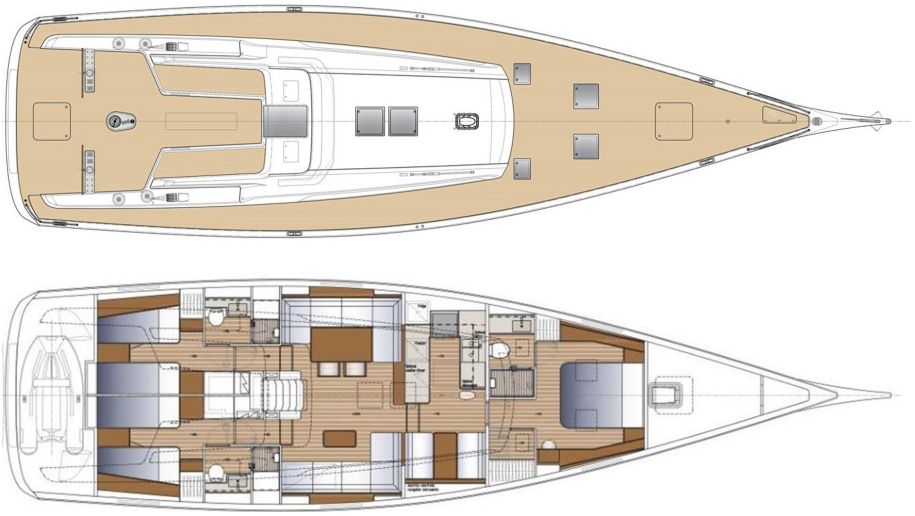


Fig. 1. A modern 65 feet sailing yacht. Both open and lower deck are inaccessible. It is important to note that, even in large boats, accessibility have never been taken into consideration.

Designers must pay close attention to the needs of the person, with or without disability, and try as much as possible to facilitate total accessibility to exterior and interior spaces. This means rethinking any accessory aid, environment or even just part of it, in order to satisfy ergonomic and spatial, safety and autonomy requirements of all those who are not able to overcome certain physical, and sometimes psychological, obstacles. Starting from the modality of accessing on board, a helpful solution consists in a simple electrically controlled scaffolding, permanently fixed to concrete piers, which facilitate access to any type of boat equipped with an open transom. A tilting platform would also ensure the safety of the individual and save the boat from the risk of damage, due to the wave motion. It would be useful for each marina to offer a small percentage of moorings for boats with disabled passengers (Fig. 2).

Analyzing the boat layout from the stern, it is incomprehensible how the vast majority of gangways, produced up to now, presents minimal dimensions. This often causes discomfort even in experienced people, due to the possibility of falling into the

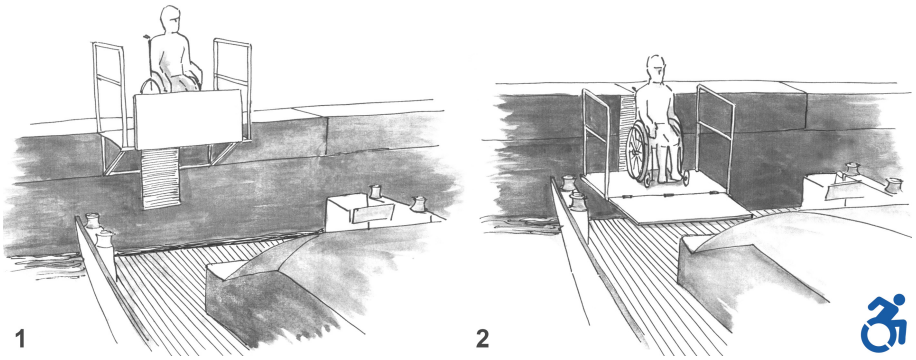


Fig. 2. An innovative system of permanent embarkation for accessible berths, suitable for both harbors and marinas.

water, going over it. It is necessary to create a dimensional standard in the design of gangways that allows all people to be able to embark, without any risk. This solution is also perfectly suitable for all kind of users (Fig. 3).

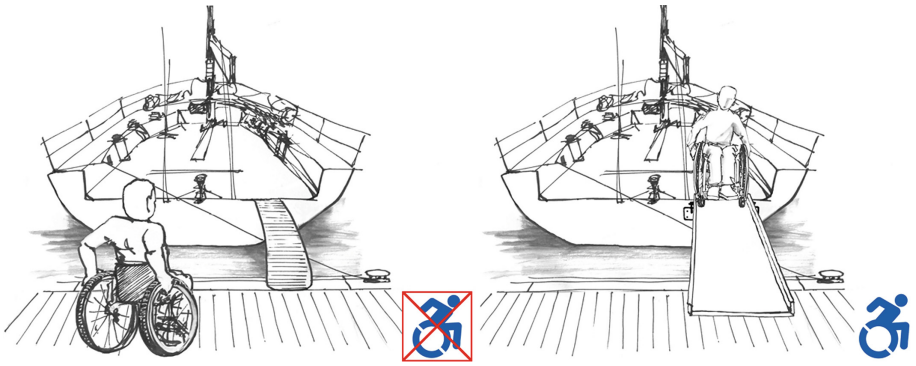


Fig. 3. An inclusive design must be able to facilitate the boarding and disembarkation of the person in a wheelchair, in total safety and, as much as possible, independently.

In order for a boat to be accessible, it is advisable to provide a fully open transom. The design of the boats, thanks to the modern geometry of hull lines, has already led to this result, but it is of fundamental importance that it is not hampered by any kind of obstacle to facilitate the passage for the person in wheelchair (Fig. 4).

Among the major problems of a sailing boat, the most evident are the size and the shape of the helm, normally designed without any consideration about the ergonomics issues for a disabled user. Moreover, it is easily conceivable that, in navigation, the heeling of the hull prevents in any way a person on wheelchair to be able to sit in safety. An innovative system consists in a passing wheel, in which the spokes and the

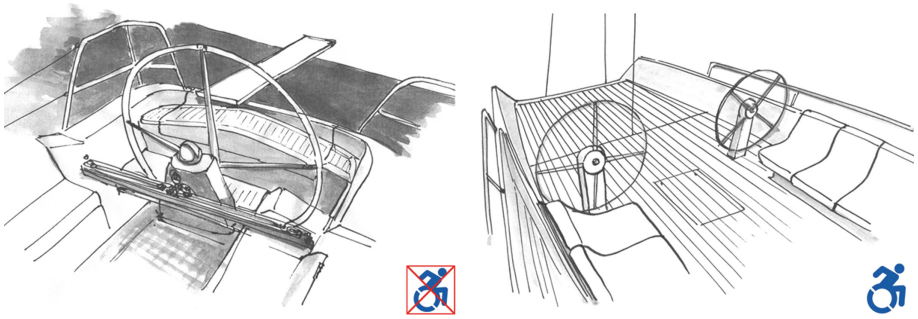


Fig. 4. The transom, completely opened, and the insertion of a helm composed of two wheels, sufficiently distant from each other, are the ideal solution for an easy boarding.

supports are placed below the deck, in order to allow the wheelchair to easily pass through the helm to access the cockpit area (Fig. 5).

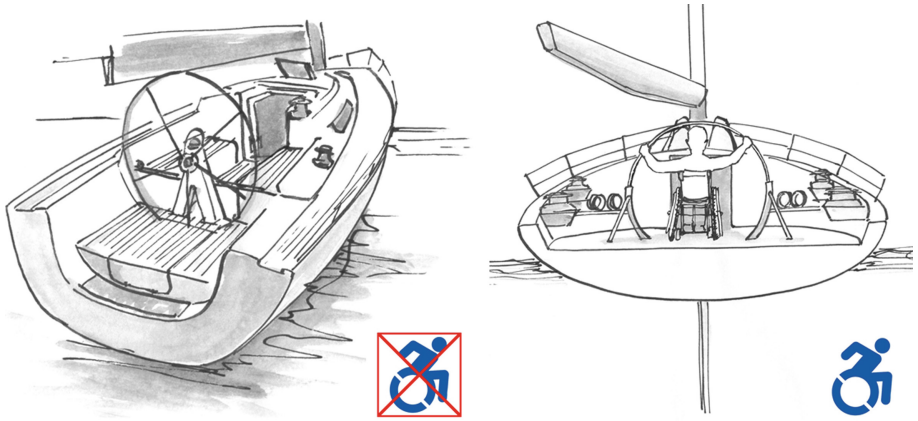


Fig. 5. The innovative concept of helm made of a central passing wheel, designed to solve ergonomic issues of people on wheelchair.

Moreover, to ensure the wheelchair in the event of heeling, a tilting platform placed close to the helm is an interesting aid: thanks to actual technologies, it is possible to modify the position of the platform at any time, through an electronic control system based on the principle of the gyroscope. Mechanical systems that fix the wheelchair to the deck and safety belts to secure the person to the wheelchair have to be previously taken into consideration (Fig. 6).

Continuing with the analysis of the open deck problems, the passages that lead to the bow from the cockpit are normally too narrow in most boats. An attentive design must therefore reconsider the entire layout and the spatial relationship between the deck and the interior, in order to be able to obtain larger spaces along the sides, to allow the

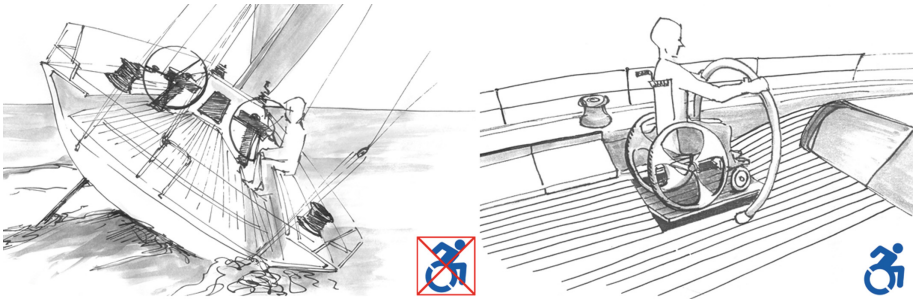


Fig. 6. In order to avoid the overturning of the wheelchair, it is necessary to place it on a tilting platform, electronically controlled.

wheelchair transit. Furthermore, it is necessary that the difference in height between the cockpit and side passages is resolved with moderate slopes, accessible to the disabled, in total autonomy (Fig. 7).

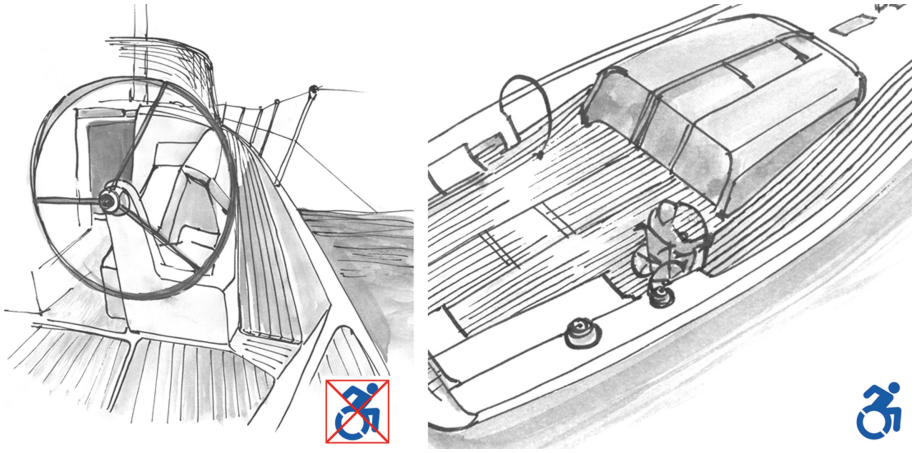


Fig. 7. The step between the cockpit and the lateral passage and the limited size of this one do not allow the wheelchair to access the bow of the boat. A flat deck, with limited slopes on its sides is the ideal solution.

A fully accessible hatch is the first element of the boat on which to set up a design that is attentive to the needs of disabled people. It must have a net light of at least 80 cm, have a one-piece hatch, which can slide sideways, and must not show coamings or obstacles higher than 25 mm. It is also advisable to insert an internal threshold, with a "wheel lock" system, for greater personal safety (Fig. 8).

To access the lower deck and to overcome any difference in height it is suggested the adoption of an electric lifting platform that gives the possibility to the disabled

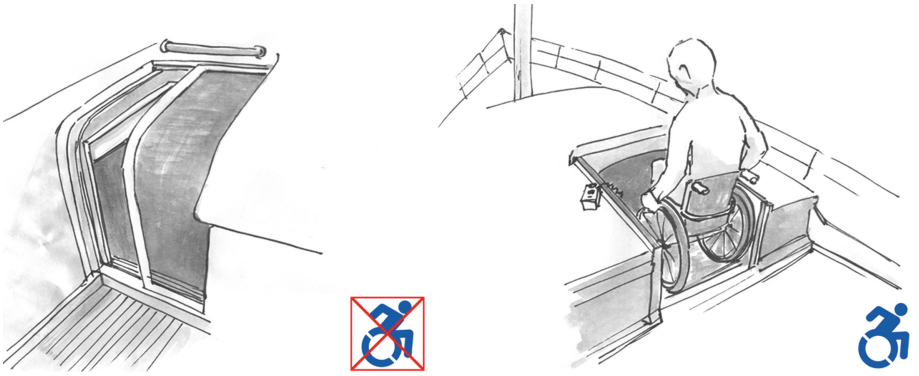


Fig. 8. It is necessary to change the current design approach to allow the best access to the inner spaces of a boat.

person to move between the various levels of the boat in total autonomy. On boats larger than 15 m, it is conceivable to use controlled slope ramps, to replace the classic access ladder (Fig. 9).

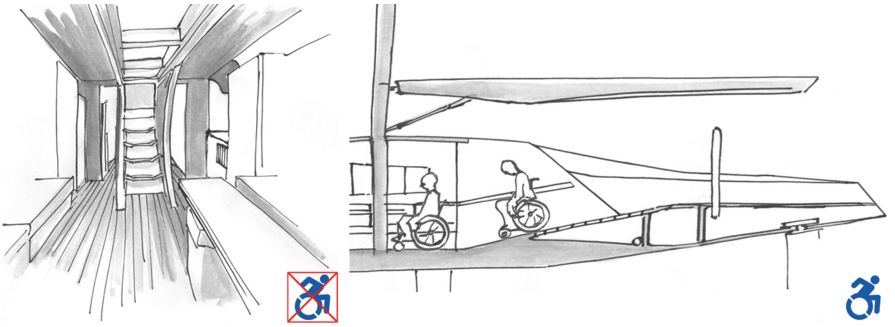


Fig. 9. Only by reconsidering the project in its entirety, according to the principles of Design for Inclusion, it is possible to create innovation with solutions accessible to everyone.

The table placed in the central dinette must not have fixed seats along the corridor, either to avoid tightening the passage. Furthermore, it is advisable to plan the interior spaces to give the wheelchair the possibility to make a 360° rotation, without having to force the disabled person to carry out complex maneuvers (Fig. 10).

As often happens in home environments, the main problems in the use of a traditional kitchen are the following: impossibility to use cooktop and sink frontally, impossibility to access the upper units due to their excessive height, difficulties to rotate the wheelchair without colliding with the lower cabinets. An accessible kitchen must therefore offer space for the legs and the wheelchair below the hob and sink, lower cabinets that allow accessing the objects placed on the bottom, large surrounding space for an easy movement of the chair and oven and microwave placed where disabled people can arrive without excessive effort (Fig. 11).

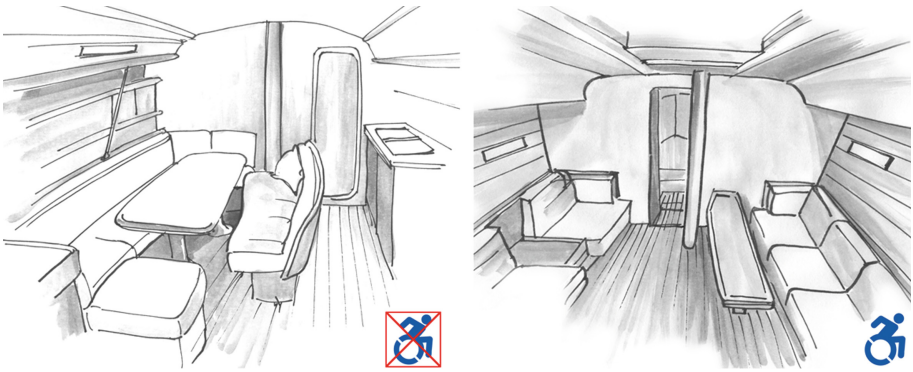


Fig. 10. Removing steps and fixed seats, placed towards the center of the boat, the lower deck space is accessible from stern to bow to people on wheelchair.

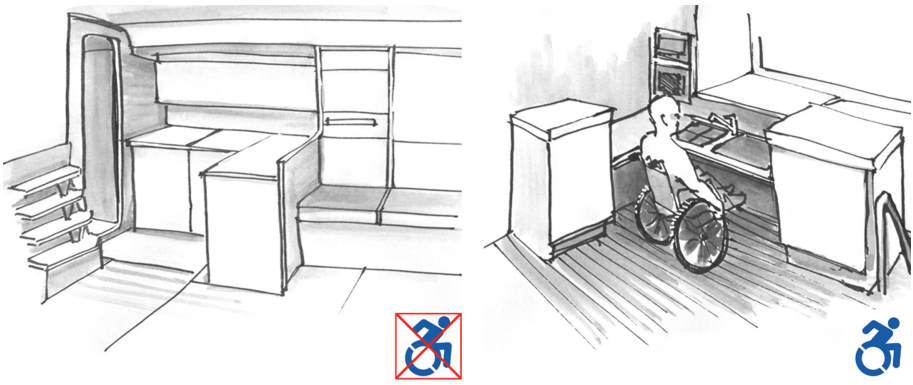


Fig. 11. A design for an extended use does not impact the usability of the kitchen by everyone: it is very important to respect the ergonomic needs that a disabled person needs.

Doors of sailing yacht are usually no wider than 2 feet and often they have a threshold to jump: all these issues make it impossible to access any indoor environment. It is therefore necessary to design wide doors, possibly sliding, and no obstacle to be overcome on the floor. In case of steps between two different spaces, a light slope is the easiest and right solution (Fig. 12).

The height of the beds should never be higher than the height of the wheelchair seat. Therefore, an excessive eight can be a problem for the disabled person when moving from wheelchair to bed. The use of excessively high beds is frequent in the forward cabins of sailing yachts, due to obtain a larger mattress surface. It is therefore clear that a cabin, to be accessible, must be equipped with an easy and sufficiently wide door passage, generous foot traffic to allow the wheelchair to rotate 360° and a bed at the same height of the wheelchair seat. In the case of cabins with single beds, it is advisable to keep a distance between the beds above 3 feet, to allow the disabled to move more simply (Fig. 13).

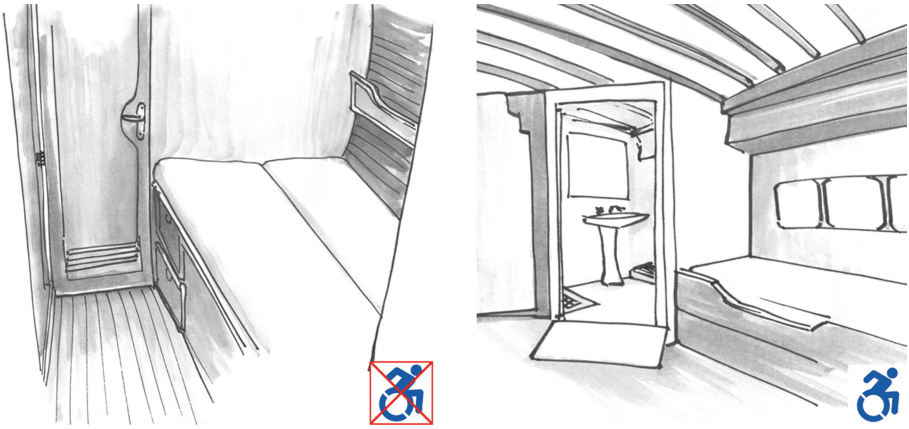


Fig. 12. The size of the doors must allow an easy passage to the wheelchair: the sliding door is preferable to the swinging one, although does not create particular problems to disabled users; a small ramp to overcome light steps is always advisable.

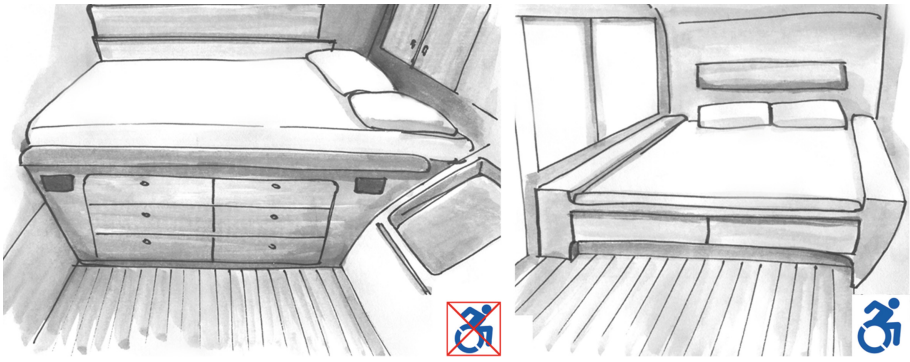


Fig. 13. The bed of a sailing boat must have a height similar to the wheelchair seat and the outer edge free from obstacles, in order to allow the disabled person to move directly on the mattress, without risking to hurt himself.

The bathroom, as the kitchen, follows the rules of ergonomics and common sense, so that disabled people can enjoy the inner space without any discomfort: a good design needs accessible doors, enough space to maneuver the wheelchair, folding seat in the shower, mirrors and fixtures at the correct height. In the case of shower box, it is not necessary to provide the wheelchair rotation, but it is necessary that the disabled person can access it from the front to be able to move on the retractable seat, so as not to wet his wheelchair (Fig. 14).

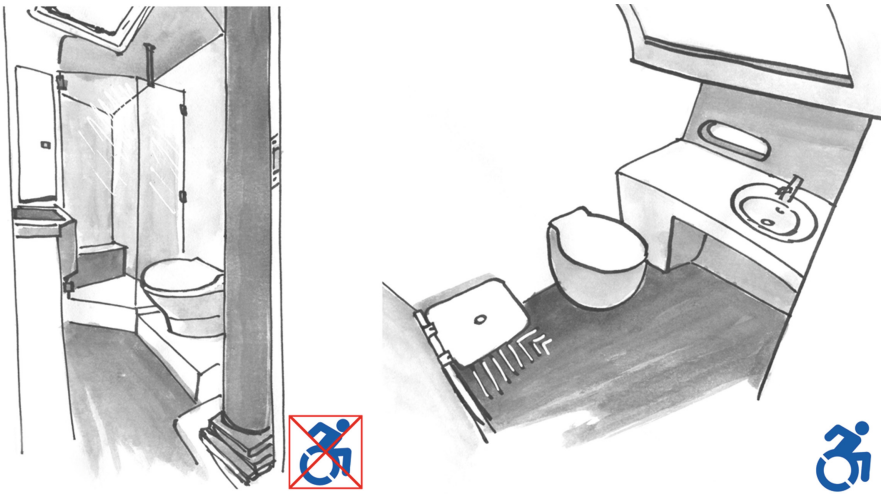


Fig. 14. A well-designed bathroom can meet the basic needs of the disabled individual also being quite small.

3 Conclusions

The research explores the offer of pleasure sailing boats usable by people with disabilities and proposing design solutions inspired by the principles of DfA, a young discipline (about 20 years old) but which starts to have concrete implications, in particular in civil architecture and in the field of product design, where the benefits of its application are immediately tangible with a positive return also on the corporate image. It is a question of translating these principles into the nautical sector: in fact, this analysis revealed that the nautical market is lacking in an offer of accessible boats. The work aims to provide a series of guidelines for the design of inclusive sailing boats, as well as to give solutions also applicable to other kind of boats, as motor yachts. It offers alternative solutions to the traditional design methodology of a boat: innovative proposals studied to improve the accessibility of a boat. The paper also tries to make up for the almost total absence of specific publications on the topic addressed, creating a precedent within the scientific literature of the sector. By adopt-ing integrally or even partially the solutions proposed, it is possible to create a new type of sailing boat and allow everyone not only to navigate autonomously and safely, but also to create new business opportunities such as charter for ex-tended users, inclusive sailing schools. The development of further solutions will be useful for making boats truly “for everyone”.

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The Effect of Sliding Door Hardware Design on Opening Operation

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Abstract. Usability of sliding door was tested with different door hardware designs, i.e., a grab bar, a vertical door pull, and a recessed door pull. Three levels of force necessary for operation (10 N, 20 N, and 30 N) were compared. Sixteen subjects of different ages participated in the experiments. They reported the ease of use, and their behavior was also observed. Results suggest that no more than 20 N force is desirable for easy operation, and depth of 15 mm would be necessary for a door pull to apply the force effectively.

Keywords: Operating force · Usability · Grab bar · Door pull · Recessed door pull

1 Introduction

Doors that were traditionally smaller, narrower, and lighter are getting larger and heavier in response to recent move toward increased functional requirements such as ease of passage or better thermal insulation. In the case of a sliding door, it often leads to the change of door hardware from a traditional recessed (grooved) pull to a vertical pull or grab bar. However, usability of such new hardware is rarely quantitatively tested. Present paper reports an experimental study examining the usability of the hardware and the effect of design on necessary operating force.

2 Experimental Setup

Three kinds of hardware design were chosen: a vertical grab bar, a vertical pull, and a recessed pull. Overall experimental setup is given in Fig. 1. The recessed pull is just like traditional Japanese hardware with vertical size of 100 mm, horizontal 30 mm and

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15 mm depth, while the other two types extend 500 mm vertical. The center height was set to be 900 mm, which is customary to traditional Japanese recessed pull design, but vertical extension of grab bar and vertical pull allows different height for force application. The detail of each hardware design is given in Fig. 2. They were attached at the end of a sliding door, and the necessary force to open the door was set with adjusted weights to be 10 N, 20 N and 30 N, respectively.

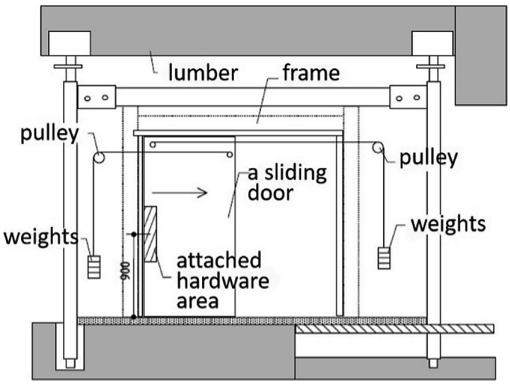


Fig. 1. Setup of simulated sliding door for experiments.

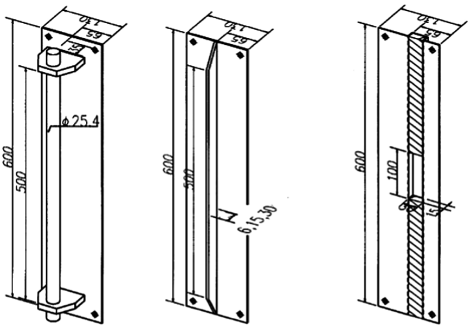


Fig. 2. Experimented door hardware. Grab bar, door pull, and recessed door pull, respectively.

Subjects participated in the experiments were ten seniors and six younger persons. Their basic characteristics are given in Table 1. They were asked to slide open the door and pass to the other side, and five-point sensory evaluation (1: very bad, to 5: very good) was conducted in addition to video recording of the movement. The subjects opened the door as shown in Fig. 3, and they answered their evaluation both ease of opening and ease of closing. No specific instructions were given other than to open the door, pass through, and close, but it turned out that most of the subjects closed the door as they turned to face the door after passing.

Table 1. Characteristics of experimental subjects. Average and range value.

		Number of persons	Age (year)	Stature (mm)	Weight (kg)
			above: average below: range		
Seniors	M	5	75	1579	59.8
			72–78	1485–1667	55.0–72.0
	F	5	80	1420	51.2
			78–83	1340–1516	48.0–54.0
Youngsters	M	2	22	1701	81.5
			22	1680–1721	76.0–87.0
	F	4	27.3	1586	49.1
			21–35	1538–1617	45.0–56.0



Fig. 3. An example of subjects trying to pass through the door after opening it.

After the experiment, subjects were shown all five kinds of door hardware, and they were asked to give rank order comparison for ease of use (point 5 the best, and 1 the worst). The result is given in Table 2.

3 Results of Force Application Experiment

The averaged points of sensory evaluation for seniors and youngsters, males and females respectively, are given in Fig. 4. As opening force increases, the evaluation gets worse. Regarding the type of hardware, vertical grab bar is evaluated best, and 6 mm vertical pull is the worst. Evaluation of other three types varied depending on the opening force. With opening force 10 N, the evaluation points are around 4 to 5, while with opening force 30 N, the points are around 2. With opening force 20 N, the points

were more scattered between 2 and 4 among the subjects and conditions, which suggests usability is easier to differentiate.

To find out the effects of subject characteristics, hardware and opening force, a quantification analysis was conducted. The result is shown in Table 3.

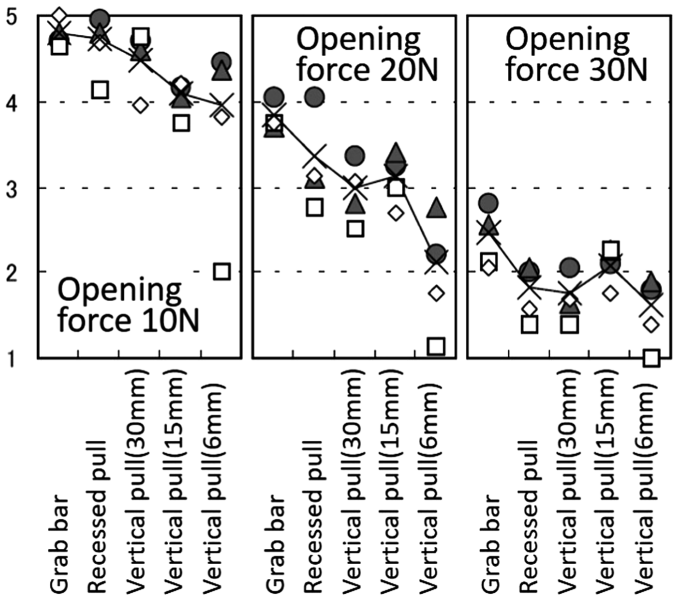


Fig. 4. Results of sensory evaluation. Vertical axis denotes evaluation value, meaning 1 = very bad, 3 = neutral, and 5 = very good. Circle = senior male; triangle = senior female; square = young male; diamond = young female; and crossed line means all averaged.

Table 2. Results of rank order evaluation of various door hardware designs.

Total rank		Pts.	Senior male		Senior female		Youngster male		Youngster female	
			Rank	Pts.	Rank	Pts.	Rank	Pts.	Rank	Pts.
1	Grab bar	71	1	22	2	20	1	10	1	19
2	Recessed pull	63	2	20	1	21	2	7	2	15
3	Vertical pull (30 mm)	56	3	18	3	17	2	7	3	14
4	Vertical pull (15 mm)	33	4	10	4	11	4	4	4	8
5	Vertical pull (6 mm)	17	5	5	5	6	5	2	5	4

Table 3. Quantification analysis of parameters affecting sensory evaluation.

	Category	-2 -1 0 1 2	Category score	Partial correlation
Subject	Senior male		0.3	0.58
	Senior female		0.18	
	Youngster male		-0.37	
	Youngster female		-0.11	
hardware	Grab bar		0.59	0.748
	Recessed pull		0.4	
	Vertical pull (30mm)		-0.03	
	Vertical pull (15mm)		0	
	Vertical pull (6mm)		-0.7	
Opening force	10N		1.25	0.939
	20N		-0.06	
	30N		-1.19	
Coefficient of determination		0.902	Constant term	3.07

4 Discussion on Ease of Use

Opening force was most influential, followed by the type of hardware. Among the hardware tested, vertical pull with the projection of 6 mm was the worst. There was not much difference between 15 mm depth recessed pull, vertical pull of 30 mm and 15 mm projection. Previous studies by Yokobayashi et al. [5], and Tanaka et al. [3] suggested that vertical pull with 15 mm is enough to apply necessary force to operate the door. Overall rank order evaluation (Table 2) also suggested that grab bar was the best, followed by recessed pull, vertical pull of 30 mm, vertical pull of 15 mm and the worst was vertical pull of 6 mm.

Expectation was that the limitation of the recessed pull on its width and placement height from the floor will lead to lower evaluation, but the sensory evaluation during use and comparative rank evaluation after the experiment both revealed relatively high acceptance level. Some seniors replied that they were accustomed to using recessed pull type at home.

5 Analysis of Door Operation Behavior with Video-Recording

Movements of experimental subjects were video-recorded from the side and from above as shown in Fig. 5. Whole activities as they open, pass through and close the door, were recorded. Both slide open the door to the left and to the right were

examined. Height of hand application as they open the door was measured from the recording. If they applied both hands to open the door, averaged height was calculated. The opening width as they pass through was also measured.

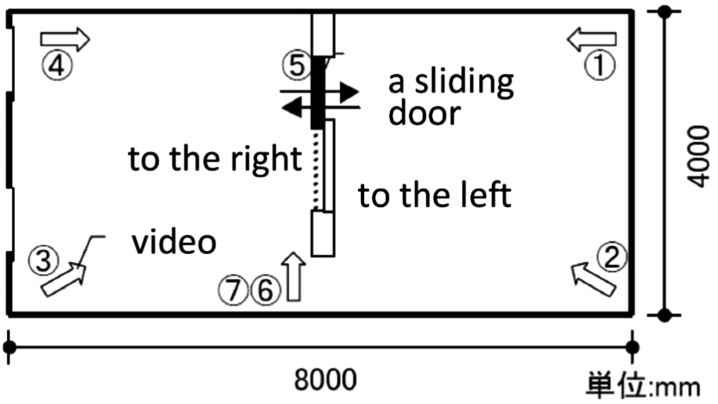


Fig. 5. Settings for video-recording. Operating height was measured from the recordings of cameras 1, 2, and 6. Opening width was measured with camera 5 from above.

6 Results of Behavior Observation

Average height of force application is given in Fig. 6 (recessed pull is not covered since its height is limited by its nature). As a group, seniors and youngsters chose different heights. There was not much correlation between the subject's stature and height of force application, just as reported by Ochiai et al. in 1988 [2]. When the subject applied the force facing backward the door just as shown in Fig. 8, the height was much lower than the case of facing forward the door. A previous study by Endo [1] reported that the force application was best at the height of just below one's elbow. However, there was no tendency among the subjects to change the height depending on the necessary force, and most applied their force somewhat higher than the elbow. No systematic difference was observed among the different hardware.

Average door opening width is given in Fig. 7. The subjects were instructed to open as they might feel wide enough, which basically resulted in an opening of 600 mm or narrower. Their behavior varied among the subjects, and young females showed narrowest opening, twisting their body as they passed. The opening tended to be narrower as necessary operating force increased, while vertical pull of 6 mm resulted in somewhat wider opening.

As to which hand they used, most used their dominant hand: only one subject used both hands according to the situation. Nine subjects sometimes used both hands, but their choice was not related with the hardware type or opening force.

Figure 9 shows the way a subject uses his wrist. It seems to depend on the hardware and opening force (pictures shown here are taken at opening width of 400 mm). With opening force of 30 N, more efforts were observed to ensure force application.

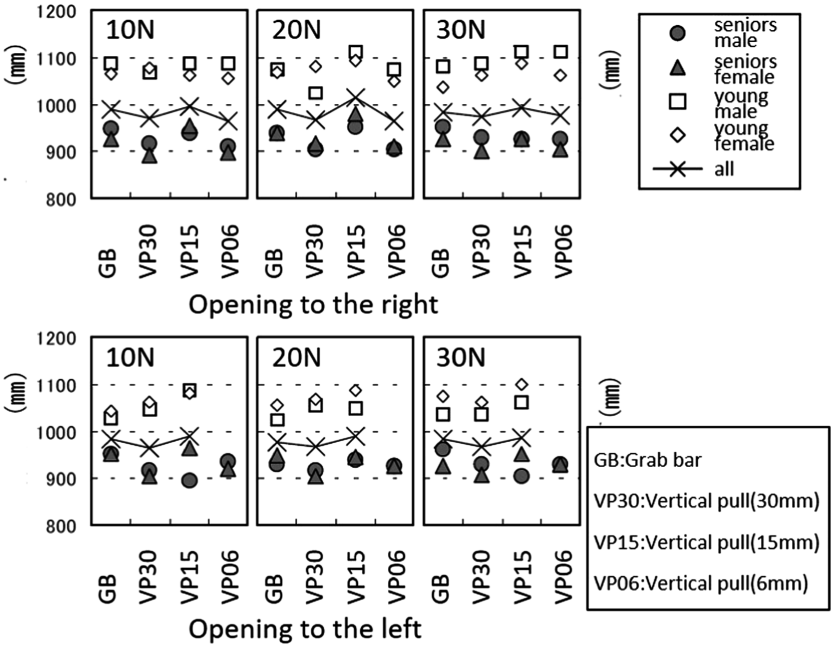


Fig. 6. Height of force application under different conditions.

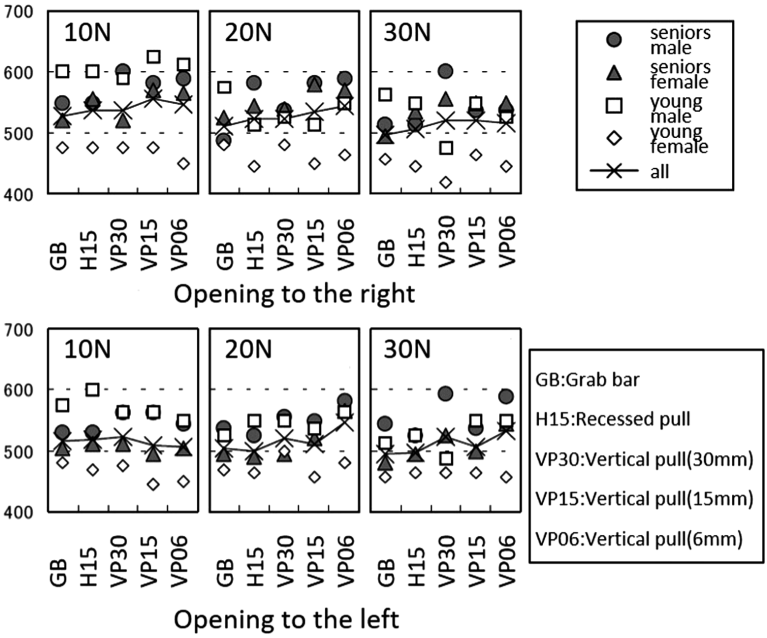


Fig. 7. Width of door opening under different conditions.



Fig. 8. Closing the door backward.

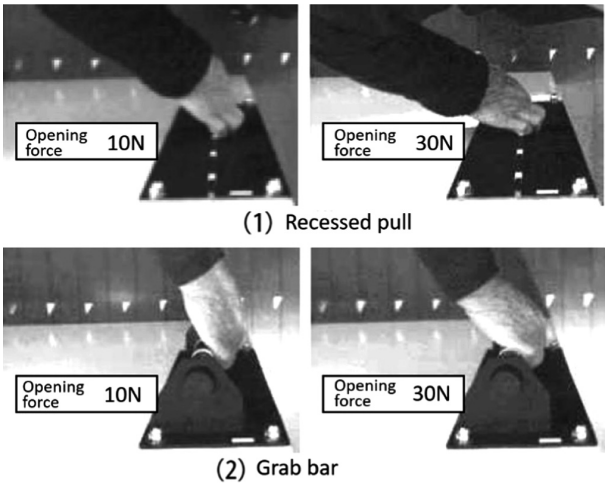


Fig. 9. Difference in the manner of wrist use as force is applied to operate the door.

7 Discussion on Door Opening Behavior

To find out the effects of subject characteristics, hardware and opening force on operating height and opening width, a quantification analysis was conducted. The effect of difference in operation was strongest in the variation of the results. The height of application was most affected by age (Table 4), while width was distinctively narrower for young females (Table 5).

Table 4. Quantification analysis of parameters affecting height of force application.

	Category		Category score	Partial correlation
Subject	Senior male		-61.86	0.986
	Senior female		-62.4	
	Youngster male		69.32	
	Youngster female		54.94	
hardware	Grab bar		2.72	0.617
	Vertical pull (30mm)		-10.17	
	Vertical pull (15mm)		12.02	
	Vertical pull (6mm)		-4.57	
Opening force	10N		-1.72	0.163
	20N		-0.68	
	30N		2.4	
Coefficient of determination		0.972	Constant term	997.91	

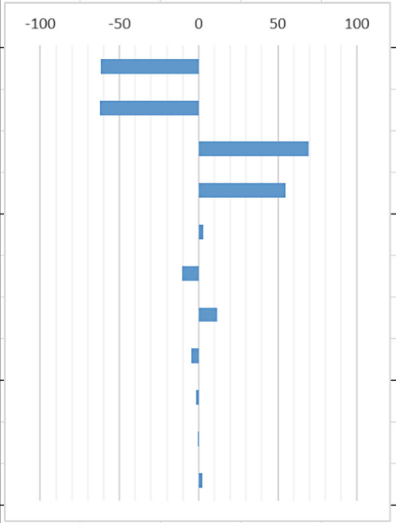
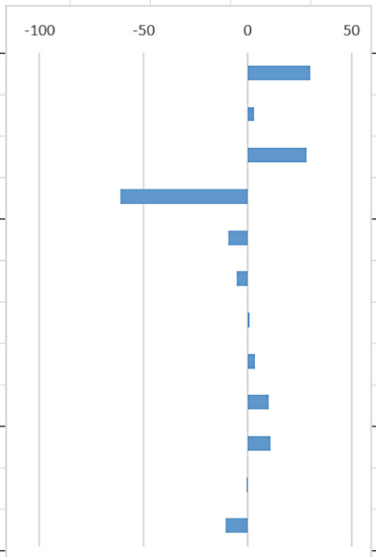


Table 5. Quantification analysis of parameters affecting width of door opening.

	Category		Category score	Partial correlation
Subject	Senior male		29.95	0.884
	Senior female		3.22	
	Youngster male		28.15	
	Youngster female		-61.32	
hardware	Grab bar		-9.22	0.328
	Recessed pull		-5.22	
	Vertical pull (30mm)		0.87	
	Vertical pull (15mm)		3.37	
	Vertical pull (6mm)		10.2	
Opening force	10N		11.05	0.413
	20N		-0.45	
	30N		-10.6	
Coefficient of determination		0.797	Constant term	524.05	



Observation of behavior revealed controlled operation such as trying to prevent the door overshoot under smaller operating force. Quantification results show that hardware with lower sensory evaluation tended to result in wider opening, suggesting the difficulty to control the door movement.

8 Conclusion

With a vertical grab bar or a door pull of better design, usability of the door can be improved, particularly for 20 N force. With 30 N and beyond, however, it will be difficult to reduce the burden. With 10 N condition, the door can be easily operated, but 6 mm projection vertical door pull is still uncomfortable to use. Both operating height and opening width depended more on individuals rather than hardware design or opening force. However, opening force clearly affects the movement of the wrist or elbow angle, which can be used as a measure of door usability.

Acknowledgments. The experiments were conducted as part of a joint research between the Building Research Institute, the Ministry of Construction and the Comprehensive Housing R&D Institute, Sekisui House, Ltd. A summary of this research was reported at the Architectural Institute of Japan Annual meeting in 2001 [4, 6].

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Designing for Inclusion in the Information Society



Collaborative Quality Function Deployment. A Methodology for Enabling Co-design Research Practice

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Abstract. The Quality Function Deployment, was born in Japan around 1965 as a method to deploy functions forming quality and measurable parameters concerning products, service or processes based on user needs. QFD is normally used in business contexts by multidisciplinary teams that, after significant training, collaborate to compile and to interpret user requirements embedded in a matrix with characteristics and attributes. However, the design discipline is changing, along with methodologies, approaches, multidisciplinary teams and working practice. The rise of recent co-designed methodologies, flexible and holistic approaches in to design research lead to a decreased use of QFD among new designer generations. It has been noticed that when people are not adequately trained, and there is no opportunity to have face to face meetings, some methodological issues can arise while using QFD. The aim of this explorative work is to investigate the key factors that limit the use of QFD in the current multidisciplinary design research practice. A methodological literature review along with holistic experience fostered the development of a manifesto for a collaborative QFD methodology that stimulates collaborative multidisciplinary design research. This research impacts on developing a stimulating approach in to design research and practice, which shall be collaborative, inclusive, flexible, adaptable and open source, following the recent paradigms in cross-disciplines research practice.

Keywords: Human factors · Inclusive design · Quality Function Deployment · Design research

1 Scientific Background

The cross contamination among applied methodologies in the ideation and development phases of industrial answers to human needs and requirements is fundamental in the design process.

Those under the domain of the theoretical approach of scientific research has given birth, during the last decades, to the practice of design research aiming to improve the life quality of people.

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According to Archer, "Design research is systematic enquiry whose goal is knowledge of, or in, the embodiment of configuration, composition, structure, purpose, value, and meaning in man-made things and systems (…)" [1].

The concept of Design research affects the convergence of two different approaches and attitudes regarding the analysis of the actual reality and the experimentation and validation of theories with different levels of complexity. Different typologies of Design research have been developed and even more are still being proposed, within the dualism between science and industry, quality and quantity, theoretic models and prototypes.

Different research processes offer a variety of outcomes: methodologies aiming to develop shareable solution to human problems provide, generally, results like configurations, processes, and designs. When the aim of the research is to understand the causes and the contexts in which those problems are generated, Design research can provide closer results to the ones related to the scientific approach, such as theories, publications, experiments [2].

It is commonly recognized that the development of innovation in scenarios such as the Internet of Things, autonomous vehicles, assistive environments, eHealth, due to the complexity and variety of the competences required, necessarily implicates a multidisciplinary approach [3].

This exploratory work, very much focused on the Human Centered Design research and very close to industrial products and processes, can provide support for the creation of collaborative methodologies, services and other approaches that can offer new human needs-driven solutions. The term "new" recalls the concept of "innovation" referring to the major drivers in the development of contemporary industrial design research.

The design research team in these cases is composed of experts coming from Industrial Design and Engineering, Social Sciences, Ergonomics and Human Factors, Law and Policy, Economics, Computer Science, Communication and Robotics. The work of such research teams requires instruments and methods to enable them to organize and harmonize quantitative and qualitative approaches.

The analysis phase, mutual understanding, the language used to communicate ideas among different specializations have to be driven towards the direction of shared objectives derived from the real human experience.

The Quality Function Deployment (QFD) is a methodology that aims at fostering the ideation of innovative solutions based on a qualitative human-centered analysis through quantitative instruments of evaluation, like matrices and algorithms and the use of graphic [4].

It is interesting to see how the complexity and accuracy of this methodology in addressing human needs has been used for many years, since 1965.

However, the increased use of collaborative platforms along with different design approaches is nowadays overwhelming the structured, and not up-to-date QFD methodology. This research work, based on observation of design research practice in different teams, is positioning a hypothesis of applying the concept of collaborative platforms to further develop a collaborative QFD methodology able to cope to the new demand of flexible, ubiquitous design approaches for the design community.

2 The Quality Function Deployment Methodology

The Quality Function Deployment, also known as QFD, was born in Japan in 1965 as a method to deploy functions forming quality and measurable parameters concerning products, service or processes, based on user needs [4].

It was developed primarily by Yoji Akao, that described the tool as a "method to transform qualitative user demands into quantitative parameters, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process" [5].

The Quality Function Deployment was further defined and rationalized by Yoji Akao, Shigeru Mizuno and Yasushi Furukawa, members of the JUSE (Union of Japanese Scientists and Engineers), in the early '70s after a applying the QFD for designing an oil tanker by Mitsubishi Heavy Industries [6].

QFD has largely been applied over half a century as a tool to literally capture the "voice of the customer". The voice of the customer is collected and analyzed in a variety of different ways: direct discussion or interviews, surveys, focus groups, customer specifications, observation, field reports. QFD is normally used in business contexts by multidisciplinary teams that, after significant training, collaborate to compile and to interpret user requirements embedded in a matrix with characteristics and attributes [7] (Fig. 1).

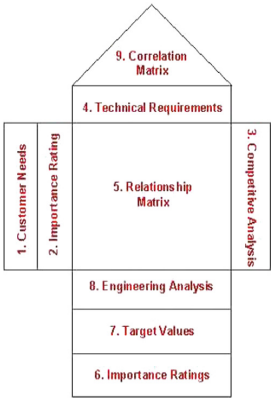


Fig. 1. Graphical representation of the traditional matrix of the Quality Function Deployment.

These parameters are embedded in a structure called the "House of Quality" that allows teams to envision solutions as an output to measure the relevance of the features for the satisfactions of the identified needs by using a graphical approach and predefined algorithms. Matrices are used as a communication tool at each step of the procedure, and the added value is within the process of communication and decision-making [8].

At the end of the 90s, when QFD has been largely diffused across the world, Professor Yoshizawa during the sixth symposium on QFD pointed out two fundamental observations on the significance of QFD in industry [9].

"QFD has changed what we have known as quality control in manufacturing processes, and established quality control for development and design. In other words, QFD has established quality management in product development and design. QFD has played a significant role when the focus of TQC shifted from process-oriented QA (Quality Assurance) to design-oriented QA and creation of a new product development system".

"QFD has provided a communication tool to designers. Engineers, positioned midway between the market and production, need to lead new product development. QFD renders a powerful arm to engineers as they build a system for product development".

After Akao, many other researchers contributed to the evolution of the QFD methodology that is currently in use. Different practitioners across the world took inspiration from different approaches such as: Conjoint Analysis, Theory of the Resolution of Invention-related Tasks (TRIZ), Conflict Management, Taguchi methods and different others [10]. A relevant fact is also shown in the application of QFD to software design other than product design [11]. Considering the perception of the design discipline among practitioners and researchers, it is easily recognizable a paradigm change that rapidly brought innovation across the years.

Methodologies, approaches and working practice are getting contaminated by cross discipline collaboration of teams. The rise of recent co-designed methodologies, flexible and holistic approaches in to design research lead to a decreased use of the originally deployed QFD methodology among new generations of designers. During the past years the authors have been using the QFD in several design research projects, with the aim of bringing innovation with support of Human Centered Design approach, including researchers from different fields and professionals from related markets [12].

It has been noticed that scarcity of awareness for designers and researchers, associated with communication difficulties, such as lack of face-to-face meetings and information exchange, developed instrumental methodological issues while using the QFD methodology.

One of the major issues is related to a lack of knowledge in interpreting matrices, not easily readable by subjects who are not proficient with QFD. An interesting research question that arises from this premise is: how to improve and update the use of the QFD methodology according to the current design practice and envision a further sustainable development for the future?

How collaborative models, platforms and technologies can foster the use and revitalize the application of the QFD tool across disciplines, countries and practitioners?

3 The Rise of Collaborative Platforms

Collaborative design has become a predominant approach in different research and working fields [13].

Collaborative design is an approach that allows a group of people to design a solution together. It helps teams to build a shared understanding of both design problem and solution [14]. It provides the means for people to work together to decide which functionality and interface elements best implement the feature they want to create [14]. Collaborative design is also described by Wang et al., as "a design process where a product is designed through the collective and joint efforts of many designers" [15].

It helps to think out of the box, brainstorms ideas with multidisciplinary teams and engages various stakeholders with different perspectives in the creative process. One of the most direct examples of how collaborative design is becoming popular among different fields is in the use of collaborative software, groupware or online platforms.

A collaborative groupware is an application software designed to support team members involved in pursuing a common task that enables them to achieve a particular goal [16]. During the process, team members use different tools and software to easier the decision making, management and creative thinking procedure.

Collaborative platforms gained popularity around 1990 when the US Government began to use them for different purposes [17]. One of the first robust applications was the Navy's Common Operational Modeling, Planning and Simulation Strategy (COMPASS), allowing up to six users to create connections with each other [18].

As the potential of Internet connection grew up, the number of users increased, the cost diminished and the continuous demand improved. Nowadays we are pervaded by an increased number of software, offering online collaborative services across the world. A short list of examples includes: electronic calendars/time management software, project management (CRM) solutions, workflow systems, knowledge management systems, enterprise bookmarking, online spreadsheets and collaborative documents, client portals, only to mention some of them.

Collaborative platforms, have been successful and used across different fields such as: Urban Planning (facilitated workshops with various communities), Community Building (such as the Detroit Collaborative Design Center (DCDC) [19]), Architecture (with different participatory methods called EDP "Equal Design Partners" and IDP "Integrated Project Delivery").

The success of these platforms is consistently described by Shea et al. in three main tasks: task interdependence (how closely group members work together), outcome interdependence (whether, and how, group performance is rewarded), and potency (members' belief that the group can be effective) [20].

To be successful, a collaborative project must establish a definition of the team, identify their outcomes, ensure there is a purpose of the collaboration and clarify the interdependencies of the members [21]. It is possible to interpret an overlap of the topics already part of the QFD methodology.

On the other hand, there are different design and implementation issues. Workers that collaborate through such groupware do not only have to address technical issues, but also carefully consider organizational aspects [22] and team processes that should be supported with the software application.

Some of the identified issues are: persistence is needed in different cases; online voice and video meetings disappears after the session, leaving behind a lack of information that cannot be stored, if not by accurately recording the sessions. Multiple input and output streams can improve concurrency issues into the shared software

applications. Motivational issues are important, especially in settings where no pre-defined group process was in place. Design patterns in the methodological process can drive design issues and choices in a way that all team members can participate in the development process.

While the QFD has been largely used over decades, the lack of a fresh, innovative and collaborative information sharing among multidisciplinary teams working on solution development represents one consistent issue in the current spreading of QFD to a wider audience.

4 The Case Study: A Methodology for Enabling Co-design Research Practice

The research team during various years of design and research practice, highlighted the majority of constraints while using the QFD methodology, particularly when the communication among teams was weak and inconsistent.

In details, during the research project "Habitat", aiming to design inclusive IoT-based solutions for older people, it has been noticed how the use of QFD methodology was not performing well across different multidisciplinary teams working from remote.

One of the major aims of the preliminary work of analysis of user needs and definition of design requirements, was to combine available technologies on the market with the design requirements expressed by the users by using the QFD methodology [23].

The Habitat research was developed around a User Centred Design approach [24] to design smart objects and systems that control them.

The applied methodology was aimed at optimizing the combination between constraints deriving from the technological choices and requirements derived from the analysis of the needs carried out with users.

During this research the inputs are the "Needs," and are defined to reflect users' necessities and the "Features", as measurable performances of the object to be designed. Both needs and features have been indexed in correlation through a matrix chart, which supported designers to evaluate the degree of relationship.

Starting from hierarchy resulting from expressed evaluations, designers developed through brainstorming the feasible solutions for answering user needs. One of the major issues encountered during this ideation process was related to the lack of communication when combining topics related to quality (emotions and necessities of selected categories of users), with others related to quantity (measurable features of the smart objects to be designed regarding both design and technologies).

As a result, the iteration among teams of designers, engineers and caregivers was not optimized, despite the rigid, functional structure of the QFD. In practice the methodology was performing well, but the connection among teams was not strong enough. This means unclear communication, time not optimized and the most important aspect, inefficiency during the design and optimization stages.

This helped to change the strategy behind the QFD, by organizing different meetings among designers, engineers and caregivers, by using online platforms as well as in person communication strategy.

In a further stage, when the prototypes were defined, a test phase was performed in order to collect feedback for mainly evaluating the usability.

At the end of the test phases, information gathered through observation, questionnaires and focus groups were further elaborated through collaborative platforms and online database.

As a result, since the process of design, implementation, prototyping and test was implemented with collaborative platforms and online database, the team performance as well as the efficacy of the design was perceivable among the team members.

The implementation of the QFD methodology with collaborative platforms available online and data sharing options fostered the inner collaboration between designers of different disciplines by improving their sense of responsibility as well as the group challenge in performing better.

5 Envisioning the Future of Collaborative QFD Platforms

The design process is evolving with a pace which is proportional to the technology development. The rise of recent co-designed methodologies, flexible and holistic approaches in design research may lead to a further decreased use of QFD methodology. This would translate in a big lost in terms of scientifically proven design methodology used in the research and development scenario.

Knowledge and training are also important in order to spread out the concept of QFD and the case study of the Habitat project proved how those topics are extremely relevant in current design research.

As a preliminary result, it is possible to state that the benefit of a ollaborative QFD platform are boosting the design outcomes.

The collaborative QFD platform could support practitioners but also researchers in interpreting matrices, analyzing workflows and foster the mutual understanding process among multidisciplinary teams, who are not physically connected.

As a preliminary statement of the Collaborative QFD platform manifesto, some of the inputs might be taken in to account:

- Allow multidisciplinary teams to foster understating of user needs;
- Enable team players to make meaningful brainstorming;
- Unobtrusively improve the quality of working practice;
- Foster a long-lasting Human Centered Design approach during different stages of the project;
- Connect mindsets, strategies and approaches with as less as possible constraints;
- Allow data sharing, information sharing, idea sharing in an accessible way;
- Increase awareness by allowing practitioners to adjust the system according to their needs.

A future impact of this work will lead towards the creation of a collaborative web-based platform that uses the QFD methodology to enable new generations of designers and engineers to intuitively understand customer needs, translate in to meaningful requirements and foster innovative designs.

This research will impact on developing a stimulating collaborative approach in to design research and practice, which shall be collaborative, inclusive, flexible, adaptable and open source, following the recent paradigms in cross-disciplines research practice.

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Inclusive Design Methodology in Practice: Turning a Prison into an Inclusive Civic University

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Abstract. This paper outlines the importance of contextual theoretical, empirical research and research by design in order to create inclusive concepts at the start of a design process. 26 master students were invited to reflect upon an old prison site in order to create a new entrance for Hasselt University representing an open university for all. Whereas many student excercises in Design for All (DfA) often focus on the needs and disabilities of people, this excercise focused on the abilities of people on site and on the opportunities of the architectural site itself. By means of linking both results, the excercise demonstrates to be very inspirational to both students and staff. The paper concludes with a categorisation in contextual analysis from an experiential as well as an architectural point of view.

Keywords: Architecture · Inclusion · Design methodology · Education · Context · Concept

1 Introduction

How can an architect work towards inclusive solutions in an extreme context of adaptive reuse in which the original typology aims at the principles of exclusion and experiences of isolation and stigma are the main goal: a prison? An old building, originally designed for prisoners and guardians, was the challenge for architects when Hasselt University asked them to reflect upon a design proposal by means of turning the old prison of the city of Hasselt into a civic university. More precisely, architects were invited to create a design proposal for the old prison in order to host the Faculty of Law. This paradox was the main goal for NoA-architects in Belgium when they were invited to renovate the old prison in Hasselt into the University's Faculty of Law. For a long time, an architectural typology was historically defined by a formal defined language and its architectural elements. This approach originates upon the common belief that the architectural language is dominant, and that people should always adapt to these by law and religion determined creations.

Consequently, a formal language outlined the main foundations for public buildings and urban creations. Moreover, the historical and cultural values formed the original

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differences in between the formal languages of Architectural Schools, like Ecole des Beaux Arts and Ecole Polytechnique. Currently, however, a democratic and inclusive approach in design has positively evolved the architectural language by means of including experiences rather than forms. These experiences are defined by economic, political, cultural and social evolutions within a historical defined society. The architectural language has been challenged because there is no limitation in the needs of people as it is a relative approach based on evolution [1]. Thus, the current challenge is to use the designated formal language of this prison in order to meet the aimed experiences and needs. Designing a building as diverse as possible, makes both the architectural language as well as its outcome more democratic in expression. This revolutionary shift can lead to a diversity of forms and style in architectural language these days. Moreover, it may indicate the level of inclusion of the buildings based on typology. This challenge in historical evolution offers new opportunities to architects and urban planners both for new and old buildings.

This paper outlines insights in design methodology based on an architectural master project for students in interior and architectural design who were challenged to reflect upon the paradoxical question to reverse the site of the old prison into the main entrance of the university. Making an inclusive entrance in an old prison's typology requires a design approach and awareness that examines the right design questions and decisions. By means of generating the different design steps, this paper evaluates and informs upon a workable educational approach by means of using the right methods and awareness in order to transfer insights to design methods.

2 Historical and Architectural Context

In the city center of Hasselt, next to the ring road -designed as a Green Boulevard- the old prison dated 1859 is now one of the main buildings of Hasselt University. Until 2005 this building hosted prisoners and guardians who counted their days in small cells connected by lateral corridors leading towards a center that reminds us of a panopticon. Using a panopticon as a prison was one of the main architectural concepts developed by Jeremy Bentham [2]. Bentham defined the panopticon as a circular place that embraced all the cells with a view. In this circular place was a circular room in which the guardians could watch all the prisoners, whereas they didn't know if they were watching or not. It was a by Foucault (1975) [3] invoked metaphor for a modern "disciplinary society" on "seeing and not to be seen" and it supported the guardians in their efforts of control. This way this structural pattern could act as a powerful object in the environment. Whereas in other prisons, guardians still had to walk all the corridors to check upon their hosts, this typology reduced the number of walking lines and made it possible to check from one control tower. Moreover, the five arms that linked the central body of the building and acted as corridors were placed in a pentagon (Fig. 1).

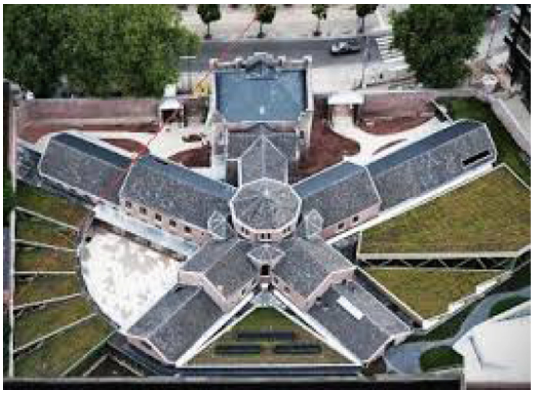


Fig. 1. Aerial view upon the old prison, the Faculty of Law at Hasselt University

By means of using this form, people who walked the corridors were confused and distracted and consequently by this formal language, orientation was undermined. This design aimed at creating disorienting architecture in order to distract its main users – prisoners- and avoid them to escape. At Hasselt's old prison, part of this concept was built but the cells were still part of five main wings and the wings themselves were connected by the center that wasn't used for a control post but instead offered place for a pulpit. The pulpit was used by a priest and guardians could listen to them. It was a star form developed by Edouard Ducpétiaux, a Belgian sociologist and reformer of the Belgian prison system [4].

In 2005, the prison moved out and the building was bought by Hasselt University. The rectorate invited NoA architects to redefine the site into the Faculty of Law and the main building for the rectorate and part of the University's administration. Moreover, the principles of a civic university, a human centred approach in terms of university vision, are crucial for the rectorate and consequently the representation of these principles into the architectural language requires an inclusive approach since the idea of creating distraction in this protected monument would be unsuccessful in order to create an accessible university.

The prison is a partly protected building by Monuments and Services and parallel to the paradoxical question to make a prison inclusive, the challenge to turn this architecture into an inclusive academic environment was challenging too.

Currently, the university exponentially grows, and this requires new buildings. Some have been built close to this site and others will soon be renovated or erected in the city center as the university has bought old buildings in order to establish its city campus. This evolution requires a vision at urban level as well. These challenges for a future university campus formed the basis for the research and design exercise in the research seminar "Designing for More" at the Faculty of Architecture and Arts at Hasselt University.



Fig. 2. Picture of the old prison, the Faculty of Law at Hasselt University, (Picture: Liesbeth Driessen)

3 Designing for More: Educational Design Research in Order to Unravel Opportunities for Inclusion

During the research seminar "Designing for More", invited lectures as well as workshops and traditional lecturing took place. Guest speakers with different expertise and from different areas and disciplines were invited (CIFAL, staff at Hasselt University, Inter, Doof Vlaanderen, Blindenzorg Licht en Liefde, …). This way students were involved with the challenges of social sustainability defined by different people, approaches and perspectives. A speaker of the United Nations came to raise awareness for the Sustainability goals, an expert in echolocation gave a workshop to train students in listening and hearing differences in architecture based on sound experiences, an architect in a wheelchair explained her experiences and approaches in work, an administrator from Inter, the Flemish expertise center for Accessibility and Universal Design, gave an extended presentation and experts in the experiences of deafness and blindness joined the students during their design research workshops in practice. For 14 weeks, weekly one day courses were built up with lecturing theory and challenging research exercises by 3 professors.

26 students from the master's in interior architecture and the master's in architecture subscribed for this seminar. The group was invited to organize themselves as an architecture office in which several groups of people were responsible for several topics and two student coordinators oversaw communication and delegation of tasks. For the research part we asked half of the group to do research on the experiences of users of the building (interviews, observations, performances); whereas others could focus on the architectural language of the context and analyzed the buildings' and site's context at different levels (history, form studies, statistics of program use of the buildings, traditional modelmaking, stringmodels, typology, architectural plans, architectural offices). At the start students didn't understand this division and they literally asked

why some of them didn't have to do research, considering the architectural model making and analysis not as research. By means of questioning them we created an awareness for the importance of analyzing both the human experiences as well as the architectural language evoking these experiences. Students were invited to question and reflect upon their actual actions and what they were doing. For example, the group that made a traditional model of the context was challenged to remove certain blocks and by means of visualizing and making the physical context by hand, they revealed certain aspects that contributed to the handicaps of the environment. Indeed, we consider the buildings and site to be impaired when people don't experience it as originally planned or intended by the designers. This is the core focus of "Design for All" or "Inclusive Design", more precisely that it is the outcome of a design strategy resulting in an environment, product or service in which users should not adapt but are supported in their actions and experiences in a positive and elegant way [5]. In other words: "Good Design enables, bad design disables" [6].

If we want a building to be as inclusive as possible, we need to know the "translation" and "representation" of different architectural languages and their impact on experiences. This personal impact in terms of spatial experience can be physical as well as social, cultural and cognitive. The physical impact is often more explicitly recognizable for outsiders as it is visually comparable with personal actions. Indeed, every person can be invited to empathize with the experience imaging him- or herself in that situation by means of thinking about the exclusion of functions or abilities linked to their physical bodies. The experiences are often valued based on human standards. The more visible and readable the differences in performance are to others, the easier it is to predict experiences. Because you cannot hide the lack of certain abilities, it is perhaps therefore the most stigmatizing experience as it is a literal and personal confrontation between the physical body of the user and the physical bodily environment. For example, if you only have one arm you will perform differently when having diner or lunch. Results can be easily made by observation and often solutions are made based on principles of accessibility and standardization. The more invisible the experiential impact is to others, the more difficult it becomes to empathize as a designer. Cognitive functions support our daily experiences but are invisible to others. Similarly, cultural and social preferences are more intangible and based on personal preferences and knowledge. Whereas in the domain of accessibility these differences are considered as "impairments" or "handicaps", in Design for All this difference is an expertise because every human is considered as a different and unique being in the world. Focus is not put on the adaptation of people or users but on how design can support the diversity of users. Therefore, it is necessary to inform designers in the best way and inform them about diversity in experiences created by design. Currently, we notice in the design world a lack of insights in this translation. In order to bridge this gap between experiences and design outcome. It takes awareness for diversity into account when designing. During the courses and lectures students were informed and invited to read related scientific articles. By means of linking theoretical knowledge with their empirical research, they were asked to reflect upon the context of the old prison, and they were invited to design concepts for future improvement.

4 Outcome Results

More precisely, students were asked to link their results to the Universal Design principles [7] and goals [8] and motivate their concepts based on the link between actual and aimed experiences and current architectural language and the supportive language. Architectural design supports and shapes interaction with the environment and architecture shows us how we use our body and senses. However, for long architecture has been dominated by a visual culture that particularly has focused on visual languages [9, 10]. In this seminar we stimulate students to design architecture that supports all senses and can contribute to human culture in all means. A panopticon or a derivate, however, was originally planned and designed to support and stimulate vision. It was designed for prisoners to be seen and for guardians to stay invisible. As part of the concept, other senses were given less attention to during the design process. Partly because it was not prioritized in terms of program. For example, the main goal was to watch the prisoners and guard them in a visual way. Secondly, in terms of programming and use, the prison was not designed to be a comfortable place because in the Victorian time it was no longer designed as a temporary transit but as a place meant to feel like a punishment and so as unpleasant as possible [11]. Finally, this architectural language has been inspired on a 19th century architectural language defined by the military design style of the Ecole Polytechnique where focus was put on the constructive and defensive translation of the building and its aesthetic visual perception. The use of the building was designed based on the prior use of the concept: visual guardiancy.

Since the current program requires just the opposite performance of the original program, there is a challenge in renovating this "handicapped" building language into a civic university. Hasselt University aims at being closely linked with society, culture and its users in general. The rector generates a common vision for the identity of Hasselt University as "an open house of knowledge in action" so the opposite of a 19th century's prison concept. Consequently, in order to be inclusive for its users an approach and façade can represent a building's identity as part of a welcoming function and cognitively accessible entrance. In this exercise we invited students to analyze the context of the users as well as the actual building. For this exercise we started from a positive approach and opportunities instead of focusing on impairments for specific groups or disabilities. The abilities and experiences of users have been analyzed as well as the existing language of the architecture on site. The research results of the analysis of both approaches are explained in the next subsections.

4.1 Architectural Language and Context of the Site

Seven years after opening, the building renovated by NoA underlines the principles of an open civic university for all, a university that links with the city and city life. NoA's concept was based on the metaphor of a bird cage where outsiders can follow and connect to what happens insides and students can stay in a protective biotope. Therefore, gateways are carefully chosen, and the powerful typology of the building is transformed into a cognitive representation of safety for students and knowledge creators. The second conceptual layer was a "city in the city" approach where the

university acts as a city and connects with its paths and squares to the actual city and is easily accessible. However, due to choices during the design process – for example to protect the outside façade- the entrance of the Faculty of Law is still unclear to unfamiliar visitors or users (Fig. 2). The rectorate was designed as a completely new green building that was stickered with the UHasselt-logo and represented the beating nerve system of the university. By connecting two new buildings to the old prison and creating a colorful green building as a landmark, people often enter this building to search for the reception desk or information. The original mason made prison-façade was originally not designed to support and welcome visitors, because it once was to keep everyone out and in. Now, the site has five possible entrances, and this is confusing as well. Based on the analysis with the expert in echolocation the main gates are the most "visible" and considered as entrances.

At urban level the ringway literally creates a boundary between the city and the university's city. The model and the photo-ethnographic studies demonstrate that the approach of the university is unclear to unfamiliar visitors. The landscape architecture with trees and rocks leads people to the main open gates in the wall and consequently visitors follow roads that don't immediately lead to the main entrance. The idea of the green building as a landmark is even stronger underlined in the concept of the architects as a contrast between the red brick building. Green stands for transparency and openness, the vision of the rector and consequently his office place.

Based on maps and time registration, the university's site is close to the railway station and close to several parking lots and a bus station. A string diagram shows that the walking lines, driveways, and crossing points should need a revision in terms of the university's approach. The program of the functions of the buildings is unclear to many people as well as the signage of the rooms and buildings.

4.2 Context of People's Abilities and Experiences

Moreover, the idea to respect the pathways in the old prison as a labyrinth was theoretically aimed for by the architects but in practice interviews with administration officers, students and staff prove that this undermines the usability and experience of the place. Hence, the flow of users does not align the objectives of the daily practice because, despite the prison holds the most public functions with the reception desk and auditoria, the green rectorate building has been defined by a welcoming façade, underlined by its architectural language. Since there is no reception desk in this building, it may lead to confusion and a less inclusive welcome which doesn't align with the civic university vision of the university. Observations demonstrate that many people use the old prison and the Faculty of Law as a walkthrough from a parking lot and other campus sites towards the city and vice versa. This demonstrates the idea of a city in the city, however, once inside the building people are lost. The green building is also for visually oriented people like people who are deaf the most obvious entrance. They suggest using small landmarks in and around the site to guide people through. Experts in visual impairments confirm the need of a good design of the university's approach and entrance. The stones in front of the building are now placed in a rhythm but can be placed in order to lead the visitors towards the main entrance.

The experience of the buildings in terms of elegance and aesthetics are very positive. The reception managers only ask for a more visible location and a more usable and practical desk. Moreover, they feel that it would decrease their workload in offering guidance, information and support to users if the building was more readable.

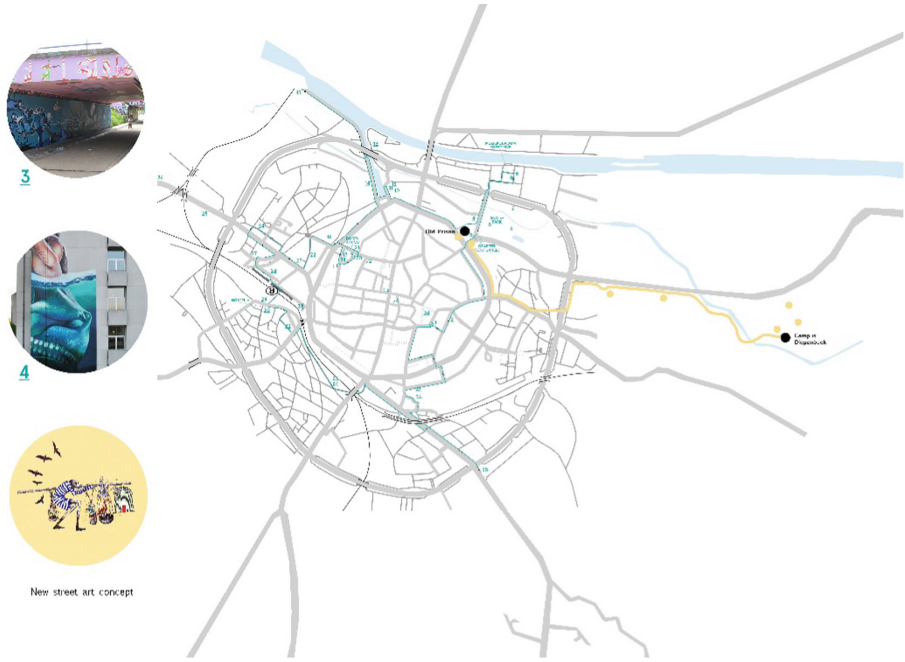


Fig. 3. Design map of contextual analysis at urban level, "New street Art concept", (design by Charlotte Neyens, Maud Orudowski, Femke Steensels, Emma Vanderwegen)

4.3 Conceptual Design Proposals

Based on all the findings in their research and design analysis, students were invited to create a conceptual design that would meet future requirements and expectations of the university. They were not obliged to design but they had to reflect about how they would link the UD-principles with UD-goals by means of their concept. Again, the students worked together in seven different design teams and their results were based on the contextual layers of inclusion of both experiences and architecture. Depending on their preferences students started with the experiences as part of their concept or the architectural characteristics but they all related to the concept of inclusion. For example, one group started from the result that the program of the green building did not align with its representation and instead of designing a new building they reprogrammed the green building with more public functions and making its ground floor serving as an entrance for the whole site. Another group also started from an architectural point of view and used the idea of the "city in a city" to design at urban levels several landmarks that support the orientation towards the university. Similar another

group designed artworks or used buildings as art in order to mark the university campus in the city (Fig. 3). Other groups started from the cognitive experience of the site and wanted to extend the signage by means of architecture. One team literally pulled the "panopticon" out of the old building by means of creating a huge surface in front of the building that also acted as a ramp. The wooden entrance door was replaced by glass that is detectable by means of echolocation. Several groups also gave attention to the location of the reception desk. Some took it out of the building and replaced it in a new or renovated building whereas others created columns that served all senses and physical orientation. It was only after the design exercise that students realized the importance of design research in relation to theoretical and empirical research with, by and for users' experiences. Whereas the first seven courses, focused on the creation of awareness for the concept of Design for All, the last part of the courses submerged them into the power of design regarding inclusion.





Fig. 4. Left: picture of the jury presentation of the results, right: picture of one of the design models (pictures by Yasmine Detavernier)

5 Discussion

This master project demonstrates the importance of a decent contextual analysis by means of research by design as well as theoretical and empirical research on experiences. These different layers of contextual information help designers to create a concept that puts priorities ahead and offers insights on inclusive experiences. We define contextual layers of inclusion both in terms of experience as in terms of architectural language. More precisely, an experience can be physically, socially, cognitively or culturally defined and from an architectural point of view a context can be historically, geographically, culturally and socially layered. Future research on how experiential as well as architectural layers can be linked is necessary.

Within the context of this project new insights arose on possible improvements for the university campus. For example, the architectural concept to define contrast on site between transparency and safety undermines the actual practical use in terms of accessibility. Consequently, the general vision of a civic university has not been

completely achieved. It would be good to consider this concept not only at an architectural but also at an urban level in which the "transparency" of the university's site is placed into the red brick city of Hasselt. The idea of the labyrinth can be kept but needs extra support in order to work as it is meant to be. Labyrinths in the Renaissance were part of the landscape architecture and parks. Considering the University's new city campus as a Renaissance park could put strength to the original concept of NoA architects. Similarly, new ideas and concepts can underline the university's vision and representation. Currently the staff administration investigates possible implementation of some of the suggestions. They were invited as jury members and the fact that this the exercise was a concrete and real time question contributed to the attitude and awareness of students and can be considered as a positive pedagogical approach (Fig. 4). Furthermore, this paper demonstrates that designers can learn from extreme conditions both in terms of experiences as in terms of architecture. A building typology that represents power and undermines comfort is an extreme situation in order to turn it towards an inclusive building for all and it shows that focusing on experiences instead of forms contributes to inclusive representations in buildings [10]. Similarly, inviting people with an extreme expertise in perception like people who are blind or deaf increases the insights in experiences for all. This is the common vision of Design for All and underlines the positive approach in order to respect people's abilities and diversity.

Acknowledgments. The author would like to thank all the "experiencers" on site, the experts, guest lecturers, students and teachers involved in the course seminar Designing for More as well as the technical team and staff of Hasselt University to give us the required support in order to make this exercise possible and successful.

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Defining a Shared Platform in China to Propose a Social, Cultural and Technological Bridge

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Abstract. China's continuous and swift transformations pose relevant challenges to a sustainable development in all three areas: social, ecological and economical. Several national policies are implemented to guide these transitions within supported, non-disruptive solutions, seeking to keep an overall balance in the very dynamic socio-economic framework. These policies are generally implemented separately. This paper presents a possible proposal to link an economical policy to a social one through a design driven approach for social innovation: how to create a potentially beneficial link between the major social challenges of the elderly and the family in rural areas and the "Mass Innovation Entrepreneurship", one of the policies to support the transition from "factory of the world" to Made in China and Design in China. This could impact millions of families and offer a new social implementation for a tech driven phenomena.

Keywords: Left behind children · Elderly · Design driven social innovation · Human diversity · Sustainable business · Makers · Generations' bridge · Cultural bridge

1 Introduction

With an increase of production costs and a decrease of productivity, China's role as the "cheap factory of the world" is decreasing and the Country is implementing the transition to the high tech production model of the Made in China 2025 initiative and ultimately, to Designed in China.

One of the solutions China is pursuing is the development of a "Mass Innovation Entrepreneurship" (a policy purposely created to support the phenomenon), where innovation means mostly technology. The maker movement is seen as an important source of technological innovation and a trigger or catalyzer for capillary micro innovation's behaviors, especially for what concerns electronics, mechatronics, robotics and artificial intelligence.

Through a development which growth is not linear nor constant, the social impact of the Chinese makers is still to be demonstrated, yet it holds quite a relevant potentiality both with the big corporations and the small business.

The management of elderly is a growing challenge on a national level. The rural areas are mostly populated by elderlies and their grandchildren, left behind by their

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parents, who moved to the cities, looking for better life conditions. The technological knowledge absorbed by the middle generation does not contribute to increase the quality of life of the rural areas where the elderly and children live.

The questions are: who is going to take care of the elderly? And who is going to bring forward their traditional knowledge as such and through innovation?

Empowering the elderly in their natural social role and bringing forward their traditional knowledge while at the same time finding a possible answer to the inverse generational gap created in the children growing with their grandparents, with the aim of bringing back the middle generation to the country side and re-tightening the link to their parents and children (as for the traditional "three generations under a roof") requires a design driven approach.

This research aims to evaluate the possibility of deploying a social design driven approach to find a unique combined solution to these two apparently far issues, with the creation of a pilot sustainable business, managed also with the elderly, which can integrate tradition in craft and production of food with technological innovation provided by the makers, serving several clusters of small towns.

2 Elderlies, Families, Policies, Projects

In China, more than 230 million people are over 60 years old. It is the only country in the world with an elderly population of over 200 million. More than 90% of the elderly are taken care of at home, following the traditional "filial pity" model.

However, the one child policy created the inverted pyramid of the Chinese population (4 grand-parents, 2 parents, one child) which is seriously challenging the traditional model. The China Family Development Report, since the 1980s, shows the average size of households has been progressively reducing. In 1990, it was reduced to 3.96 person, and in 2010 it was reduced to 3.10 person. According to the National Bureau of Statistics, the average size of households in 2012 was 3.02 person. China is already a country with a small average family size.

The 2015 Report on the family development in China, published by the National Health and Family Planning commission highlights as the proportion of socialized aged care services received by the elderly is very low, being mainly for physical health checkups and consultations.

On top of that, millions are elderly have been left behind when over 270 million people left their rural villages to move to the multimillion people cities.

Many of them left their children with the other parent, grandparents, relatives or other adults. By 2010 the number of "left-behind children" overcame 60 million The government is fully aware of this issue and in February 2016 released a directive recognizing the very negative impact of the distance had on millions of families [2] (Fig. 1).

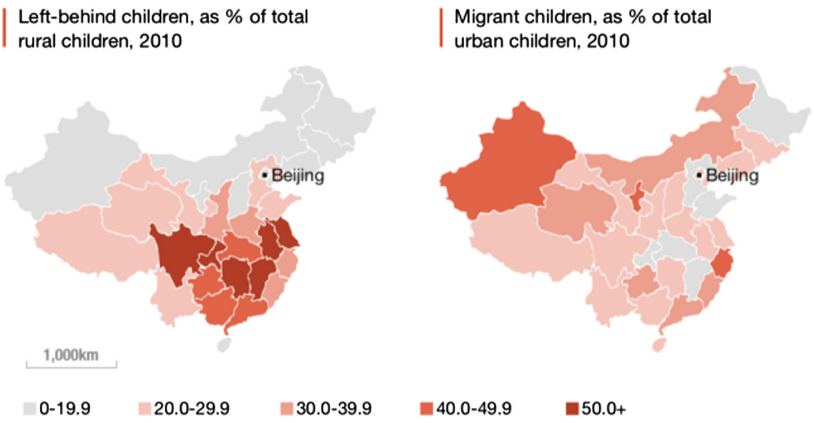


Fig. 1. Left behind and migrant children in China [2]

While China was able to dramatically reduce the number of people living in poverty conditions, many inequalities are still present. The so-called poverty traps is still present, and persistence and immobility are the dominant characteristics in the income distribution dynamics [4].

Brining urbanization to the extreme is not the solution "China cannot turn all the countryside into cities and it must pursue a new path to sustain rural development economically and environmentally," said Du Zhixiong of the Chinese Academy of Social Sciences [5].

The part of population mostly affected are the elderly and the children. A very high percentage of them belong to the above mentioned "left behind".

As an extreme consequence of aging and urbanisation, the pattern of suicide in China changed, with a much higher number of suicides among elderly and specifically those living in rural areas [6].

As already mentioned, the Chinese Government recognized the need for policies aimed to improve the economic situation of the rural regions. This theme was consistently included in the last 15 years No. 1 documents[1]. The establishment of local cooperatives was one of the initiatives supported by several policies and funding. In few years, more than 600.000 farmers' cooperatives were created, covering in theory more than 18% of total rural population [7].

Many projects have been supported with funding dedicated by the Central Government and deployed at local level.

However, many of them failed to have an important impact on the living conditions of the rural residents.

The lack of a real contextualization of any project in the local environment if often a failure factor. In fact, the approach to contextualization is most of the time translating in "treating the social and ecological environment as exogenous forces to which

[1] The first national document the Chinese government issues every year, outlining the top priorities of the nation for the coming year.

organizations must respond to while pursuing profits, competitive advantage and other more central objectives" [8].

The case of YuHu, described by Yang and Hung [9] shows how, when the competition started to seriously challenge the prosperous tourism cooperative, the whole venture was taken over by a private entrepreneur which was much less interest to the involvement of the local residents and merely aimed to increase its income.

One more reason for the failure of these local initiatives is, as underlined by the UNESCAP report [10], "the lack of infrastructures. and an underdeveloped environment of intermediaries and services providers" which "threatens the evolution of the impact investment sector and, ultimately, its ability to realize its potential to achieve social and environmental impact".

Again in 2017, United Nations Under-Secretary-General and Executive Secretary of ESCAP, Dr. Shamshad Akhtar, stated "As infrastructure provides wide economic, social and environmental benefits, it constitutes an essential part of the 2030 Agenda for Sustainable Development".

However, infrastructures are not only streets, sewage or railways. ICT plays a very important role as well.

3 China's Makers and Mass Entrepreneurship Innovation

With the first high-tech business incubator born in 1987[2], the first makerspace in 2010[3] and the second one in 2011[4], China seems to have experienced, from 2015 to now, an incredible growth, reaching the biggest number of incubators and makerspaces in the world and planning to grow further. According to data from the Torch High Technology Industry Development Center of the Ministry of Science and Technology, at the end of 2016 China owned 3.255 incubators and 4.298 makerspaces triggering the creation of 223.000 SMEs. By 2020 the plan is to reach 10.000 between incubators and makerspaces, plus 100 overseas.

As stated in its 13th Five-Year Plan (2016–2020), China aims to become an "innovation nation" by 2020, an international leader in innovation by 2030, and a world powerhouse in scientific and technological innovation by 2050.

The Chinese maker movement started typically with people, makers and hobbyists, experimenting, and creating from scratch mainly tech prototypes in shared workshops which offered shared components, machines, processes and training for research and invention. The makerspaces were funded by rent and membership fees, also with sponsorships from schools and companies.

In 2015 the policy Made in China 2025 is published and indicates a push for innovation led economic growth, changing China's focus from low-cost and Shānzhài[5] manufacturing to innovation, creativity, and design.

[2] in Wuhan, Hubei province.

[3] Xinchejian in Shanghai, founded by David Li, a Taiwanese startup entrepreneur.

[4] Chai Huo in Shenzhen.

[5] Shānzhài, 山寨, refers to counterfeit consumer goods, including imitation and trademark infringing brands and/or particularly electronics, in China.

In the same year the Government policy "Mass Entrepreneurship Innovation" pushes the maker movement to another level and a different significance: makers became synonymous of entrepreneurs and makerspaces of startups. The maker movement is subsidised to boost china's capillary capability of innovation and entrepreneurship, to generate wealth and workplaces.

Today there are 39 registered fablab[6], approximately 100 makerspaces nearer to the original spirit[7] and, according to the data from the Ministry of Science and Technology, more than 5.500 more than 4,000 incubators for technology companies more than 500,000 incubators and enterprises.

Within a specific "Chinese Character" the technological innovation potentiality is being considered and exploited both from the business and the tech educational point of view. Considering the social challenges mentioned earlier and the social potentiality of the maker approach, it is worthwhile to explore a different area of implementation and application to both experiment new opportunities and give a new thrust to the movement. A makerspace with a social innovation focus in rural areas could (i) collect the elderly A.N.A.s, input, practice and transfer their traditional knowledge; (ii) offer to younger adults to use their acquired tech knowledge locally; (iii) facilitate the coming back of young parents, thus the reunification of rural families (three generation under the roof); (iv) enhancing the quality and efficiency of small farms, thus enhancing the living standards of the farmers and their income.

4 The Project: A Mobile Shared Platform

The project foresees the creation of a mobile Fab Lab, having the same capabilities of a fix Fab Lab but providing the advantage of being able to reach different locations. While the choice of the location is a key success factor when planning to install a traditional Fab Lab, as there may be no local need for the Fab Lab neither local human resources able to create it and manage it, the mobile Fab Lab can be moved among different locations, offering several advantages:

1. Make possible assess the appropriateness of a location in order to evaluate to the possibility of eventually installing a stationary Fab lab.
2. Reach a much larger number of users.

The first mobile Lab was created by a group of MIT students in 2007, to offer the very successful making course to a larger base of students, starting from the a high school in Cleveland.

Mobile Fab Labs are presently a growing reality with several pilot experiences deployed in the United States Europe, Turkey, Saudi Arabia, and Brazil. This approach find its best application as the first step to bring digital fabrication technologies to the rural context and clustered locations.

[6] https://www.fablabs.io/labs?country=cn.

[7] https://media.nesta.org.uk/documents/made_in_china-_makerspaces_report.pdf.

In the agriculture sector, there has been some interesting initiatives. Most of them were very specifically dedicated to issues related to precision agriculture (Smolka 2016).

In early cases, such as the of smart irrigation of peanuts fields in Alabama described by Hoills [16], the involvement of the University was a key component to success although the lab was still centralized in the university.

However, our project is the first in China and it is peculiarly aimed to involve the elderly in the use of the technologies developed by the makers of the mobile fab lab.

In this way we aim to create a cultural and inter-generational bridge.

5 Conclusions

A design driven approach to social innovation brought to a possible way to combine a tech-driven government policy, derived from an economic and production challenge, to different socially focused government policies addressing a pervasive and multi-layered social challenge, with economical and health large implications, due to the huge demographics.

*D*esign is a social act, it can define and help to achieve a social-economical goal that could otherwise be difficult to achieve for a solely tech driven phenomena which tend to assume that technological micro innovations will bring China from a production-led to a design led economy.

"Designer's ability to envision and give form on material and immaterial products that can address human problems on broad scale and contribute to social well-being" [17].

"Design has always played a role in the process of production, transformations in society and the economy, shifts in technology and impacts on the environment […]. The post-industrial era is creating complex projects for technology, service, systems, strategy and products. Clients are even becoming undefined stakeholders, and this can be extended to the entire community and the environment. The rise of digital technology and the knowledge society are introducing a new culture, which can be open, participatory, shared and collaborative. Here the designer is acting as a researcher, always questioning the character of the project, its outcomes and process. Open access, co-design, crowdfunding, digital manufacturing, open-source, DIY, enabling systems and networking can be included in the toolbox of the designer and can create opportunities to drive the change towards sustainability, equity and democracy. Social innovation is leveraging forms of collaboration and co-production in which designers, innovators, users and communities co-create knowledge and solutions for a wide range of social needs, exploiting the networking technologies" [18].

The proposal of this research is to explore the feasibility of a design driven approach to a social challenge not with the consolidated assistive approach but with a participative policy, proactive, creative, holistic system integrated locally.

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Methods and Techniques Used in the Evaluation of Interfaces in Brazilian Studies Focusing on Visually Impaired People

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Abstract. The aim of this paper is to map the state of art of Brazilian researches focused on the accessibility of interfaces, identifying the methods and techniques used on the evaluation of digital interfaces based on the approach of the visually impaired user. An exploratory search was made, filtering studies between 2013 and 2018, at the Catalog of Theses and Dissertations of CAPES and at the Digital Library of Theses and Dissertations. The found documents were filtered and analyzed, aiming to list the procedures used on the evaluation process. Subsequently, the results were synthesized and compared with the literature. The study is justified by the lack of evaluative research with an inclusive approach. As a result, this paper indicates that usability tests, task analysis, verbal protocols and satisfaction questionnaires are relevant procedures for the interface evaluation from a user's centered approach.

Keywords: Methods and techniques for evaluation · Interfaces · Visual impairment

1 Introduction

Newspapers, books and magazines can be easily accessed with a few clicks. Digital inclusion in parallel with technology advance enables people to participate actively in society, performing professional, personal and entertainment tasks independently.

In contrast, due to a large amount of digital content currently produced, there is a loss of information quality and, consequently, a lack of accessibility. For digital inclusion is necessary that system developers consider the user's needs and limitations to choose the best decisions for interaction [1]. Accordingly, they will be able to reach a larger number of people and come close to a universal interface.

Visually impaired people, for example, use computers, smartphones as an important Assistive Technology (AT) for their communication. Screen readers, interface customization, enlarged and high contrast fonts are adaptive features that intermediate the Human-Computer Interaction (HCI). However, these features are not enough to provide accessibility to the user. Interfaces must comply with the Web Content

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Accessibility Guidelines – WCAG 2.0 and the standards provided by World Wide Web Consortium – W3C [2]. Although, comply with the established standards do not guarantee the accessibility [3]. In order to enable a better interaction, is necessary to develop a simple and intuitive interface, considering coding, graphical and textual information balancing usability, accessibility and user-experience [1, 4].

From this context, this paper aims to map the state of the art of Brazilian research focused on the accessibility of interfaces, detecting methods and techniques used on interfaces evaluation with a user-centered design approach. For this purpose, an exploratory search of studies was performed at the Catalog of Theses and Dissertations of CAPES and at the Digital Library of Theses and Dissertations, from January 1st, 2013 until December 1st, 2018. The found documents were filtered and analyzed, aiming to identify the procedures used for the evaluation of interfaces. Subsequently, they were compared with the literature in order to recognize the methods and techniques of evaluation. This study is justified by the lack of research in the area and the need to map methods and techniques with a user-centered approach that can be used on the interface's evaluation, based on the visually impaired user's opinion. Consequently, this paper intends to help researchers and interface developers to select evaluative procedures to include the end user on the development process.

2 Accessibility, Usability and User Experience (UX)

According to the Web Accessibility Initiative – WAI, everyone can contribute to web interaction. Therefore, making an interactive system accessible is more than enhance access to content. This promotes inclusion, offering to the population the same quality of information independent of age, limitations and disabilities [2].

Attached to accessibility is the concept of usability which is defined as [the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use] [5]. [6] establishes that usability is related to de level of easiness in which the user can perceive the interface, the time spent for this perception, and linking with five components showed on Table 1.

Table 1. Usability components.

Components	Definition
Learnability	Indicates how easy is to perform a task on the system
Efficiency	Measures the time it takes to perform a task after learning it
Memorability	Indicates the ability to remember how to perform a task on the system
Errors	Indicates the number of errors, how severe they are and how the user recovers from them
Satisfaction	Indicates how pleasant is to use the system

Nowadays, the information society is prioritizing the use of digital resources instead of analogical practices. Consequently, is important to take care of principles to facilitate and integrate the HCI, providing effectiveness, efficiency and satisfaction.

Balancing fundamentals of usability and accessibility into the design process tends to promote the universal access of digital information [4, 7, 8]. If developers do not consider these principles, the final product tends to be incomplete and not inclusive for people with disabilities [9]. These authors suggest that accessible and inclusive interfaces and systems have a considerable impact not only on the HCI, but also on the socioeconomic development of the population.

User Experience (UX) is another important practice that influences HCI [10]. The term encompasses all aspects of how end user perceives and makes decisions to interact with systems, interfaces, services and products. These decisions are influenced by *superficial elements* - how it looks, *structural elements* - how it behaves, and *functional elements* - what it allows to do. In this way, it is necessary to consider the user's perception in the design process (*strategy*), the functional attributes and presented content (*scope*), the information architecture and possible interactions (*structure*), elements that facilitates the interaction (*skeleton*), and finally, but not less important, the graphic and visual appearance (*surface*) [10].

Considering these needs, is indispensable to use User-Centered Design (UCD) approach to understand the user's behavior in front of the interface and propose inclusive solutions. UCD can be defined as [*a design approach based on user engagement in an active, participatory or non-participatory way, using iterative processes, methods, techniques and procedures to use the user experience in expanding design requirements to meet the needs of these users, the tasks and context of use*] [11].

Several studies [1, 4, 12, 13] point out that the use of user-centered design methods presents more assertive, accessible and inclusive solutions, mainly in qualitative approaches. Therefore, when developing structurally accessible interfaces, it is fundamental to consider the user's opinion, and follow the accessibility standards for the web content [2].

2.1 Methods and Techniques for Evaluating Interfaces

In scientific research, there are several methods and techniques that can be combined to structure the design process and guide specialists on the research, development and evaluate stages of the process, whether in a user-centered or non-centered design approach [13]. It is important to point out that methods can be understood in terms of their *research approach* (deductive, inductive, hypothetical-deductive, dialectical), or *procedure* (concrete steps of the research) [14]. From this definition, this paper will discuss method as a procedure, a set of systematic actions that uses mechanisms (techniques) that help the researcher construct the path to achieve the result and hence materialize the research.

When considering the user-centered approach (empirical method), it is possible to propose meaningful and useful solutions through observation of people's actions and their experience [15]. [16] state that there are several procedures that can be used to develop, update, redesign and evaluate an interface: from understanding the concepts of usability, information architecture, to prototyping and testing with users. The authors mention that, on iterative and interactive process, two kinds of evaluation can occur: *formative evaluation* (iterative or developmental), when is conducted before the system's implementation, to identify characteristics of development; and *summative*

evaluation, when is carried out after the system's implementation, to propose improvements. Significant data come from the environment in which phenomena occur and can be collected through field or laboratory research [17]. In terms of interfaces, the evaluation of this step requires user-system interaction to provide requirements for refinement and development. The evaluation process [16] is related to the ergonomic aspects and the level of usability of the interface, in other words, from the ability to adapt the interface to the user's profile and the interface's potential based on levels of effectiveness, efficiency and satisfaction.

From the methodological approach of the study, qualitative or quantitative, it is possible to select the most appropriate instruments for the user-centered evaluation. It is relevant to mention that there is no consensus on literature on the procedure's classification on methods or techniques, nor of its indication to a specific target audience. In this paper, the evaluation procedures will be classified as shown in [14, 17], in which evaluation can be organized in systematic processes (methods) using mechanisms (techniques) that help in these processes.

Based on methods, ergonomics and HCI's experts [15–20] Tables 2 and 3 present the methods and techniques for evaluating interfaces, its objectives in the computational context, the data obtained, as well as other procedures that may be associated. According to [21, 22] it is important to merge data collection techniques in order to evaluate the usability and accessibility focusing on the visually impaired, with an user-centered approach.

Table 2. Methods and techniques used on interface evaluation [15–20].

Methods	Objective	Data	Associations
Heuristic evaluation [17, 19, 20]	*Usability inspection with experts to identify interface, interaction and structure problems before the end user's evaluation (end user may have expert knowledge)*	Qualitative, quantitative	Interviews, questionnaires
Experiment [15, 20]	*Measure the effect that an action causes in an interaction with the manipulation of controlled variables*	Quantitative	Task analysis, questionnaires
Focus group [15–17, 20]	*Identify user's opinions, feelings and attitudes about the interface and interaction*	Qualitative	Observation, interview, questionnaire
Usability test [16, 17, 19, 20]	*Observe the quality of the user-system interaction experience (effectiveness, efficiency and satisfaction)*	Qualitative, quantitative	Observation, task analysis, verbal protocol, interview, questionnaire
Task analysis [18, 20]	*Analyze the HCI based on the pathway performed, decision-making and system's feedback*	Quantitative	Observation, questionnaire

Table 3. Techniques used on interface evaluation [15–20].

Techniques	Objective	Data	Associations
Interview [15, 17, 20]	*Collect user's opinions, perceptions and experience of interaction, face to face*	Qualitative	Observation, questionnaire
Observation (participatory or non-participatory) [15, 17, 20]	*Observe passively or actively (in a structured or non-structured way) in order to identify user behavior during interaction*	Qualitative	Interview
Questionnaire [15–17, 20]	*Collect user's opinion, perceptions and experience of interaction, without researcher's interference*	Qualitative, quantitative	Observation, usability test
Think aloud (verbal protocol, verbalization) [15, 20]	*Collect information from the user's verbalization of feeling seized and actions performed during the interaction*	Qualitative, quantitative	Observation, questionnaires

3 Method

With a theoretical-conceptual and exploratory approach, this paper aims to map the state of the art of master's and doctorate's Brazilian researches that utilize methods and techniques to evaluate the accessibility of interfaces under a visually impaired user's perspective. As a result, this study intends to list procedures to assist researchers and developers of interfaces and systems on the evaluation process with a user-center approach.

The search strategy that guides this study is derived from the literature review proposed by [23]. According to the authors, from a research question is possible to establish the key words that represents the scope, as well as relevant databases to conduct the research. In parallel, is necessary to establish the inclusion and exclusion criteria, in order to limit the results based on the scope of the research. Figure 1 shows the strategy of this study.

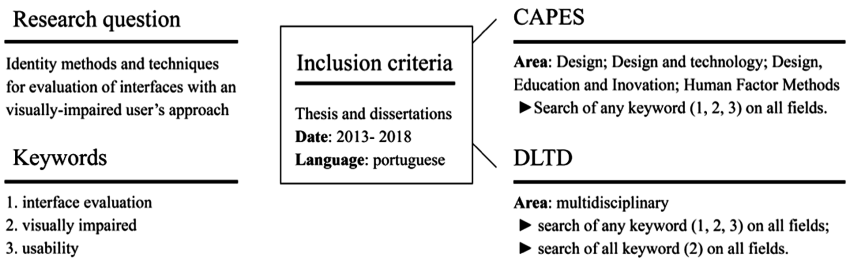


Fig. 1. Search strategy: research question, keywords, database, inclusion criteria.

Based on the research question, representative keywords (interface evaluation, visual impairment and usability) were defined to map the documents. In parallel, two databases: the Catalog of Theses and Dissertations of CAPES, because it is a search system that disseminates theses and dissertations produced by postgraduate programs in Brazil, recognized by the National Council of Education/Brazilian Federal Government [24], and the Digital Library of Theses and Dissertations), also an Federal Government agency which aims to provide visibility to national scientific production in partnership with institutions of education and research [25].

The inclusion criteria to select the studies, were defined from the search strategies of each database. The CAPES Thesis and Dissertation Catalog allows a comprehensive search of indexed documents. In this Catalog it is not possible to define the location of the keyword (e.g. title or abstract), however the website presents filters by areas of knowledge (Applied Social Sciences), date, among others. In this way, the search in the Design area was delimited, since it is an area related to HCI. The Digital Library of Theses and Dissertations allows an advanced search, in which it is possible to select whether all, any or none of the keywords should be tracked, including the search fields in which they can be inserted (e.g. abstract, title, all fields). In this library it is also possible to search by date, however, it is not allowed to select the documents by area of knowledge, this is automatically defined by the system from the results obtained. Consequently, the search was carried out in multidisciplinary areas. Due to the fact that the scope of this study is related to technology, and consequently, in constant evolution, we considered the studies published in Portuguese in the last 6 years, from January 1st, 2013 to December 1st, 2018.

4 Results

According to the presented search strategy, a total of 592 documents were found, among them 93 theses and 499 dissertations. An initial screening was carried out from reading the titles, abstracts and if they were related to the scope of this study were selected for a detailed analysis. Based on this screening, only one dissertation was repeated in both databases, resulting on 3 theses and 11 dissertations (Table 4). This result demonstrates the lack of studies with an evaluative approach from the perspective of the visually impaired, justifying the present study. Based on this selection, the documents were analyzed from reading the objectives, methods and results.

Table 4. Result of documents found and selected from the inclusion criteria.

Database	Theses (Total)	Dissertations (Total)	Theses (selection)	Dissertations (selection)
Catalog of Theses and Dissertations|CAPES	42	427	2	2
Digital Library of Theses and Dissertations|DLTD	51	72	2	9
TOTAL	93	499	**3***	**11**

**As mentioned, one document was duplicated.*

With a multidisciplinary approach, the selected researches correspond to human, social, applied and exact sciences. The studies present a qualitative approach and insert the user into several stages of the design process. It is reiterated that, as seen in the literature review, there is no consensus on the classification of procedures into methods or techniques. In general, searches address terms as synonyms. For the purposes of this article, Tables 5 and 6 organize the procedures (methods and techniques) based on [15–20].

Table 5. Synthesis of *Theses* and corresponding methods and techniques found.

Area/Researcher	Evaluation goal	Evaluation methods	Evaluation techniques
Education [26]	*Evaluate WebSonora application under aspects of ergonomics and usability with the visually impaired*	Usability test, heuristic evaluation, focus group, course analysis	Questionnaire, verbalization
Engineering and knowledge management [27]	*Propose a template for a Thematic Social Network, accessible for disabled people*	Usability test	System Usability Scale (SUS) questionnaire
Science education and mathematics [28]	*Evaluate the usability of a video game about geometry with visually impaired students*	Usability test	Questionnaire, participatory observation, interview
Design [29]	*Usability evaluation of the Brazilian Health Portal, from the perspective of blind people, through WCAG-EM 1.0.*	Usability test, task analysis	Questionnaire, observation

Table 6. Synthesis of *Dissertations* and corresponding methods and techniques found.

Area/Researcher	Evaluation goal	Evaluation methods	Evaluation techniques
Design [30]	*Measure the blind user's level of satisfaction when using an haptic equipment*	Experiment, usability test	Systematic observation, interview
Media and technology [31]	*Develop an evaluation process of screen readers focusing on the visually impaired*	Usability test	Questionnaire
Nursing [32]	*Develop and evaluate an instructional health online course for blind people*	Task analysis	Experience report

(*continued*)

Table 6. (*continued*)

Area/Researcher	Evaluation goal	Evaluation methods	Evaluation techniques
Computer science and mathematics [33]	*Investigate if gestural interactions improve accessibility of videos during the visually impaired user's interaction*	Task analysis	Questionnaire, interview
Social communication [34]	*Evaluate the accessibility of applications from the perspective of the visually impaired*	Usability test, task analysis	Task report
Public policy and management of graduation [35]	*Evaluate the interaction of visually impaired servers with a Federal Academic system*	Activity analysis	Questionnaire, interview, *in loco* observation
Design [36]	*Evaluate ergonomic solutions for designing inclusive interfaces for people with visual and/or auditory impairment*	Experiment, usability test	Questionnaire
Information science [37]	*Identify the behavior of blind people in interactions with interfaces through the screen reader*	Interaction test, task analysis	Experience report
Computer science [38]	*Evaluate the interaction of visually impaired people in a mobile application*	Usability test, heuristic evaluation, task analysis	Direct observation
Information systems [39]	*Evaluate the interaction of visually impaired people in a mobile application*	Experiment, functionality test	Questionnaire

5 Discussion

Considering the literature review and the analysis of the documents, it was possible to observe initially that there is a lack of studies focused on interface evaluation from the perspective of the visually impaired user. The literature defends the relevance of the subject and the results of this search integrate multidisciplinary areas and confirm its importance, even though is still scarce. Another aspect identified corresponds to the nomenclatures of the procedures. In the literature there is no consensus about its classification in methods or techniques. The theoretical approaches and methodological basis differ according to the areas of knowledge, and this can influence the understanding of methods and techniques, as well as their distinction.

Researches that focus on interfaces evaluation from the user's point of view can use several methods, techniques and their associations [13, 16]. There is no specific method or technique for interface evaluation directed to a profile of end user, for example,

visually impaired. However, it was possible to observe that the procedures pointed out in the literature are adjusted according to the methodological approach, context, objectives and target audience of the study, being thus dependent on these factors.

In general, the analyzed studies used the usability test, also known as interaction test, as an interface evaluation method. As mentioned [16], the potential of using an interface is an essential factor to make it efficient and provide a satisfactory interaction. Regardless of whether the research demands the analysis of qualitative or quantitative data, the method helps the identification of the quality of HCI [19].

As shown in literature [21, 22] depending on the approach, the association of methods and/or techniques is indicated to guarantee a better control of the data evaluation, as well as to reach a greater level of specificity. Among the studies analyzed, it was possible to identify the recurrence of the use of more than one evaluation procedure. In addition to the usability or interaction test, the task analysis [26, 28, 30, 34, 37, 38] was indicated as a complementary procedure that aims to verify the user's decision making, as well as the difficulties encountered in the interaction [18, 20].

[30, 36, 39] include both usability test and task analysis as complementary methods to experiments. It is worth emphasizing that this method has a quantitative approach, since it aims to control the manipulation of the variables and to allow the replicability of the research. However, the analyzed studies present a qualitative approach, which limits the use of the method. Therefore, adaptations of the procedure can be used, for example: field experiment, quasi-experiment, among others [15, 20] and the association with other methods.

[26] associates four methods for evaluating an application. The author calls one of the methods as a course analysis, which can be understood as task analysis, since there is a to-do list to be carried out and, in the sequence, the user narrates his actions. [35] indicates the same procedure as activity analysis and associates it with interview, questionnaire and *in loco* observation. The mentioned observation technique cites the intervention of the researcher, when necessary, at the moment task accomplishment. This procedure is like participant observation, according to [16, 17, 20].

Narrative evaluation techniques (e.g. experience report, task report, verbal or oral report) are cited [26, 28, 32, 34, 37] as a complement to the usability test and task analysis. These narrative techniques equate to verbal protocol, think aloud [15, 20] or verbalization [19]. These procedures aim to identify the sensations seized during or after the HCI.

Interviews, observation and questionnaire were also cited on the studies. [28, 33, 35] use interview as a complementary evaluation technique to task analysis or activity analysis. Observation was cited by [35, 38] and aims to identify user behavior during interaction [15, 17, 20]. [35] mentions *in loco* observation, or a real environmental observation [17] that aims to evaluate the task with the minimum of external interference. [38] points out direct observation, which seeks to understand the facts and their interpretation, by the users, in a participatory or not participatory way [17].

Questionnaires were used more frequently, as satisfaction questionnaires, which aim to measure and understand the user's reactions about the interface. It was often associated with usability test [26–29, 31, 36] and task analysis [26, 28, 29, 33, 35, 36].

[36] uses a Questionnaire for User Interaction Satisfaction model (QUIS) [40] associated with a questionnaire based on the predictive model GOMS - Operators,

Methods and Selection rules. The last indicates the time of the actions performed to complete a requested task [19]. [27] complements the usability test with a questionnaire based on the System Usability Scale (SUS), composed of 10 questions with five response options (Likert scale), developed in 1986 by John Brooke [41].

Finally, [39] presents the term functionality test referring to the evaluation of the functional requirements of its product. According to [10] functional specifications are initial abstract concepts related to users' needs, which are analyzed separately from the interaction, interface and visual aspects. In this way, it is possible to infer that the functionality test is an evaluation method of the scope of the interface, either in relation to the desired functions or its contents.

6 Considerations

There are many researches in the area of interface evaluation, however a lack of studies that measure its accessibility from the visually impaired user. It is possible to infer, from the literature review, that there is no specific method or technique directed at this target audience. From the exploratory search of this paper, it was possible to identify that the Brazilian researches present a qualitative approach, able to evaluate the interfaces through the association of procedures, regardless of their classification in methods or techniques.

Among the studies found, user-centered evaluation is a requirement for the validation of a digital interface. Regardless of the area in which the study is allocated, the researchers consider the end-user's opinion to guide usability and accessibility improvements for interaction. It was possible to observe that usability tests and task analysis are recurrent methods used on interfaces evaluation by visually impaired. Associated with these, verbalization techniques and satisfaction questionnaires are frequently used. However, it is important to verify the possibilities of using methods and techniques and their associations according to the scope of the study, available resources and research expectations [19]. From this inspection, it was possible to map the procedures that best meet the assessment objectives, providing relevant data to adapt, restructure or redesign an interface with a user-centered approach.

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Usability Analysis of the Payment Method with an Application of Digital Parking Meters with Younger and Older Users

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Abstract. This research aimed to identify usability issues in the interaction with a payment application for a digital parking meter system located in Guadalajara, Mexico. A usability test was carried out by twenty participants divided into two groups—ten younger and ten older adults—. The main task evaluated was making a payment using the application. Participants were asked to do the task on two consecutive occasions. Once the interaction with the application finished the usability questionnaires A and B were administered. The results show that younger and older participants found problems and made mistakes when using the system. Younger and older participants suggested the need for modifications to the application. The paper discusses how understanding the experience and needs of both groups of users can help to develop a more accessible and usable app.

Keywords: Usability · Parking meters · Smartphone · Inclusive design · Ageing population

1 Introduction

The continuous technological development, mainly known as Information and Communication Technologies (ICT), has stimulated the emergence of a new economy with an impact on the way people use public services, manage businesses and communicate every day. Smartphones play an essential role among the general population because it is one of the first accesses to the ICT, which has been developed mainly through the use of applications [1] that aims to facilitate the execution of the daily activities.

The National Institute of Statistics and Geography (INEGI, for its designation in Spanish) reports that 63.9% of Mexicans aged 6 or over are Internet users. The same report mentions that of people over 55 years old are Internet users, 36% are women and 31.1% are men. Although these represent a smaller group of users compared to younger

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ones, this number is continuously increasing [2]. It also matches with data provided by the National Statistics Institute (INE) in Spain, which states that the use of technologies by older adults has increased by 85% [1]. As well, it is necessary to consider that the older segment of the population is continually increasing. It is expected that by 2050 this group will represent 22.3% of the total world population; while in Mexico it is calculated to be 21.5% [3].

Similarly, INEGI reported an increase in the number of users of smartphones in Mexico, from 60.6 million people to 64.7 million from 2016 to 2017. Particularly, during the same dates, the number of users with access to the Internet through a smartphone increased from 89% to 92%. A higher percentage (69.7%) of these people downloaded some application [2].

However, although the applications are aimed at improving everyday activities, they have not yet managed to capture all sectors of the population, as is the case for older adults. This group of people often experiences some disadvantage about concerning the use of electronic devices because their capabilities are often reduced (i.e. reduced visual and auditory acuity, motor difficulties and cognitive deficits), factors that are not taken into account during the design of the interface of some applications [4–6]. Also, it is necessary to keep in mind that the pace of learning, the adaptability, and consumer habits constitute the main barriers to the older population regarding using the ICT [1].

Another critical aspect to consider about the adoption of new technologies by older adults is the lack of familiarization, considering that they have not been raised with these technologies around and thus they might ignore how these systems operate [1]. This situation could promote the presence of anxiety and the refusal to use these digital platforms [4, 7]. However, a study conducted by González-Oñate and Fanjul-Peyró in 2018 shows that 48% of its 256 participants over 65 years stated they would use ICTs if someone taught them compared to 15% who were not interested [1].

Therefore, it is necessary to develop applications that respond to the requirements and needs of older adults. Specific parameters must be considered in the design process of smartphone applications, i.e. bigger typographies, the elimination of double-clicks to show more functions, easy access to the menus and the reduction working memory loads by limiting the number of options available to users [5].

1.1 Parking Meters in Guadalajara

In 2017, a new virtual parking meter program, called “Parkimovil”, was implemented in the Metropolitan Zone of Guadalajara (ZMG) Mexico. The intention was to replace the old parking meters that operated with coins with a self-service payment system in which users can opt for three different options: (1) paying with cash in at designated store; (2) sending a text message; and, (3) paying through an application [8]. According to the local government, the use of the app is considered the most important feature in the modernization of the service.

Previous analysis of the digital parking meter system detected that only two out of nine older adults decided to interact with the App of this parking meter system and only one of them was able to complete the payment successfully [9]. It is also important to

emphasize that nine of ten younger participants in that study qualified their use of the service as a miserable experience, which could suggest specific difficulty on the interaction with the app.

2 Method

The participants in this research were twenty people divided into two groups; group A included ten older people aged 60–72.9 with an average of 67.3 years (SD ± 5.8319); group B consisted of ten younger people between the ages of 20 and 29 with an average of 22.9 years (SD ± 3.3482). Three aspects were taken into account in the inclusion criteria: the participants had to have their smartphone, they had to have previously interacted with an application before, and they should not use the Parkimovil application yet.

The method used in this research was a usability test of the virtual parking meter, in which four tools were applied. (1) A questionnaire to collect sociodemographic data in which were included questions about the type of cellphone and if it had credit at that time, as well as a Facebook account or e-mail because it is necessary information to carry out the registration in the application. (2) A usability questionnaire "A" where the participants were asked about previous experience with similar applications, preference concerning the use of previous parking meters and whether they wished to use the app again. (3) Usability questionnaire "B" which included open-ended questions about its ease of use in comparison with the first attempt. They were also asked about modifications they considered convenient for the interface as well as a Likert scale to rate the application in general, how the information is distributed, ease of use for data entry and ease of use for payment. The scale consisted of five points which were rated from 1 = very good to 5 = very bad. (4) The After Scenario Questionnaire "ASQ" [10] to know the satisfaction of the participants when interacting with the application in which it was considered a seven-point scale where 1 = strongly agree and 7 = strongly disagree.

2.1 Parking Meters in Guadalajara

The following instruments and materials were used to undertake the usability analysis:

- A Reflex camera, to record on video the interaction of users with the app.
- A tripod.
- A smartphone with a stopwatch.
- The ASQ Questionnaire.
- Usability questionnaires A and B of the digital parking meter application.
- An exact reproduction of the Poster whit the same information and measurements as the posters placed on the streets, printed on a rigid material, shown in Fig. 1.



Fig. 1. Picture of the instructions for the digital parking.

2.2 Procedure

The payment process was divided into three main tasks: (1) Downloading the application to the smartphone following the payment instructions. (2) Introducing the data required by the application and finally (3) Making the payment for 30 min of parking.

Each main task was divided into sub-tasks that included the steps required by the system in order to complete the parking meter payment.

The participants were visited at home for the test where it was verified that they had an Internet connection. The activity they were asked to do was to pay through the application 30 min of parking only with the help of the printed information poster that was presented to them; however, the researchers provided help in case the participant needed it. The general procedure followed is shown in Fig. 2.

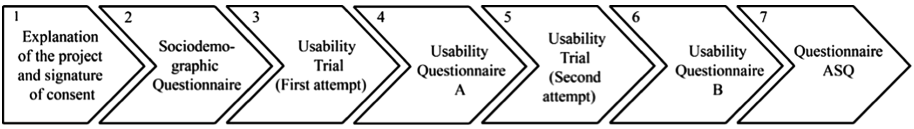


Fig. 2. Usability test procedure

The payment process during the first attempt was divided into three main tasks: (1) Download the application to the smartphone following the instructions on the poster. (2) Enter the required data for the account, vehicle, and credit card registration. (3) Make the payment of the 30 min of parking (Selection of the city, area, vehicle, time and mode of payment). It is important to mention that previously a Hierarchical Analysis of tasks (HTA) was carried out to be able to divide the three steps into sub-tasks and later to be able to make a table of errors in order to have a better follow up when registering them.

On the other hand, the payment process for the second attempt had only one main task; to make the payment for the 30 min, since the previous steps that were made during the first attempt are saved in the cell phone of the users. In both attempts, the time was taken, and the number of errors was recorded.

3 Results

Concerning the characteristics of the smartphones, seven of the younger participants and seven of the older adults confirmed that they have credit on their cell phones, which is necessary to be able to use the application on the street. Also Besides, the operating system used by the majority of the participants was Android, while only two participants from each group had a phone with an iOS operating system.

Regarding the mistakes during the first interaction with the "Parkimovil" application, the most frequent mistake in both groups corresponded to the filling of data of the vehicle where the older adults obtained 13 errors and the younger participants nine.

In addition to this in payment confirmation sub-task, the older adults had made ten mistakes and the younger participants made nine mistakes. In Table 1 the mistakes made during the interaction can be seen with more precision.

Table 1. Mistakes made by the participants during the interaction with the parkimovil app

Task	E* Older group		E* Younger group		Error description
	1A	2A	1A	2A	
1. *Downloading the application to the smartphone*					
Search app in the virtual store	5	0	0	0	Search for the application in a different site than the virtual store
• Select the "Parkimovil" app icon	0	0	0	0	Select a different icon to the one of the Parkimovil app
• Download the app on the cell phone	4	0	0	0	Download another application than Parkimovil
• Open the App	1	0	0	0	Do not find the icon in the cell phone menu
• Register via Facebook	0	0	1	0	Do not allow the access of the app to their Facebook account
2. *Introducing the data required by the application*					
• Select the option to create an account	1	0	0	0	Select login instead create an account
• Register via e-mail	6	0	2	1	Do not register the data required correctly

(*continued*)

Table 1. (*continued*)

Task	E* Older group		E* Younger group		Error description
	1A	2A	1A	2A	
• Link account with the cell phone number	5	0	0	0	Do not enter the cell phone number correctly
• Request the access code to the app via:	0	0	0	0	Do not request a code
– Whatsapp	5	0	0	0	Do not register correctly the code sent via Whatsapp
– SMS	1	0	0	0	Do not register correctly the code sent via SMS
• Scan QR code	2	2	0	0	Do not scan QR
• Enter the option of vehicle registration	13	0	9	0	Do not enter the vehicle data menu.
• Save the data of the registered vehicle	1	0	0	0	Do not select the option to save vehicle registration
• Log in to the account (this step is the start of the second attempt)	0	0	0	0	Register again in the app
– Enter email address	0	1	0	1	Do not register the email correctly
– Enter the password	0	0	0	0	Do not register the password correctly
3. *Making the payment for 30 min of parking*					
• Select the city	4	1	0	0	Do not select the city/Select another city
• Select zone	2	0	4	1	Do not select zone
• Select vehicle	0	0	1	1	Do not select a saved vehicle
• Select parking meter time to pay (30 min)	2	0	1	0	Do not select parking meter time to pay
• Select the payment method					
• "Parkimovil" credit	0	0	0	0	Do not select the option of "Parkimovil" credit
• Select the payment icon	10	1	9	0	Select to pay without entering all required data
• Wait for payment confirmation	1	0	0	0	Quit the app without confirmation of payment
Total number of mistakes	**63**	**5**	**29**	**4**	

Note: *E number de mistakes made by the participants *1A = fist attempt, 2A = second attempt

A comparison was made between the results obtained among the younger people and the older adults regarding concerning to the number of errors presented during the interaction with the application and the total time recorded in the two attempts that were made; this results can be observed in Figs. 3 and 4.

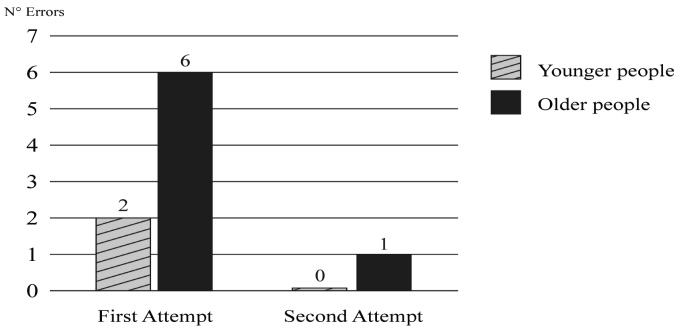


Fig. 3. Comparison of the number of errors recorded in both groups

In Fig. 4 it is shown that the average number of mistakes made by the group of older adults was higher than the mistakes made by the group of younger people in the first attempt, whereas in the second attempt the differences in mistakes made between the two groups decreased.

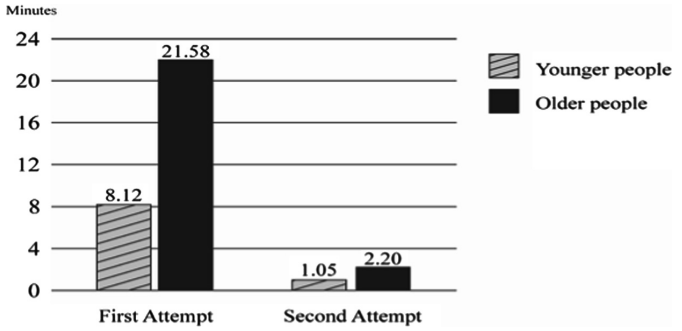


Fig. 4. Comparison of the time required for payment of the parking meter recorded in both groups.

In the same way, in Fig. 4 a similar behavior can be observed to the results obtained in Fig. 3 since the registered difference of total times between both groups decreases in the second attempt, 19.38 min in the group of older adults and 1.44 min in the younger group. It is important to consider that this decrease in time can be explained by the fact that in the development of the second interaction with the application the participants do not have to download the app and register, because these data were already registered.

It should be noted that the lower time recorded by an older adult (19 s) was lower than any other time registered in, the younger group, in which the minimum time was 27 s.

During the interaction with the application, the participants could ask for help from the researchers. Considering this, it was observed that nine of the ten older adults requested assistance in the first payment attempt, while in the second attempt just five of them asked for help from the researchers. In contrast, the younger participants asked for help at a lower proportion than the older adults, as six of the ten younger users requested the intervention of the researchers only at the first attempt.

Referring to the moment in which the participants request the help, it was observed all the users of the group of older adults asked for assistance before they had made a mistake; on the other hand, four of the younger users requested help once they failed in the interaction with the app.

In relation with the section of the payment process in which the participants requested assistance, eight members from the group of older adults asked for help from the researchers in the sub-task related to the entry of the confirmation code. Also, six older adults asked for assistance in scanning the QR code and searching for the application in the virtual store.

In comparison, the younger participants asked for help in fewer amounts than the older adults; this group of users requested assistance mainly in the sub-task related to the QR code scanning with two of the ten participants.

Regarding the overall assessment of the parking meter payment application, it can be found that the majority of the participants rated the application positively. The results are shown in Table 2.

Table 2. Assessment of the system characteristics.

Scale	Evaluated characteristics of the application							
	Qualification of the parking meter application		The way that the information is spread in the app.		Ease of use for logging data		Ease of use to pay the parking meter with the application	
	Older	Younger	Older	Younger	Older	Younger	Older	Younger
Very good	2	1	2	2	3	3	2	2
Good	4	8	6	5	4	4	6	6
Average	4	1	0	3	1	2	1	2
Bad	0	0	2	0	2	1	1	0
Very bad	0	0	0	0	0	0	0	0

Note: older group n = 10, younger group n = 10

Concerning the previous experience with the use of other payment applications, none of the older adults expressed that they had used this kind of application before, they only mentioned having interacted with social networks. Meanwhile, five participants from the younger group indicated that they had used similar applications, mostly for bank operations.

Regarding the results obtained in the usability questionnaire, in the question on whether the new payment method is better than traditional parking meters, half of the participants in the group of older adults considered the application to be more effective, as did seven of the younger ones. Also besides, in both the first and second attempts, younger and older adults expressed a desire to use the parking meter payment application again. Finally, the main suggestion for modification concerned for to menus to facilitate data entry.

In Table 3 shows the results obtained from the ASQ questionnaire by each user based on the average of the three questions that constitute the questionnaire, in which the group of older adults obtained a total average of 3.1, while the group of younger people had an average of 1.9. Thus it can be established that the perception of user satisfaction is high.

Table 3. Results from both groups of the ASQ questionnaire.

Statement	Average	
	Younger group	Older group
1.Overall, I am satisfied with the ease of completing this task	1,9	3,2
2.Overall, I am satisfied with the amount of time it took to complete this task	1,9	3,2
3.Overall, I am satisfied with the support information (on-line, messages, documentation) when completing this task	1,9	3
Total average	**1,9**	**3,1**

Note: older group n = 10, younger group n = 10

4 Discussion

At the end of the interaction process, 60% of the participants from both groups considered that using the app to complete the parking meter payment was proper. This may be related to the perception of ease of use mentioned in The Senior Technology Acceptance and Adoption Model (STAM), which attributes this to the level of effort required to interact with these technologies [11].

In contrast to the results, difficulties were observed among the participants according to the sequence of actions necessary to complete the task correctly. Mainly referring to the vehicle data entry; which highlights the need to design applications with more straightforward menus, in order to reduce the difficulty of their use and avoid the rejection of these applications by older adults [4].

At the same time, we can identify that both, in the number of errors and in the time in which to complete the first task, the group of older adults considerably improved their performance during the second attempt. This finding seems to reduce the gap with respect to the results of the group of younger people; a factor that agrees with González-Oñate and Fanjul-Peyró who affirm that currently there is no element that limits the use of technologies according to age, but instead that it is necessary to adapt the teaching of these technologies [1].

Therefore, ease of learning should be considered as a factor that influences the acceptance and acquisition of smartphone devices because since older adults have greater difficulty in terms of processing and selecting information, which has an impact on the learning process of new technologies [4].

It is important to highlight that the majority of older adults expressed their discomfort when they did not understand what they should have to do next within the application and they justified themselves by affirming that they did not have enough familiarity with this type of technology; which is consistent with the arguments presented by González-Oñate and Fanjul-Peyró, they mentioned that an important factor for which these new technologies have presented difficulties to be accepted in the elderly population is the lack of familiarity, since they have not grown with them and are unaware of their functioning [1].

Additionally, some many participants expressed their dissatisfaction with the information contained in the poster because when they attempted to follow the payment instructions, they pointed out that it did not explain the whole process.

A further factor to highlight is that none of the participants registered their credit card in order to make the payment, although the app asked for it as a mandatory registration since most people expressed distrust of apps based on previous negative experiences with other similar applications.

During the interaction process with the app, there was an inconsistency observed in the design layout of the two different operating systems that were used. Such differences were detected in the data input task alike as time selection, time zone, state, city and in the task concerning the payment finalization; in the android systems all the options previously selected by the participants were deselected when redirected to a new menu (i.e. vehicle data input), while in the iOS systems these options remained saved.

A second problem presented by the application was that some participants did not receive the message with the activation code necessary to complete the registration, which caused a delay in the process. Also in the cell phone of one of the participants, the application presented an error, so it had to be reinstalled.

A limitation of this research was that the usability test was carried out in a controlled environment in order to guarantee internet access to the participants. Therefore an interaction of use could not be observed in the place where the parking meters are located; added to this is the poster used, where the area to which it belongs is not appreciated and the signpost with the information that accompanies this poster in the public street was not included.

5 Conclusion

In contrast to the good ratings obtained by both groups, it was evident that the times obtained especially with older adults, who had reached 33 min, were quite elevated especially if we consider that they were continually guided in order to carry out the activity; This indicates the need for a redesign of the menu interface of the application in order to facilitate and simplify the registration process, a step in which a higher number of errors occurred.

However, it is important to consider the process of familiarization of the users with new technologies; as the participants experienced the payment process with this new

application. In the second interaction a better execution of the task was registered, with a the reduction of errors, a diminution of the request for help and in the decrease of the time invested in making the payment; This is consistent with that proposed by Fanjul-Peyró [1] in which it is established that older adults will be receptive to these new technologies as long as they would be instructed in the use of them.

Finally, it is important to emphasize that users find in the application many advantages and conveniences once it is installed in their smartphones. However, there are still many improvements that will help new users to register more efficiently and less confusingly so that they can understand how the application works more efficiently.

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The Influence of Screen Brightness and Moving Speed of Visual Icons on Visual Acuity

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Abstract. In this experiment, static visual acuity and dynamic visual acuity were tested with standard visual acuity charts and vision testing software for three groups of people in different age groups under different lighting conditions. The results showed that the dynamic visual acuity and static visual acuity had a certain correlation with each other and the dynamic vision was always lower than static vision. Static vision and dynamic vision were gradually decreased with increasing of the age. As the brightness of the screen increased, the individual's vision acuity increased. The moving speed of visual icons had great effect on the visual acuity.

Keywords: Screen brightness · Visual icons · Visual acuity

1 Introduction

Vision is the most important sensory channel for human beings, and it is also the most important means for human beings to obtain external information. Vision plays an important role in distinguishing physical properties such as light and shade, color and shape of external objects, as well as distinguishing spatial attributes such as the size and distance of objects. In the event of visual movement in the outside world, for example, the vehicle runs at a certain speed on the road, and the driver is also in constant motion relative to the external environment. At this point, the dynamic visual characteristics of the personnel are very different from those at rest. Dynamic vision refers to the visual acuity measured when a person and a fixation object are in relative motion.

In daily life, the movement of the human head is very frequent and complex, which will cause the continuous movement of the image on the retina. Studies have shown that even when standing still, the main frequency of the head movement can even reach 5 Hz, the maximum frequency can reach 10 Hz; the maximum speed of the head during running can reach 90°/s, and the main frequency in the horizontal direction is about 2.7 Hz. The vertical direction is 8.2 Hz. However, if the image motion on the retina exceeds 2°–3°/s, it will cause blurred vision. The fixation of the target by the human eyes in different body movements involves complex physiological reflexes, including visual tracking mechanisms, vestibular eye reflexes, smooth tracking, saccades, and neck-eye reflexes [1]. Therefore, dynamic vision is a comprehensive

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manifestation of static vision and physiological reflection of the human body in different motion states.

Under normal circumstances, dynamic vision will be lower than static vision by 10%–20%, and by 30%–40% in some special cases. This is because when the human eye is in motion, the fixation point may move from side to side, the imaging of the target on the retina is also unstable, and the human eye has very short observation time on the object. Sometimes it is too late to discern it and the object leaves the field of vision. Therefore, people's visual acuity is always lower than static vision. Dynamic vision decreases rapidly as the speed increases. When the speed increases, with the reduction of dynamic vision, it will affect people's perception and observation of the external environment.

The purpose of this experiment is to investigate the visual threshold in different visual velocities for different age groups under different light conditions. The test results are expected to provide an important reference for industrial design.

2 Experimental Variable

2.1 Test Subjects Selection

In this experiment, participants with a total of 191 participants aged from 18 to 75 years old were divided into three age groups Table 1 shows the basic information of participants in each age group. The research goal of this experiment is to provide basic data to support the industrial design which is different from the visual inspection in medicine to evaluate the health of human eyes. Therefore, this experiment is to test the subject's corrected vision.

Table 1. Three age groups

Age group	Number	Age range	Average age	Standard deviation
Youth group 18–35	67	19–35	25.5	5.3
Middle-aged group 45–55	65	45–55	49.4	4.8
Elderly group 60–75	59	58–72	63.2	3.8
Total	191	–	–	–

2.2 Test Screen Brightness

Screen Brightness are divided into 3 levels, which are respectively 10 cd/m^2, 100 cd/m^2 and 300 cd/m^2, representing low brightness, medium brightness and high brightness.

2.3 Visual Target Speed

Visual tests were performed on the visual target under static, low-speed, medium-speed, and high-speed motion conditions respectively. Due to the different line-of-sight used in related research, the linear velocity corresponding to angular velocity also

varies. In dynamic visual acuity tests, angular velocity is generally used to represent the unit of velocity. In many studies [2, 3] dynamic visual acuity checks generally have a range of speeds of 0°–150°/s, basically covering the range of motion speed of common objects in daily life. The maximum inspection speed can be determined according to the test conditions, such as checking the viewing distance, and the maximum time that the visual icons can display at the maximum speed on the display screen is not less than 100 ms.

3 Experimental Equipment and Environment

The standard logarithmic vision chart, vision testing software, 50 inch of TCL displayer with a resolution of 1920 * 1080, Z-10 smart illuminometer were used in this experiment. Vision testing software is now available on TCL 50-inch monitors.

The experiment was conducted in a 3 m * 5 m visual ergonomic laboratory with adjustable lightings. According to the national standard, "common indoor and outdoor illumination standards" in the provisions of 100–200 lx between the common office environment light level, the test environment lighting is set to 200 lx, and the test lighting environment was adjusted using a brightness adjustment software system to achieve the required illumination level.

4 Experiment Process

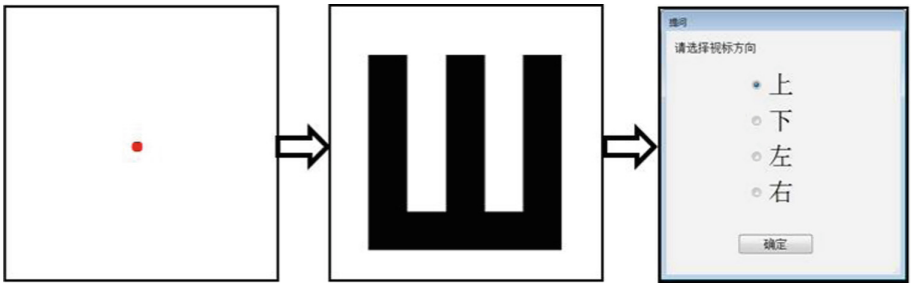
4.1 Preparation

In the preparatory step, the subject first introduced the subject's purpose, the experimental process and related requirements to the subject, and demonstrated the use of the test instrument in the experiment. And the subjects performed training operations and solved the problems existing in the operation of the subjects. After the subjects were completely familiar with the whole experiment, formal testing began.

4.2 Test

(1) First, to use a standard vision chart to test the visual acuity under 300 lx light conditions, and record the left and right eye vision, binocular vision. The test method refers to the standard eye chart usage specification.
(2) Visual acuity testing software was used to test the static visual acuity of the subjects under 3 different screen brightness (10 cd/m^2, 100 cd/m^2, 300 cd/m^2).
(3) Visual test software was used to test the dynamic vision of the subjects under three different screen brightness (10 cd/m^2, 100 cd/m^2, 300 cd/m^2). Dynamic eye movement speeds were: low speed (10°/s), medium speed (50°/s), and high speed (100°/s), for a total of 9 tests equaled by 3 multiplying 3.
(4) Vision testing software testing process interface, as shown in Fig. 1. First, the subjects stared at the red gaze point in the center of the screen to ensure that the initial eye gaze position was uniform, and clicked on the gaze point screen to

randomly present the visual target. In the static vision test, after the subject has finished identifying the visual target (generally not more than 2 s), press the "pace bar", the screen presents the visual target opening direction selection interface, the system records the test results and test results are correct; In the dynamic vision test, when the subject is waiting for the target to be displayed on the screen, the target opening direction selection interface is automatically presented, and the system records whether the test result and the test result are correct.



(a) Staring at the interface (b) Mission interface (c) Judgment interface

Fig. 1. Visual test software vision test process

4.3 Record of Data Results

The visual acuity of the subjects under different screen brightness under different speeds was recorded.

5 Statistical Analysis of Data

5.1 Compare and Analyze Whether There Are Differences Between the Test Results of the Standard Eye Chart and the Vision Test Software

The visual acuity results of the visual acuity of the different age groups by the standard visual acuity chart and monitor are shown in Table 2.

Table 2. Test results of corrected visual acuity under two methods in different age groups

Age group	Visual chart (300 lx)		Vision test software (300 lx)	
	Mean value	Median	Mean value	Median
Youth	1.2	1.2	1.3	1.2
Middle-aged	1.3	1.2	1.3	1.2
Elderly	1.0	1.0	1.0	1.2

The corrected visual acuity and illumination of the subjects were visual acuity values of 300 lx. There was no significant difference in visual acuity between the two genders and three age groups ($p < 0.05$), indicating that the visual acuity of the monitor was consistent with that of the standard visual acuity chart.

5.2 Correlation Analysis of Static Vision and Dynamic Vision

The visual acuity at 0°/s, 300 cd/m^2 as static visual acuity was compared with dynamic visual acuity at three different speeds: low speed (10°/s), medium speed (50°/s) and high speed (100°/s) (Table 3) .

Table 3. Correlation coefficients of static vision and dynamic vision

Age group	10°/s, 300 cd/m^2	50°/s, 300 cd/m^2	100°/s, 300 cd/m^2
Youth	.689**	.777**	.676**
Middle-aged	.658**	.714**	.607**
Elderly	.535**	.600**	.560**

5.3 Analysis of Dynamic Vision Influencing Factors

(1) Visual acuity values of different age groups, different screen brightness and different moving speeds
Figures 2, 3 and 4 show the visual acuity values of different age groups of young people, middle-aged and elderly people under different screen brightness and different moving speeds.

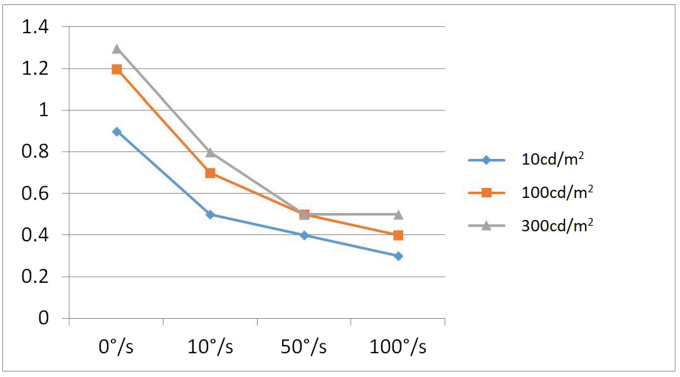


Fig. 2. Visual acuity of young people under different screen brightness and visual speed

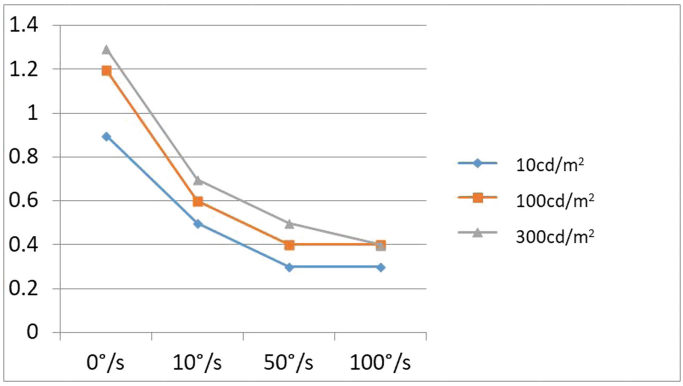


Fig. 3. The visual acuity of middle-aged people under different screen brightness and different moving speed

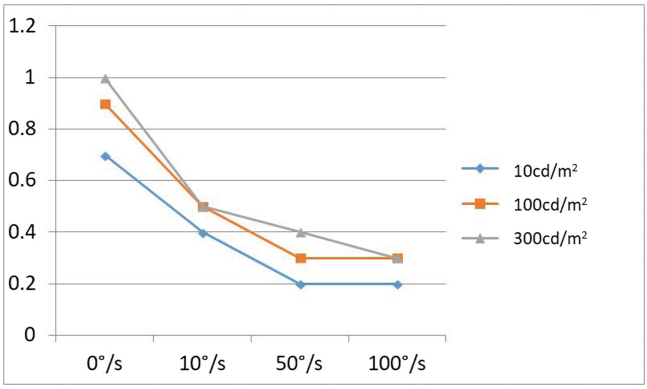


Fig. 4. The visual acuity of the elderly under different screen brightness and different moving speed

(2) Effect of visual speed on dynamic vision

From Figs. 2, 3 and 4, it can be seen that the young people's vision gradually weakens with the increase of the speed of the target. Visual acuity decreased by about 44% when the moving speed of the visual target was 10°/s, and visual acuity decreased by approximately 56% when the moving speed of the visual target was 50°/s. When the moving speed of the visual target was 100°/s, the visual acuity decreased by about 67%. The sight of middle-aged people gradually weakens with the increase in the speed of the visual target. Visual acuity decreased by about 44% when the moving speed of the target was 10°/s, and decreased by about 67% when the moving speed of the target was 50°/s and 100°/s. The visual acuity of the elderly gradually weakens with the increase in the speed of the visual target. Visual acuity decreased by about 43% at a visual movement speed of 10°/s, and decreased by about 71% at a visual movement speed of 50°/s and 100°/s.

From the statistical difference data, with the increase of the speed of the visual target, the individual's visual acuity showed a downward trend. For youth, the vision of visual speed under conditions of low speed ($M = 0.67$, $t(66) = 15.96$, $p < 0.0001$), medium speed ($M = 0.46$, $t(66) = 21.36$, $p < 0.0001$) and high speed ($M = 0.41$, $t(66) = 15.96$, $p < 0.0001$) was lower than that under static status ($M = 1.12$); vision under medium-speed ($t(66) = 12.50$, $p < 0.0001$) and high speed ($t(66) = 15.68$, $p < 0.0001$) was lower than that under low-speed status; and vision under high-speed condition was lower than that under medium-speed status ($t(66) = 4.08$, $p < 0.0001$. For the middle-aged, the vision of visual speed under low-speed ($M = 0.59$, $t(64) = 14.99$, $p < 0.0001$), medium-speed ($M = 0.41$, $t(64) = 19.44$, $p < 0.0001$) and high speed ($M = 0.37$, $t(64) = 18.86$, $p < 0.0001$) conditions was lower than that under static status ($M = 1.06$); vision under medium-speed ($t(64) = 10.39$, $p < 0.0001$) and high speed ($t(64) = 10.85$, $p < 0.0001$) was lower than that under low-speed status; and vision under high-speed condition was lower than that under medium-speed status ($t(64) = 3.92$, $p < 0.0001$). For the elderly, it went the same. The vision of visual speed under low-speed ($M = 0.46$, $t(58) = 15.00$, $p < 0.0001$), medium-speed ($M = 0.31$, $t(58) = 20.21$, $p < 0.0001$) and high speed ($M = 0.28$, $t(58) = 21.00$, $p < 0.0001$) conditions was lower than that under static status ($M = 0.89$; vision under medium-speed ($t(58) = 10.43$, $p < 0.0001$) and high speed ($t(58) = 10.84$, $p < 0.0001$) was lower than that under low-speed status; and vision under high-speed condition was lower than that under medium-speed status ($t(58) = 3.93$, $p < 0.0001$).

When the angular velocity of the relative motion between people and the fixation object increases, the minimum visual angle of the eye also increases, and the visual acuity decreases, resulting in a decrease in the perceptive ability of dynamic vision. In addition, as the operating speed of the visual target increases, the visual field of persons gradually becomes narrower, and the fixation point moves forward, and the ability to distinguish objects near and on both sides is greatly reduced, resulting in a reduction of human recognizable space. In other words, as the speed increases, the human visual acuity is reduced, the spatial recognition range is reduced, and the dynamic visual characteristics become worse. Therefore, during the process of people's progress, it is necessary to avoid the accidents caused by the difficulty of recognizing the obstacles in front and the lack of reaction time due to the drop of the dynamic vision function during high-speed movement.

(3) The influence of age on dynamic vision

Dynamic vision has a lot to do with people's age. The study found that the older the age, the worse the visual acuity. The analysis of variance with age group (variation between groups), visual speed (intragroup variable) and screen brightness (intragroup variable) as independent variables and visual acuity as dependent variable showed that visual acuity of individuals of different groups was significantly different. It showed better visual acuity in youth group ($M = 0.67$, $t(58) = 4.94$, $p < 0.001$) and middle-aged group ($M = 0.63$, $t(58) = 3.21$, $p < 0.01$) than in elderly group ($M = 0.49$), and youth and middle-aged group vision did not differ significantly ($t(64) = 1.02$, $p = 0.31$).

Table 4. Variance analysis results for variables of age group, visual target speed, and screen brightness

Effect item	F Value	df1	df2	P Value
Age group	13.39	2	188	<0.0001
Visual target speed	919.23	3	564	<0.0001
Screen brightness	391.46	2	376	<0.0001
Age group × Visual target speed	3.89	5	564	<0.0001
Age group × Screen brightness	2.24	4	376	0.06
Visual target speed × Screen brightness	45.25	6	1128	<0.0001
Age group × Visual target speed × Screen brightness	0.94	12	1128	0.50

Human dynamic vision is performed by the eyes and the entire visual system, and the influence of age on the visual system is very obvious. As people grow older, their visual function gradually deteriorates, and their dynamic visual characteristics decline rapidly. Moreover, as the age goes up, the chance of suffering from eye diseases will also increase. If you suffer from eye diseases, you may experience amblyopic or loss of vision, affecting the effective movement of the eyes and causing a decrease in visual function (Table 4).

(4) Effect of background target brightness on dynamic vision

From Fig. 5, we can see that as the brightness of the screen increases, the individual's vision increases: For youth group, the visual acuity under medium brightness ($M = 0.70$, $t(66) = 12.49$, $p < 0.0001$) and high brightness ($M = 0.77$, $t(66) = 16.07$, $p < 0.0001$) is higher than low brightness ($M = 0.55$), and visual acuity under high brightness is higher than medium brightness ($t(66) = 5.22$, $p < 0.0001$); For middle-aged group, the visual acuity under medium brightness ($M = 0.66$, $t(64) = 11.44$, $p < 0.0001$) and high Brightness ($M = 0.72$, $t(64) = 13.25$, $p < 0.0001$) is higher than low brightness ($M = 0.49$), and the visual acuity under high brightness is higher than visual acuity under medium brightness ($t(64) = 4.30$, $p < 0.0001$); the elderly group has the same result.

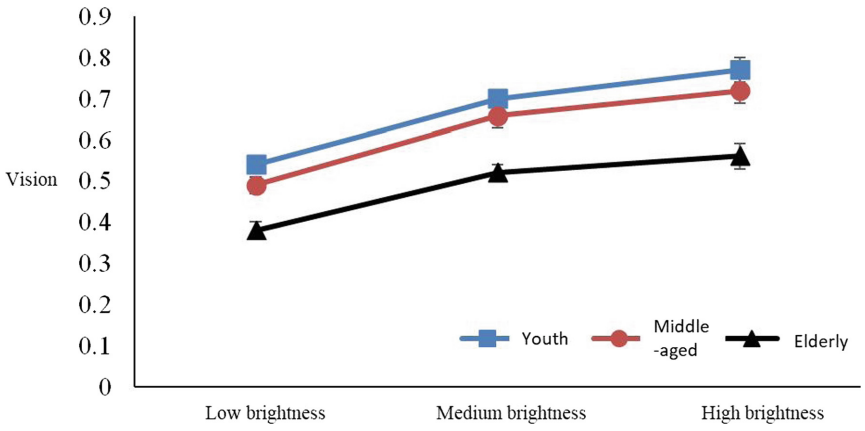


Fig. 5. Effect of background target brightness on dynamic vision

6 Conclusion

In this experiment, static visual acuity and dynamic visual acuity were tested with standard visual acuity charts and vision testing software for three groups of people of different ages under different lighting conditions. In the experiment, it is found that dynamic visual acuity and static visual acuity have a certain correlation with each other. The level of dynamic vision is based on static vision, that is, dynamic vision is always lower than static vision; with increasing of age, and static vision and dynamic vision are gradually decreased.

The quality of dynamic vision is closely related to whether the task can be completed under exercise or not. Therefore, dynamic vision detection plays an important role in checking various types of drivers and improving the training effect of drivers. At the same time, dynamic vision testing is an important part of selecting various types of special workers, which plays a significant role in improving work efficiency.

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Participatory Design with Older Adults: Exploring the Latent Needs of Young-Old and Middle-Old in Daily Living Using a Universal Design Approach

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Abstract. In 2017, global population aged 60 years or over reached nearly 963 million, becoming twice the figure recorded in 1980. Not surprisingly ageing population will continue to accelerate due to continuing decline in fertility and improvement in survival in major diseases. When people who are suffered from cognitive or physical impairment, they often feel alone and experience different degrees of social loneliness. This paper discusses co-design experiences with various stakeholders to explore latent needs of older persons in their daily living using a universal design approach. Through iterative use of creative methods, freehand sketching and physical models, older adults can express their needs in a more accurate, tactile format. Findings reveal that commonality of interest among older persons are important in building rapport among other participants. It also helps designers develop assistive design related to health care, mobility, dining and leisure activities involving older persons, benefiting society as a whole.

Keywords: Participatory design · Universal design · Elderly · Activities of daily living · Rapid prototyping

1 Introduction

A recent report from the United Nations (UN) indicated that by 2030, the number of older people around the world will reach 1.4 billion. This is expected to double by 2100, putting pressure on current social protections, health care systems, housing and intergenerational solidarity [1]. The rise in the number of older persons is also driving the cost of health care services all over the world, suggesting a need to address social exclusion in both physical and mental health. As the global population aged 60 and over has been growing, population ageing in Hong Kong has become more pronounced than in any other major Asian city. By 2024 Hong Kong will be expected to have 397,000 people over the age of 80, constitutes a 24.8% increase from 2014 [2]. Among those aged 65 and above 12.7% will live alone, constituting a 9.5% increase from 2006 [3]. People who are cognitively impaired are particularly vulnerable because they often feel alone and are socially isolated. They may be unable to communicate with friends,

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or lose them entirely [4]. People can experience loneliness in various ways, and may even be lonely when they have regular contact with family members. Having said that, research has shown that 17% of older people have contact with family and their neighbours less than once a week, and 11% have contact less than once a month [5]. When people lack social networks, they experience different levels of social loneliness.

2 Participatory Design

Action research has played a crucial role in Scandinavian Participatory Design projects since the 1970s, leading social researchers to follow its guiding principles [6]. Local accountability has been crucial to these studies, which have found that to produce reflective 'designerly' design research interventions, social and design researchers must be accordant with local needs, contribute to the knowledge pool and serve as a stimulus for later research. The purpose of this type of research is to collect, organise and improve on existing design and its operation, and to accumulate knowledge in the design participatory process. 'Design intelligence' offers a new and distinctive view from the scholarly and scientific approach, contributing to a greater understanding of design research [7]. Participation design is driven by social interactions because users and designers work together to create and develop their ideas [8]. The evaluation of possible ideas and insights also plays a critical role in this process and has a strong influence on how design uncovers unforeseen opportunities and desirable outcomes. Participatory design involves all stakeholders in the collective action of creativity, understanding and mutual learning opportunities, offering constructive solutions in terms of products, services and systems. When the idea of participatory design began in the early 1970s, it involved a process of understanding between users and designers representing the two principal participating roles. This practical research method has allowed participants to realise their genuine needs through collective thinking and production. The co-produced outputs have value because they have contributed to the professionalism of the workforce in addition to meeting its wider needs. Researchers have begun to realise that user experience is becoming more important, and should be embedded into the core of the design process, unlike conventional system-centred design [9]. The participant design approach considers the 'user as partner', rather than the 'user as subject' [10]. It involves several key attributes that differ from other typical design methods, producing tangible design ideas through processes in which design insights are gained, and a collaborative design experience is achieved by addressing unmet and unrecognised needs [11].

A recent review of the literature has shown that participatory design practice and theory are becoming more vigorously applied to health care [12]. The shared decision making of participatory design allows common goals to be attained, benefiting every participant when they work together to make improvements. Inviting every user into such a collective process requires a trusting relationship between each of them. This creative method relies on brainstorming, freehand sketching, quickly generating models to facilitate participation and promoting the idea of design as a process. It has been suggested that the elderly could become engaged in product and system testing in addition to being actively involved in the iterative application design process to

improve functionality [13]. The idea would be to equalise power between vulnerable and abled persons, allowing them to share their thoughts. The platform would facilitate a mutual learning experience in which designers and older persons work together to explore the problems the latter face in their day-to-day activities. A range of techniques, including paper-based dirty models, print-outs and foam models would be used to identify the form factors, physical sizes and proportions, individual preferences, product details and the use of products. The use of technology by older persons in both their workplace and home would become an expression of equality, because such technologies improve the quality of their lives and standard of living.

3 Universal Design

Universal design has already become a design philosophy in a global design context, influencing our day-to-day activities and the quality of life for people of all ages and abilities. The term 'Universal' refers to a wide range of human diversity where the application of design should be based on user-centered approach, while 'Design' is the creative solution underpinned by the empirical investigation [14]. Universal designing requires designers a deeper consideration and understanding of the extensive range of human abilities throughout a person's life during the development process [15]. Adopting the principles of universal design could make the design of environmental elements accessible to their greatest extent as it addresses all range of functionality. It serves as a fundamental condition and requirement of good design, offering an accessible and convenient way of using things. It plays a vital role in enhancing the potential for better and the significant part of living for every individuals [16]. Universal design promotes inclusiveness in design, to shape products, places and systems by reducing the need for expensive assistive devices and special accommodations – a method of designing that focuses on all ages, sizes and dimensions and thus lowering the economic burden that products and services need to be specially designed to cater people in need. The definition of universal design as a process enables and empowers a wide range of population by enhancing human performance, wellness and social participation [17]. By fully utilizing the principles of universal design, it provides an opportunity for better social support so that people in need become more self-reliant and socially engaged [18]. As the self-image of people becomes more important, the social status of people who are suffering from functional limitations will be largely determined by assistive resources, clothing and living environment. When the assistive design becomes universal elegance, it will have a higher degree to remove stigma and discrimination. By applying the principles of universal design, product design can reduce social stigma and promote social engagement by putting people with functional disabilities on a level playing field with fully functioning people [19]. In short, it is an integrated concept that emphasises accessibility, adaptability, aesthetics and affordability [20]. As the health care cost including long-term caring is rising, in search of universal design solutions to health related issues is becoming both a social responsibility and a financial necessity. The seven principles of universal design adopted to serve as a guideline during the design process in the later stages of research include (1) equitable use; (2) flexibility in use; (3) simple and intuitive use; (4) perceptible

information; (5) tolerance for error; (6) low physical effort; (7) size and space for approach and use [21].

4 Aims and Objectives

This study is funded by the Social Welfare Department, Hong Kong Special Administrative Region, to promote social inclusion and active ageing. Its specific objectives are (1) to establish and reinforce mutual support network between older neighbours, (2) to develop community-based education activities that promote social inclusion, (3) to facilitate active ageing through a series of workshops aimed at eliminating social isolation, (4) to offer a collective learning experience with older persons using information technology, (5) to promote social inclusion through design participation with tertiary students and people with disabilities, (6) to preserve local and traditional culture and indigenous intelligence through an iterative production process, (7) to offer tangible product design solutions that improve the quality of living of older persons.

5 The First Day

Forty-two Hong Kong residents (3 males, 39 females) who were 70 years old and above, were invited to join this study. These individuals were placed into seven groups to participate in design workshops with two sessions for each group. Each group included one graduating product design student (designer), one social worker and six elderly participants, all of whom were facilitated by the principal investigator (PI). The duration of the brainstorming session in the first session was limited to 20 min. All of the participants, including the older persons, were required to jot down keywords related to (1) mobility, (2) personal hygiene, (3) dining experience, (4) health care, and (5) leisure activity. They were assisted by student helpers whenever necessary. A sorting process took place after each session, delivering up to 60 fresh ideas or keywords according to specific topics. An unstructured interview was conducted by the PI with leading questions corresponding to different research areas. All of the key concepts, dialogues and answers to the questions had been written down on a long roll of paper covering four units of long benches. This ‘knowledge pool’ in paper format was accumulative, (i.e., words in context were added according to each unstructured interview). Interview sessions lasted one hour, followed by the first attempt at the production process in the participative design workshop, with full support from Food Grace Centre and Action Care Centre. Both are well established non-profit organisations that support the development of active ageing and community education activities in Hong Kong. All sessions were conducted in a natural setting, a mini hall at the Food Grace Centre and a communal activity room at the Action Care Centre. All of the participants were familiar with the actual location because they visited their corresponding centres to collect free vegetables and lunch boxes twice a week. The first production process lasted 60 min. The designer and the other participants were seated three in a row on both sides of a table. The designer and the social worker sat diagonally from each other, allowing the senior participants to actively participate. Among

the 42 older people who joined the workshop, very few failed to show up because their assigned schedules clashed with their regular medical check-ups. The pace of the workshops was controlled by the PI to make sure the process remained on track and the procedures were fully understood by all of the participants. Marker pens, cardboard, clay, modelling foam, felt sheets and thick paper were given to the participants to build a sketch model for testing and evaluation following an iterative approach. No detailed models were expected because the data collection method was new to the older persons. In addition, many of them did not have a fundamental educational background. Therefore, if the participants could express their thoughts freely it was deemed relevant to the study. In this study, the PI decided to adopt unstructured interviews with five preset groups of questions relating to the key themes: (1) mobility, (2) personal hygiene, (3) dining experience, (4) health care and (5) leisure activity. The main objective was to explore the potential problems older persons might have in their day-to-day activities.

6 The Next Day

The PI and the designer scrutinized the data collected during the brainstorming sessions, unstructured interviews and the first attempt to produce several testing mock-ups. Thereafter, they prepared a digital model to deliver a true-scaled three-dimensional output for an advanced physical trial with older persons and stakeholders. The tangible format allowed the participants to comment according to what they saw and felt, so that the optimum size and proportion could be determined through collective contribution. Unsurprisingly, the printed objects offered a new approach for users to test, not only in terms of cosmetic and ergonomic considerations, but also in selecting the actual appearance of the materials, colour variants and the simple mechanism to be applied to the prototypes. The first set of physical models was printed on the second day of the participatory design workshop, after the digital models had been prepared by the designer after the first day's participation. Three-dimensional (3-D) files were built using a freeform modeller in true scale, visualised in a photo-realistic renderer to ensure all surfaces were in excellent condition. The models were then converted into another machine language that could be recognised by the 3-D printer. The model was built up layer by layer using a fuse deposition modelling technique with preferred plastic-like substance and biodegradable Polylactide (PLA). This process was executed at least two times during this session to ensure the printed mock-ups fulfilled the fundamental requirements of universal design. Detailed feedback was recorded and the physical models were immediately modified with the aid of light clay if the gripping size and overall proportion did not match most of the models.

Alternation occurs only when the first attempt does not satisfy the user needs proposed in the process of data collection. The production process was new to the older persons even though they were assisted by the designers and research assistants. It required knowledge to synthesise their creative ideas and put them into practice through the interactive process, cross-fertilising ideas and applying technologies to resolve problems with day-to-day activities. In the first attempt, the participants used corrugated boards and a handheld wire cutting machine to model the preferred shapes and modify the existing design. They were asked to form groups of two to make dirty

models according to their thoughts and beliefs. Both paper and foam models could effectively express the genuine needs of the elderly, however, there was a limitation in that some tiny details could not truly be reflected in the first attempt using these basic materials. In the second attempt, the designer prepared the digital model and delivered a few possible variations in each category according to the evaluation of the first attempt. The digital model took time to be printed through fuse deposition, therefore, prior preparation was crucial to maintaining the participative workshops within the two-hour schedule. The iterative development helped the PI collect tangible data in a valid and reliable way. The designer circulated the mixture of the print models and foam components to collect immediate feedback from the participants. Modifications were iteratively made using computer simulation if the testing samples were far from the needs of the elderly people. In the end, several testing models were produced for further evaluation in terms of their aesthetics, ergonomics, ease of use and design innovation, with the goal of promoting healthy attitudes, active ageing and an inclusive society.

7 Discussion

7.1 Mobility

This study revealed that over 20% of the participating elderly used walking canes to assist them most of the time. WL, a 74-year-old woman, said she had asked the owner of a local fruit shop to drill a hole in her cane to help her put a typical cotton cord through it because she refused to spend extra money to do it. WL preferred a holding cord because she could manage her cane with her left hand and choose her fruit without putting aside her belongings. This cane was a valuable asset to her and she had been using it for years. She lost a similar cane when she could not hold it with her hands and left it at the fruit market. WL remarked that the overall structure of the cane should be sturdy and without a foldable function. Her motto was ‘safety first’. Another priority was that the cane should be light-weight and easy to carry. It was also easy to observe the personalised name plate attached to the upper part of the aluminum cane to make it easy to see, and to make sure everyone collected their own cane, because the typical design of canes was similar. SF, a 65-year-old female participant, mentioned that the hand grip was important to elderly people, and that it should fit for both directions. Although she agreed that most users would locate the cane outwardly, she deliberately kept it closer to her body so that the centre of gravity was closer to her. In this case, the product should have a certain degree of ‘tolerance for error’, to reduce accidents caused by mistakes or misuse due to different interpretations. The replaceable cane foot also played an important role in this participative design development. Ruby, a social worker from Food Grace, commented that many of the older participants did not want to pay extra to purchase a replacement even though they realised the rubber foot had already lost much of its physical function. Having an optimum level of material softness could facilitate human movement and the user experience with such a product design. KW, a 72-year-old female participant said the developers and designers should pay extra attention to the position of the walking cane, which should not be at a

ninety-degree angle to the floor, but in a tilted position. The development of the walking aid was given the highest priority because it affected the social activities of the older persons. They indicated it could be a hurdle to attending social gatherings if it had an unfavourable design, and they also wanted to hide its social stigma. Not surprisingly, nearly half of the participants said they preferred an umbrella cane.

7.2 Personal Hygiene

The dialogue began with female participant, SM, aged 68, who had an unpleasant experience trimming her fungal toenails. She related that the appearance of infected toenails was different from normal nails. It required additional force to cut the toenail, and both the trimming size and actual shape should be considered to allow for exploration. A well-designed trimmer should only require 'minimal physical effort' so that older users benefit without needing a tool specifically designed for them. A sample with an oval magnifier attached to it was not viewed favourably by most of the participants because the pre-defined focus did not match each individual user. At the beginning of the study, the research team believed that the bigger the trimmer, the easier the trimming process would be. However, it was observed that the size of the trimmer should be optimal for older persons to master without having to guess the area to be trimmed. In addition to the trimmer, two shower heads were circulated on the floor to gain insight on the existing product design. SJ, age 66, said she preferred a smaller shower head because she believed it would reduce her water consumption when she showered a few times a week. Larger shower heads with adjustable water outlets were believed to consume more water, which was wasted. Contrary to SJ, CL, a 68-year-old retired female pointed out that large shower heads were useful because they had more space to hold them in a firm position. The turntable on the shower head also allowed users to adjust the volume of water. Thus, water control become easier. Clear instructions should be shown in a graphic presentation so that they can fulfil the basic requirement of product semantics and be easier to understand. They should be *'simple and intuitive to use'* to enable older persons to operate them on their own.

7.3 Dining Experience

FF was a 65-year-old disabled female who had limited ability when she tried to pick up a piece of a cherry tomato with assistive chopsticks. She could master the assistive chopsticks on her own, however, her holding direction was completely upside down, which was unexpected. Even if there had been an in-depth study of the ergonomic considerations of this tool, she could not have felt the curves and textures with her fingers due to a series of minor strokes. The failure to properly use the assistive tool even made the picking-up process improper and impolite. A few of the older participants refused to use it even when they reported it as being useful and reliable. They did not want the social stigma in this regard. If the older persons could pick up the chopsticks during their meal time, they would not opt for assistive tools even if such tools could make it easier for them. More importantly, the typical tool could only help its user pick up chopped food piece by piece. It could not facilitate rice eating due to the wide gap between each chopstick. This study also revealed that some of the Hong

Kong elderly still preferred their knives to be polished before carving their meat, but realised their cutting tools were not in good condition. CL reported that when she polished her knife with a sharpening stone, she put the stone on top of a wet towel. She added that she had stored the stone under the sink for years because of its size and weight. Even though she realised that there was an easier way to do the sharpening, she preferred the traditional method, which gave her the best result and made her cooking experience easier. The overall food preparation experience should blend the chopping process with sharpening, forming an effective tool to fulfil the actual requirements of the users. This study shows that many existing kitchen utensils have failed to satisfy the basic needs of the elderly in Asian cities, without any deep consideration being given to the entire cooking experience most face in their day-to-day activities.

7.4 Health Care

CL was concerned with the pill case and said it could be more user-friendly if the depth of each compartment was carefully designed. According to her, it should allow human fingers to grasp the small pills or turn it upside down to take out the exact amount. The PI passed around a few samples to the participants to collect feedback based on their past experiences and selection criteria. Ruby commented that the existing pill case, designed as a souvenir by the Social Welfare Department, was a good solution except for its oversized and elongated shape, which was not good for carrying pills. The pill case with four compartments (for four distributions in a typical day) seemed to be the best fit for the majority, so they could either take the pills by themselves or with assistance from family members. In this case, the design should follow the 'equitable use' principle of universal design so that older persons suffering from stroke and disabilities, or related diseases, could still operate it on their own. In addition, designers should pay extra attention to 'perceptible information' so that the information appearing on the pill case is easily read, regardless of the sensory abilities of different users. A participant sitting next to CL was unable to operate the sample because the design was totally different from hers. False pressing could be needed to go through one cycle and return to the correct direction. After the workshop, two older participants said they did not know where they could buy the traditional pill cases that are crucial to their daily living. This study revealed that a few of the older participants were living alone and lacked social activities, which might have presented barriers to them keeping up with current information and the news around them.

7.5 Leisure Activity

This area explored the social and leisure activities that older persons do on a regular basis. SF remarked that over the past few years she had visited a local community centre twice a week, where she took training courses, received health checks and networked with people of a similar age. Every Friday afternoon she collected assorted vegetables for free, after she enjoyed a two-hour social gathering. SF shared her views with CL on occasionally attending Chinese opera. The classic opera house was located far away from her residence, therefore, SF needed to rely on a modified walking cane. This study showed that some older persons did not want to carry a walking cane.

Instead, they preferred to use an umbrella cane or even a shopping cart to serve the same purpose. WL preferred to play card games with companions instead of going out in the summer, due to unfavourable weather. The games, she said, made her feel like she belonged to a group and sometimes she could even meet new friends.

8 Recommendations

8.1 Deeper Encouragement

Deeper encouragement to facilitate overall discussion and participation in the participative workshops was needed. Given that all of the senior participants invited to the two-day consecutive workshops did not have similar experience, they might not have been familiar with the workshop setting even though it was organised in a familiar venue. The data collection process seemed to be new to most of the participants. In general, when informing the study group, only one to two senior participants could actively offer personal advice and were eager to share their experiences with the research team. A few needed the PI to open the dialogue on their day-to-day living to obtain research insight for a typical day. Because most of the participating elderly did not have a strong educational background or even a foundation, they needed further explanations in terms of the production process, including the objectives of the study. Concepts such as 'digital printing', 'ergonomic consideration' and 'physical model' were new to these senior participants. For those who did not speak Cantonese, but only spoke their indigenous language, they were either assisted by the translations of teammates or through body language and written words. When the older persons saw the tangible product samples being demonstrated by the research team to facilitate discussion, they became more actively immersed in the data collection process.

8.2 Clear Instructions

This study involved the use of both low-cost materials and digital printing to support two sessions of idea exploration and the development of a product design. The goal was to obtain a genuine understanding of users' needs and how to enhance the quality of their lives. However, even though the physical modelling skillset was not mandatory in this research, the adaptability of the senior participants did not meet expectations. Demonstration was necessary to help them understand what we were doing, what we were going to do and what we expected. Clear guidance was the key to ensuring that every participant, including the social worker and design entrepreneur, fully participated and understood the meaning of the activities in the participative workshop. In this case, a seminar on the effectiveness of participative workshops associated with older participants and stakeholders, followed by a series of videos with working examples among Taiwanese and Chinese would be beneficial. This could provide a holistic picture for the senior participants to help them become familiar with the actual practice. Researchers should make clear instructions, break down the procedures and explain each step one at a time.

8.3 Timing and Time Management

The research schedule was deliberately designed for workshops to be held on Fridays, when Food Grace Centre and Action Care Centre regularly distributed free assorted vegetables and lunch boxes to needy older people. The participation rate was expected to be higher than 92% in this study. Very few participants could not attend the workshops because the schedule clashed with their medical appointments or they decided to attend other free community activities. A public seminar on the participatory workshop intended to generate design experience with older persons familiar with information technology had been organised a week before the first workshop. Both the first and the second sessions consisted of two hours each, which might have exceeded the limits of the majority. It is suggested that the duration of each session could be shortened to one and a half hours to coincide with the typical activities in day care centres. If vulnerable participants are familiar with the regular time schedules within their community centres, it enhances the efficiency of data collection. The longer the time spent in the participative workshops, the worse the attention span. The ideal number of participants was between six and no more than eight in each session.

8.4 Common Interests

The commonality of interest among the older persons played a vital role in building rapport among the other participants, such as the facilitator, social worker and design entrepreneur. Because the project aimed to explore the genuine needs of the elderly in their daily activities through brainstorming, interviews and design participation, the areas that created common interest between the older participants helped to facilitate the on-going research process. When the participants were asked to discuss their dining experience in the past, for example, they might share their experience with the research team and other participants they otherwise seldom paid attention to, due to different generations and living habits.

8.5 Social Benefits

This study found that a few older participants were not satisfied with their existing living environment. Most of them preferred a safer cooking environment when they used a gas stove. The location of the pipe that transfers the gas should have a sturdier design and be in a more reasonable location to make sure it will not easily be damaged by fire or extremely hot temperatures. SF explained that she paid extra attention when she fried vegetables in oil every day. Her interior environment was the standardised typical design of a public estate where the existing interiors still have room for improvement. Although SF had been aware of the unsafe condition for years, she did not know how to improve it, and even she had realised there was a gas leak, she would have to cook in the same way as she had from the first day she moved in. SF was living alone, and her near relatives were living in northern China. She spent thirty minutes with the PI discussing the current transportation system in her district. After suffering from a stroke and cancer she had been required to walk with a cane to travel between the community centre and her residence. By sharing their stories with the other

participants, the elderly living alone could meet new friends and interact with neighbours living near the community centre. The participative workshops offered opportunities for them to establish deeper relationships with other older participants and centre staff.

9 Conclusion

Failed product design affects people's initiative to deal with it and removes the incentive to give it a try. In many cases, misuse of the cutlery and walking aid could induce serious injuries that the care givers and even the end users had not thought about. There is a rising trend in social isolation among the elderly. Following universal design principles in assisted living and health care design makes a significant contribution to product development by reducing the social stigma and empowering vulnerable people to become more capable of living independently. Loneliness and social isolation can be mitigated by using the proper assistive tools and daily products that facilitate social interaction and physical activity. If researchers could put designers and end users together to participate in friendly workshops so that new ideas and interpretations could be achieved, it would be meaningful. The contributions of the other stakeholders, such as the nursing home people, care givers and social workers, helped to encourage the older persons to participate in the group. Representatives from a manufacturing company also actively participated in the group to learn the seniors' demands and improve the usability of their existing products and services. This was the main objective of this study.

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Public Spaces, Building Environment and Communities

A New Inclusive Housing Prototype

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Abstract. A new model of sustainable housing has been designed, thanks to a research conducted with different kind of users. A ready-made wood residences prototype is proposed as a project able to guarantee a height home environment quality. The research aims to improve people daily Life related to multiple factors. A study has been conducted on materials quality to guarantee a safe environment and a high air quality and at the same time, also a research on colors and contrasts between the volumes. The structural elements are already built in the factory equipped of flexible interiors furniture (multiple layers): this technology permits an ergonomic use of the tables, the armchairs, the windows, handrails, kitchens and toilets [1]. Plugs and switches have a minimum range to be moved and adapted. The house project results anti-seismic, ergonomic and sustainable and it makes people interact inclusively with the outside landscape thanks to a movable windows system that allows to the different users of the house to change the windows height. The flexible structure is able to contrast the earthquake vibrations because of its flexible structure and at the same time the home environment becomes safe thanks to the integrated furniture. Guides for the wheelchair users are integrated in the ready-made panels and can be customized for the clients [2]. The prototype is also eco-friendly and detains all the requirements to be constructed in NZEB (Nearly Zero Energy Building) [3]. It has to be pointed out that the interior walls panels and furniture are made of recycled materials, mixed with chipboards, to increase the project sustainability and to reduce the expenses. The economic factor has been considered as a fundamental element of the research and the already-made technology permit sustainable costs. Users Expert have been involved in the design process thru workshops and seminars organized to investigate needs and measures of people housing thanks to the collaboration of a consultant that works with public administrations to improve people home environment.

Keywords: Ergonomics · Flexible furniture · NZEB

1 Introduction

A new model of sustainable housing has been designed, thanks to a research conducted with different kinds of users. A ready-made wood residence prototype is proposed as a project that guarantees a large home environment quality. The research aims to improve people's daily life, related to multiple factors. The quality of the domestic environment depends on the space quality, the air conditioning, the light, the attention dedicated to user's dimensions, the ergonomic factors of furniture and details. The design project

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consists in the experiment of a new connection technology between the structural elements. It allows the installations of structural and final layers ready-made in the factory, with an integrated system of conditioning, home automation, electrical and air systems. A study has been conducted on materials quality to guarantee a safe environment and a high air quality. At the same time, has been conducted a research on the effect of colors and contrasts between the volumes in a domestic context. The structural elements are already built in the factory equipped of flexible interiors furniture (multiple layers). The house project results anti-seismic, ergonomic and sustainable and it makes people interact inclusively with the outside [4]. The flexible structure is able to contrast the earthquake vibrations because of its flexible structure and at the same time the home environment becomes safe thanks to the integrated furniture. Guides for the wheelchair users are integrated in the ready made panels and can be customized for the clients. The prototype is also eco-friendly and detains all the requirements to be constructed in NZEB (Nearly Zero Energy Building) [5]. It has to be pointed out that the interior walls panels and furniture are made of recycled materials, mixed with chipboards, to increase the project sustainability and to reduce the expenses. The economic factor has been considered as a fundamental element of the research and the already-made technology permit sustainable costs. Users Expert have been involved in the design process through workshops and seminars organized to investigate needs and measures of people housing thanks to the collaboration of a consultant that works with public administrations to improve people home environment [6].

2 Paper Preparation

Nowadays the development of timber construction models is based on the use of two main technologies: the X LAM construction systems, and the frame and massive system named *BLOCKBAU*. In particular, the United States market has always used the frame system such as the *balloon-frame* and *platform-frame*; in Europe during these last years the X LAM has become the most popular system used, which provides an excellent compromise between tradition techniques and prefabrication, with a significant time-saving concerning the construction time, but it's still expensive technique. In particular, the application of wood in the construction field is fundamental for two different aspects:

1. Environmental/energy aspects. Thanks to the possibility to build several new green buildings made of eco-compatible nature of materials and of high performance envelopes, it is possible to have a minimal bearing impact on the planet.
2. Structural/anti seismic aspects. The excellent response of wooden buildings to the stresses due to seismic events, allows the use of this technology to all the geographical areas in the world vulnerable to this risk, such countries as Italy, California (USA) Japan and Mexico.

3. Sustainable indoor life. Wood is an organic material, and if it's not treated with harmful glues, its release of substances can be relaxing for the smell, and it can capture the pollution contained in the indoor spaces [7].

In particular, in 2007 the *CNR-IVALSA (Italian Research National Centre for timber application)* and the Province of Trento, in cooperation with the National Institute for Earth Science and Disaster Prevention (NIED), the Building Research Institute (BRI), Shizuoka University and the Centre for Better Living in Japan, have worked on a research program named *SOFIE Project 2007*.

The program focuses on the verification of the seismic resistance of multi-level buildings built with the X-LAM system. The seismic tests were carried out on the largest vibration platform of the world in Kobe, Japan. In particular, the timber building (seven floor height) has passed the test positively, thanks to the specific qualities of the material (lightness and strength) and because of the construction system adopted (ductility and capacity to dissipate energy). After more than ten consecutive earthquake simulations at variable intensity there was no residual displacement, indeed, the building has always returned to its right position, keeping the structure safe from the damages [13].

IEL research project, is in continuity with the proposals of the current worldwide market and with the latest scientific applications used in the field of timber housing. In particular, the project consists in the development of a prototype of a single-family house with adaptable dimensions that provides a *360°* integration of all the technological, social and environmental aspects that characterized the development of each design process.

The main goal is to place on the market a wooden model of ergonomic residential houses that allows to give the right answers to the performing requirements, from the performing point of view to the shell. A maximum flexibility of the interior spaces had been designed according with customer needs. The study of interior spaces is fundamental to create inclusive solutions applied to the furniture, walls and flexible partitions. Any object can be designed with multiple functions. All the spaces have a system of adjustable guides that increase both the inclusion in the domestic environment and the adjustment of the light spots. Long handrails can be integrated in furniture guides or for example towel-holders. The same kitchen surface can be adapted for all family members in different moments.

The use of sophisticated technology combined with the use of innovative assembly systems, can be solutions economically advantageous and competitive on the global market for wooden constructions. The particular external structure of the envelope and the way with the wooden elements have been assembled, make possible the integration of photovoltaic systems on the roof, to realize a building totally self - sufficient from the energy requirements point of view (stand alone system) (Fig. 1) [8].

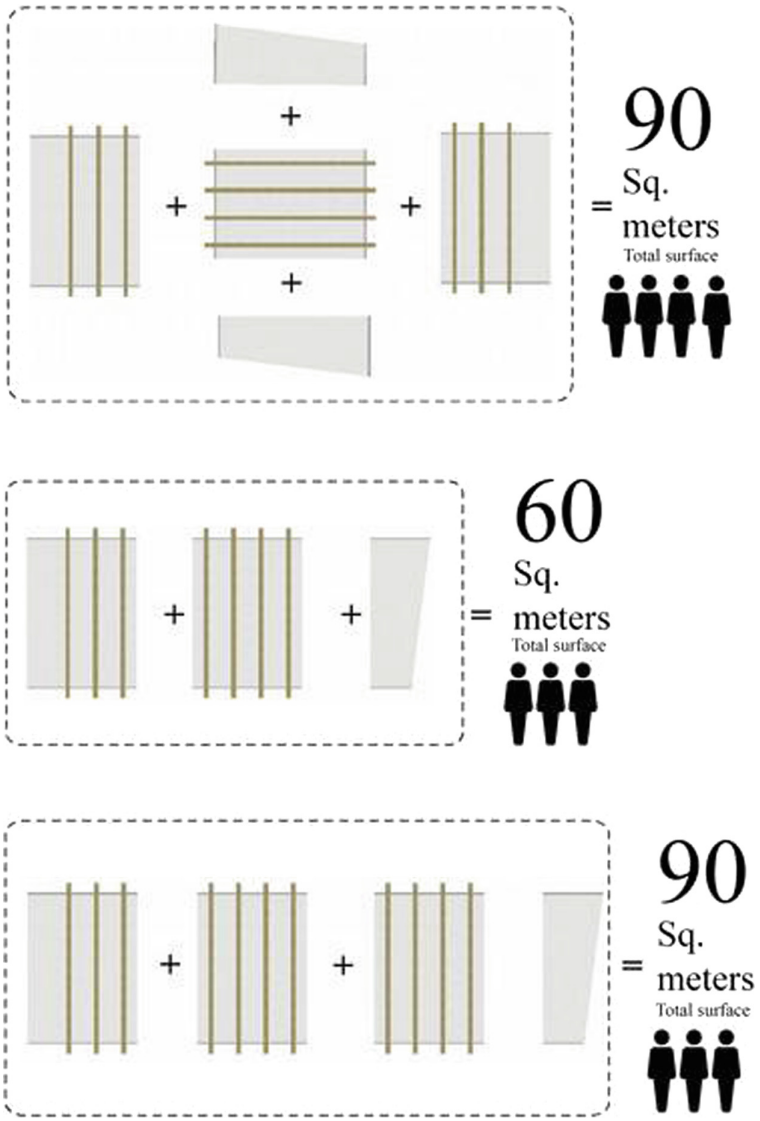


Fig. 1. Different kind of assembly. Those are just a few type of modular possibility of assembled.

Costs reduction is achieved by maximising the production process of prefabricated modules from the production to transportation and assembly on worksite. The wooden modules are designed to be contained and transported thru trailers (according with standard dimensions for conventional trucks), and we've designed these modular elements in easy shape to be easily operated. These types of houses are designed for different kind of users, thanks to the easy way in which they can transform the interior spaces and the possibility of adjusting equipment and furniture. The research has studied a new sliding guides system with rails connections that allow to fix the furniture and all the equipment of different kinds to the walls, to prevent, in case of earthquake any damages caused by the furnishment (Fig. 2).



Fig. 2. External view of prototype's rendering. A multi-storey villa 125 m^2 large with two balconies modules.

Research has investigated also the LCA Life Cycle Assessment of materials Buildings have been designed to have a life cycle of 100 years, wood components and other materials used are almost totally recyclable (90%).

Flexibility, already mentioned in indoor environments, is at the same time a fundamental characteristic of the external design of the prototype; indeed, although the elements are standardised according to the characteristics and its adjustability, the building can be customizable, according to customs requirements.

The project is divided into different areas, each of these stands out to find out new innovative solutions applied to the prototype, such as:

- Structure and Safety of the shell;
- Environmental Sustainability and the use of materials with a natural origin
- Spatial Flexibility and integration of systems,
- Inclusive Design of interiors, according with a large number of potential users (Elders, Families with children, Young couples, Singles Disabled) [9].

2.1 Structure and Safety

The aspect related to the structural safety is one of the main aspects of the design of the prototype. Our engineering team has worked to develop a new type of connection between the different structural elements, something that has not been developed yet in the field of timber constructions. Thanks to the use of these connector systems consisting in a special springs and steel cables, we aim to improve the structural seismic response without significantly affecting production of costs and at the same time improving the prefabrication of modules.

This technology has been developed favouring the possibility of installing the prefabricated modules in any type of parcels and location, and the method of installation and assembly has been designed with the aim to realize a product that can be easily dismantled and reassembled in another different place.

Users well-being is an important characteristic of the project referring to the choice of materials that maintain a good level of *IAQ Indoor Air Quality* standards, this has been possible thanks to the use of wood in particular for the furniture and interior finishes, coming from certified woods according with *FSC© Forest Stewardship Council* and treated without the use of chemicals or dangerous product toxics for the humans health [14].

For us, it is very important to realize liveable residences both from the comfort and the society-economic point of view [10].

2.2 Environmental Sustainability

Another fundamental aspect that this prototype underlines is the model of living the indoors spaces. It's a sustainable model because of the materials but also thanks to the efficient use of energy. The wood is used for the structures, which has itself high environmental standards, cardboard, made of recycled sources, as the filling for the cavities that permit thermal and acoustic insulation in addition to vegetable fibres. This particular combination makes possible the creation of light buildings than the norm, favouring both a better seismic response and a greater ease of manoeuvre during transportation and assembly on site. The model is designed to be easily integrated with roofing systems for the production of energy from renewable sources such as photovoltaic or solar thermal systems. This is because the model is designed to be a *NZEB Nearly Zero Energy Building*, so it will have satisfied the requirements and

performance standards according to the *LEED* (for USA and CA system) and *KLIMAHOUSE* (for IT and EU systems) certifications. The possibility of setting up the model with alternative energy systems allows to the houses prototype to be realized in different contexts:

- urban areas (such as towns and villages)
- isolated areas (such as country sides, and all these areas where there is not a direct connection to the infrastructures/networks - electricity, gas, telecommunication, internet and water).

In order to overcome the problem of water supply, a rainwater collection tanks system has been designed, which can be extended if required, also to the treatment of waste water, in the absence of a suitable sewage system (Fig. 3) [11].



Fig. 3. Interior view of living area. Mobil walls flexible system integrated with spot lights.

2.3 Flexibility and Interaction of Spaces

To this prototype, the flexibility of interior spaces is a fundamental element, that permit to extend the housing model to a large market share. The model can actually be adapted for several user needs, considering that in the life of everyone needs can change and our capability can suddenly change, for a temporary timing or permanently. The flexibility has been ideated thanks to the use of special devices and technological equipment that allows the flexibility of the walls and consequently of the interior spaces, especially the regulation of the furniture. This technology permits an ergonomic use of the tables, the armchairs, the windows, handrails, kitchens and toilets. Plugs and switches have a minimum range to be moved and adapted. The house project results anti-seismic, ergonomic and sustainable and it makes people interact inclusively with the outside landscape thanks to a movable windows system that allows to the different users of the house to change the windows height.

Nowadays, indeed, the phenomenon of the high requests of characteristic of sustainability and flexibility is increasing. It's necessary to design ergonomic products that can be commercially attractive for an enlarged target of audience.

Until now, we've mostly considered the inside aspects of the houses. The flexibility of the building can be explored also from the outside of the structure, where the customization of the external skin allows to the module to be placed in different environments and contexts, from the city to the countryside, ensuring a maximum integration. The external shape can be creating depending on the customer needs related to the interior room position. The interior spaces can be composed according to the user's needs, both during the assembly phase that later.

For special categories of users, such people with reduced mobility, a special vertical and horizontal guides allow to change furniture height and are physically integrated with light system and he ceiling.

The lift system is provided on request, and it allows also to persons to go up and down from the ground to the upper floors, in totally autonomy and in few minutes, without the use of the regular elevators or stair lifts [12].

2.4 Production Costs

At present, despite the prefabrication and the short construction time, the use of wood technology is not convenient, because of the high cost of the certified raw material, such as coniferous timber. Currently prices to build prefabricated houses in wood are approximately between 1,200.00 and 1,500.00 €/m^2 (standardized in the EU zone). The challenge of our team consists in the propose of a new prototype for the international market with an estimated cost of 800.00–900.00 €/m^2 (EU currency) or 900.00–1,000.00 $/$m^2$ (USA currency).

The achieve of this new prototype is the rationalization of the use of raw material (wood), exclusively for structural partitions and internal finishes such as false ceilings and various fittings. This allows a significant reduction of costs. The masonry package is also filled with wood fibres (less expensive) mixed with organic materials fibres and recycled rigid cardboard. The innovation in the use of this material allows - not only a reduction of costs- but also a significant reduction in the mass of the wall, or rather a reduction in the its weight, maintaining optimal levels of quality and climatic standards.

3 Customers, Users, Developers, Universities - Research Institutes

IEL Architects team is developing the research project thanks to the collaboration of a multidisciplinary staff made of professionals, academics, engineers and trainers. We consider at the same level all people and customers, because we believe that all categories must have the same opportunities to buy a good design level products.

Within the research project the team has started several partnerships with leading companies in the field, based in Italy and abroad. Research institutes and universities are also potential partners during the development and testing phases of structures and materials if they pursuit the same ideals, or they'd like to train students through practical activities. We are constantly looking for new future collaborations with academic-scientific sector, research and development companies, to reach new goals for a better living (Fig. 4) [15].

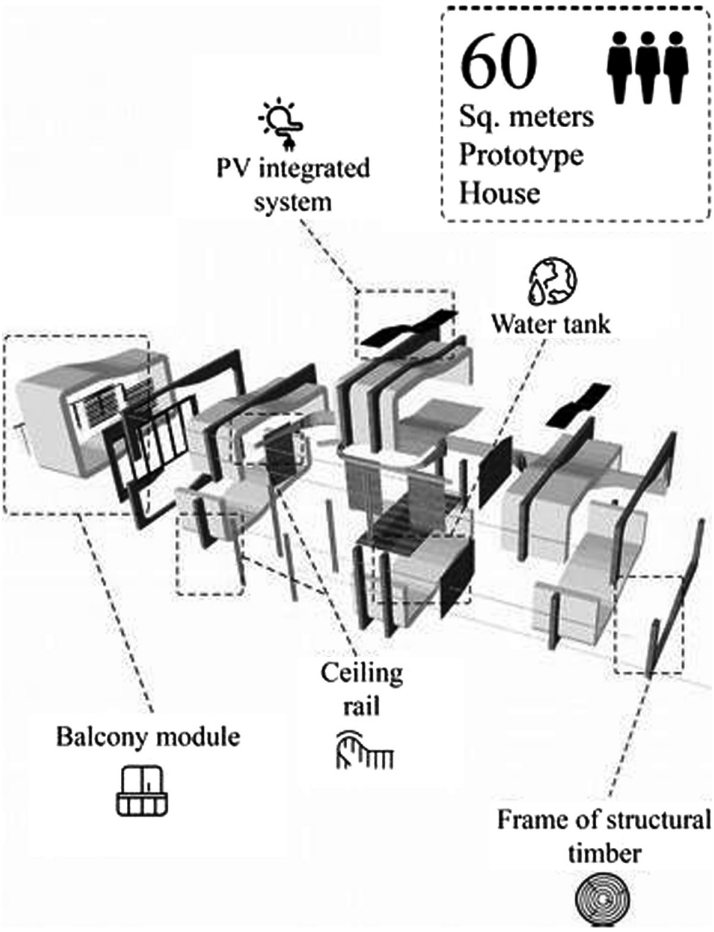


Fig. 4. Exploded axonometry of a housing module, (60 m^2 house).

Since 2018 have been activated new training activity at IEL headquarter in Sabina, a region close to Rome, in Italy, characterised by a significant number of fields where to test structures and where to locate training courses. In particular the training offer is addressed to technicians, workers and companies in specific field related to sustainable principles starting from the ergonomic design, to the use of organic materials or techniques (Adobe), prefabrication of wood and innovative construction solutions, oriented towards the construction of NZEB buildings.

3.1 Customers, Users, Developers, Universities - Research Institutes

See Fig. 5.



Fig. 5. Interior view of living area. Detail of rail system (ceiling and wall), thanks to this technology furnitures and walls can be customizable by all kind of users.

Customers

- Elders (75 +)
- Families and young couples
- Singles
- Disabled people
- Younger (18 +)

Developers- Companies

- General constructors
- Building construction companies
- Timber construction companies
- Social housing developers
- Public administration and municipalities

Research Institutes & Universities

- Research institutes (tests and labs analysis)
- Universities (research and developer)
- Trainings classes and activities
- Design and research programs

4 Green Housing | for All

The research project has been convinced starting from the principles that sustainability is a necessary condition to build a better world for our future generations, from a social to an environmental point of view. It's not a "slogan", it's a possible objective to perceive if we try extend it to as much people as possible.

The project of ergonomic prefabricated wood housing aims to reach a sustainable design without economic or social barriers. To make it possible, developers, administrations, designers, architects have to be open to critics, suggestions, changes.

So we are (Fig. 6) [16].

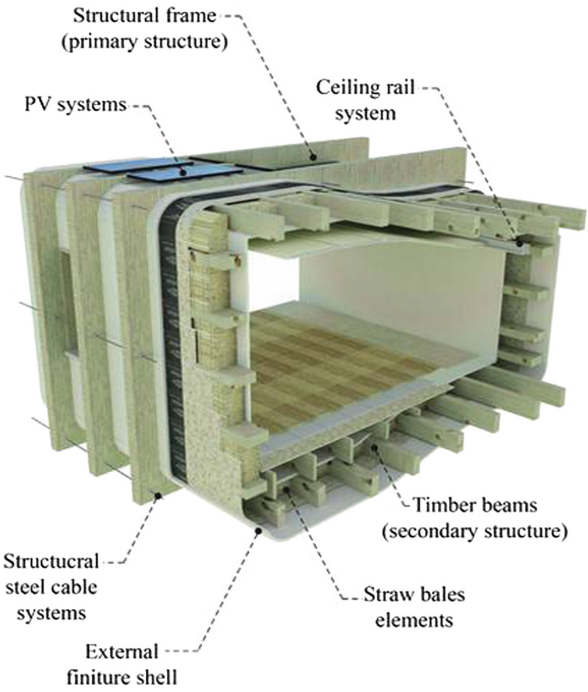


Fig. 6. View of prototype. Stratification of the building package, specification of each different layers.

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Bioclimatic Design Approach for Low-Income Dwelling at Monte Sinahí, Guayaquil

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Abstract. This document presents the procedures used to carry out architectural design of a housing prototype for low-income people under bioclimatic criteria in Monte Sinahí, at Guayaquil. Bioclimatic design starts with the characterization of the local climate and, based on inclusive design, considers the needs of a family that currently lives in that territory. With climate data obtained from a weather station located on site, region climate is described, which is characterized in two climatic seasons: hot-dry and hot-humid. The analysis of the micro-climatic particularities of the place allowed defining cooling requirements and proposing passive design strategies into architectural project for interior spaces. It also outlines recommendations for dwellings with bioclimatic criteria taking into account architectural morphology, urban form, building elements and solar and wind flow control devices. The use of Ecomaterials as construction elements in the efficient management of local resources is the result of a research program whose objective is to provide solutions in order to improve the constructive quality of low-cost dwellings using bamboo and other natural resources as fibers, leaves and parts of the trunk of plant species. Climatic characterization, added to future dwellers requirements, citizen participation as an example of social inclusion in the decision-making design process and the use of Ecomaterials, will contribute to the appropriation of the prototype by its users to be used as a housing solution that contributes with the care of the environment and the improvement of the quality of life of the inhabitants of Monte Sinahí.

Keywords: Bioclimatic design · Concurrent engineering · Ecomaterials · Participatory design · Low-income housing

1 Introduction

In Ecuador's National Development Plan within its goals to 2021, it is indicated to increase from 53% to 95% the number of families with proper and dignified dwelling units that are in extreme poverty; where access to dignified home and safe and healthy habitats within it is still a fundamental pillar, the *Casa para Todos* Plan, where "the integral guarantee of this right will be achieved through the implementation of coordinated and articulated actions between the Technical Secretariat of *Plan Toda una Vida*, the Ministry of Urban Development and Housing (MIDUVI), the National

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Secretariat of Planning and Development, the Public Company *Casa Para Todos*, BanEcuador, the Development Bank of Ecuador and the Social Sectoral Council" [1].

The production of social interest housing carried out in Guayaquil since 1942 can be divided into two large groups: formal and informal housing. Within the first one are those of public promotion, which until 2017 registered more than 158 thousand single-family housing solutions [2] being the MIDUVI and the Municipality of Guayaquil the institutions that recorded higher production with 44.7% and 28.8% respectively, followed by the *Junta Nacional de Vivienda* with 22.6%; thus covering 96.1% of formal public housing production. This production is complemented by private production sponsored by the NGO called *Hogar de Cristo* since 1971 [3] with wooden housing types using bamboo and in recent years they have included new construction systems with different materials. These dwellings, which amount to about 185,000 units, were built in areas of low economic resources such as *Isla Trinitaria*, *Flor de Bastión* and *Monte Sinahí* in Guayaquil.

Traditionally these formal and informal Social Interest Housing (VIS) dwellings [4] are not designed to respond coherently to the climatic reality where they are located. Both materials used in its architectural envelope and its construction systems have high rates of thermal transmittance (U-value). Nor are considered aspects such as textures and colors from its thermal performance, as well as the proportions of its interior spaces and designs of windows and doors, configure different scenarios where humidity and temperature present throughout the year, generate absence of any sense of comfort; that is, they have an inadequate thermal performance that affects its dwellers [5, 6].

2 Bioclimatic Design Methodology

The bioclimatic design starts from the collection of information related to the climatic data of the area where the project is located to determine its most relevant characteristics. Within the reality of a specific locality, the construction materials and systems of the building must take into account, because its decisive influence on thermal performance that accompanies the habitability conditions of a dwelling.

Determination of thermal comfort conditions is a fundamental step within the bioclimatic design process, since it establishes the reference of design temperatures inside a dwelling to meet that demand. They are established and visualized in Givoni's psychrometric chart, which also allows us to understand which strategies to develop for the different types of scenarios throughout the year and hours of the day [7].

In this way, main seasons must been described, which gives rise to their diagnosis and characterization to establish cooling requirements and propose passive cooling strategies to condition interior spaces. Bioclimatic recommendations according to urban environment, construction elements and design resources, within which orientations respect to the sun and the prevailing winds, layout, thickness and combination of materials and construction systems, spatial arrangements are also taken into account in relation to the design of the plan, as well as the finishes and textures of the architectural envelope.

Once the architectural project is elaborated integrating the described variables, it is subjected to a thermal validation or simulation with specialized software to be able to evaluate its thermal behavior according to its materials, construction systems, finishes and other essential characteristics of the architectural envelope. Finally, the construction phase allows having an in-situ learning laboratory to analyze and feedback this bioclimatic design process [8] as shown in Fig. 1.

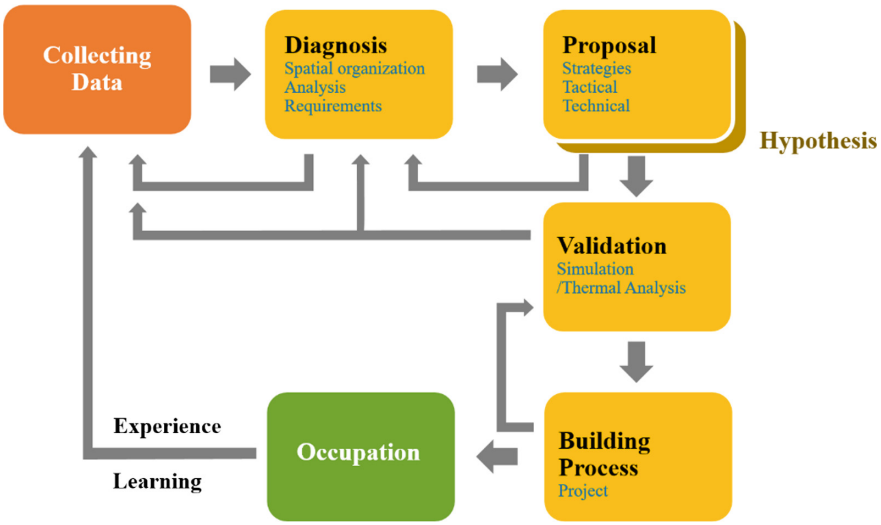


Fig. 1. Bioclimatic design methodology.

2.1 Characterization and Climate Analysis

Guayaquil is located on a plain beside Guayas River, nest to the foothills of the Chongón-Colonche mountain range that is located to the northwest of the city in whose area Mount Sinahí is located. This zone expose to winds of moderate intensity at night, due to the combination of topographic and climatic effects added to the humidity coming from the coast and which converge in this area of the city [5]. Its warm-humid climate, has two clearly differentiated seasons: the dry season, from May to November, where average temperatures range between 23 °C to 25 °C with relative humidity between 67% and 73% to register maximum thermal sensations average of 29 °C and fresh nights with averages of 22 °C. Described scenario is configured due to the presence of the cold Humboldt Current that runs along the Pacific coast of South America from the south. On the other hand the rainy season, generated by the presence of the El Niño ocean current, coming from central Pacific in the opposite direction to Humboldt from December to April. This generates average temperatures between 26 °C and 28 °C with humidities between 68% and 80% with average thermal sensations of 32°C.

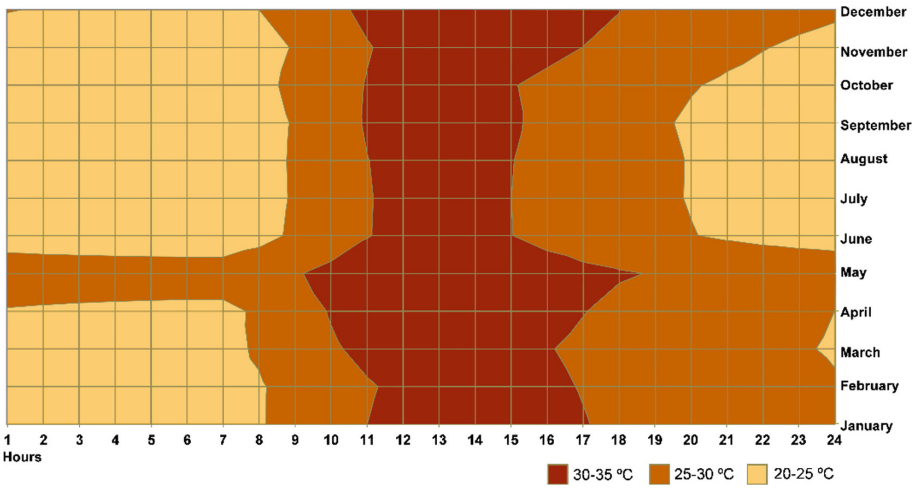


Fig. 2. Isothermal chart for Guayaquil. Hour and monthly temperature graphic behavior displayed indicates different temperature averages. Data has been acquired from an *epw file generated with Meteonorm software [9].

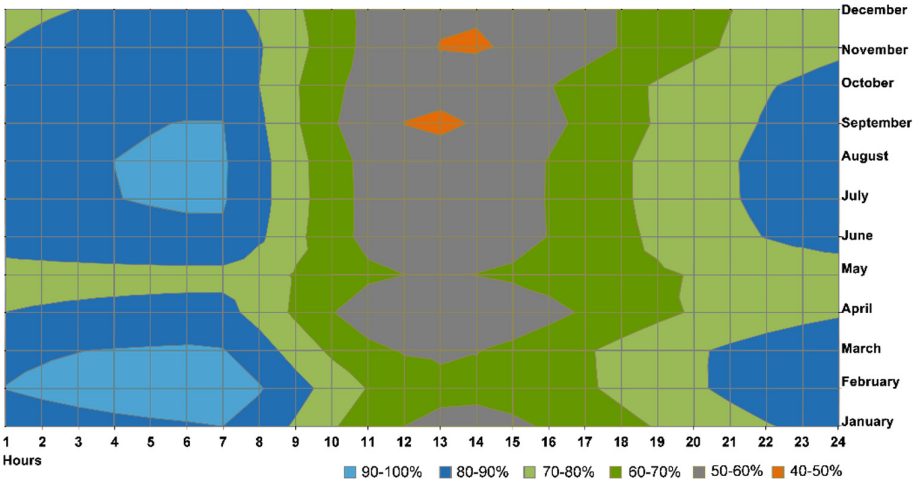


Fig. 3. Isohygral chart for Guayaquil. Hour and monthly relative humidity (RH) and its average percentages over a year [9].

Because it's located close to the equatorial line, solar radiation is fairly strong throughout the year, in addition to its incidence of approximately six months on north and south facades respectively [7, 10]. The hourly thermal behavior obtained according to the method described by Tejada [11] and analyzed through Gómez-Azpeitia's application [9] plots the isothermal chart for each month of the year in Guayaquil.

Highest temperatures are concentrated between 11:00 and 16:00 h for all months of the year, while the lowest temperatures are limited to the months of June to October at night as seen at Fig. 2. As for the hourly relative humidity for all the months of the year of the same city, [9] it is observed that the highest concentration is recorded from January to March in late night and early morning hours between 01:00 and 08:00 h indicated in Fig. 3.

2.2 Requirements

Based on the interpretation of Givoni's psychrometric chart (Fig. 4), it can be established that the main requirement for the project is to cool throughout the year, as well as passive climate control strategies such as natural ventilation, protection passive solar, evaporative cooling and nocturnal convective cooling. Some of these strategies are selective according to the realities and scope of the project and its inhabitants.

The estimation of comfort ranges are projected based on the adaptive model proposed by De Dear [12] with very similar results to Auliciems [13] and compiled in the ASHRAE55 standard [14] which is a dynamic approach related to physical and psychological processes that generate the interaction of the dwellers with their environment in order to achieve comfort.

Other approaches like thermal equilibrium proposed in the seventies by Fanger [15] which PMV (Predicted Mean Vote) model works best with air conditioning and not with naturally ventilated spaces, which are recommended for warm-humid climates. Based on the foregoing, it is established that the comfort temperature for Guayaquil is 26.4 °C, with design ranges between 28.9 °C maximum and 23°C minimum, which are fundamental values for bioclimatic design [13, 16, 17].

3 Bioclimatic Project

According to the cited, the project focuses on strategies; tactics and techniques used on it to achieve the main requirement of cooling down interior spaces to reach that described thermal comfort ranges.

At an urban level, separation between buildings need to be guaranteed to allow natural ventilation between dwellings, and the proper use of vegetation that does not block wind flows. It must be avoided designs with large façade areas exposed to radiation with East-West orientation and provide solar protection elements on those facing North and South where solar incidence will be approximately of six months on each of them.

It is essential to perform solar geometry analysis in order to design windows with good performances according to requirements stated in the previous statements. In addition, spatial arrangement of dwellings must foresee that different uses respond to orientations related to temperatures and direct solar radiation as shown at Fig. 5. Spaces occupied at night, must be located at East side, so indirect heat gains of afternoon hours through walls and roof will not affect those spaces.

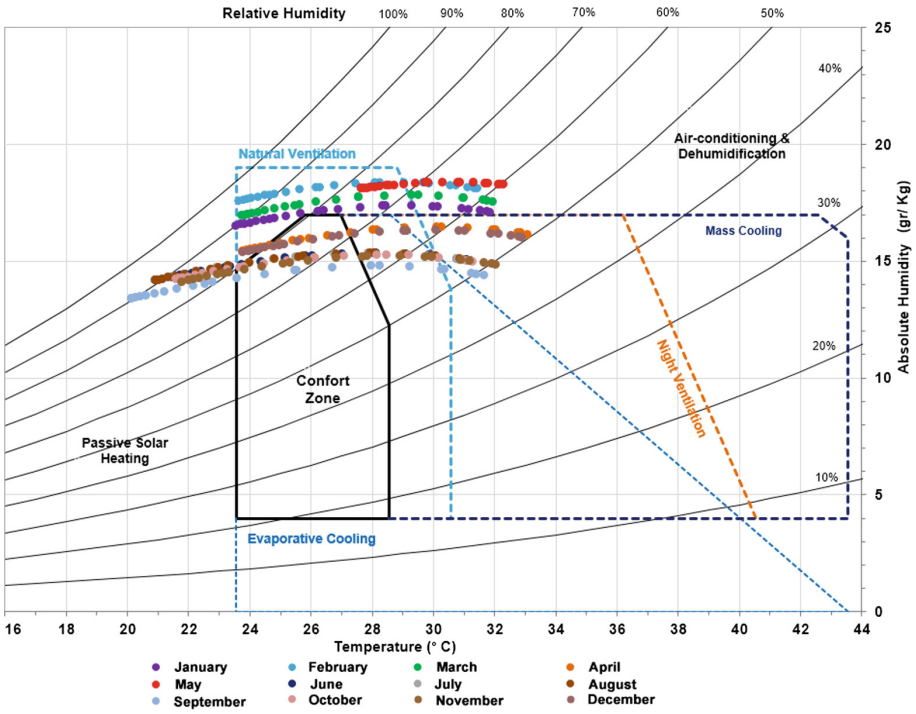


Fig. 4. Psychrometric chart for Guayaquil. Dots indicates hourly mean *temperatures* (°C) for each month of a year. *Natural* and *Night Ventilation* strategies are needed through all the year and it is even needed some heating at night and early morning during the hot-dry season as well as *Confort Zone* temperatures (*center*) at morning and night. During the hot-humid season, some *Air Conditioning and Dehumidification* recommended as well [9].

It is also required that the internal volume is the necessary one that hot air layers are not in contact with the users. This can be achievement with minimum heights of 3 m duly ventilated. The compactness of the home should be in the 1:2 ratio range to ensure adequate ventilation of its interior spaces, although authors like Olgyay recommend 1:1.3 to 1:1.7 with slender volumes [18].

Thermal transmittance of construction materials must be low to avoid as much as possible indirect solar gains within dwelling. In this order color, texture and finishes also play an important role. It is recommended finishes and highly reflective materials (albedo index) as well as low thermal emissivity [19].

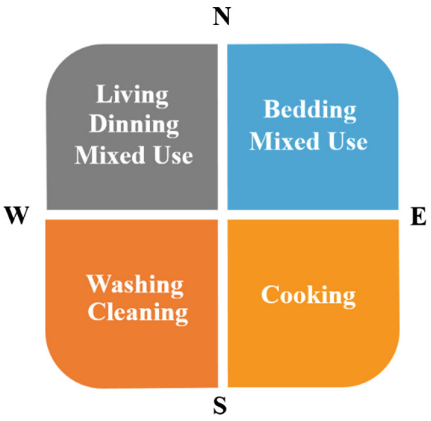


Fig. 5. Spatial arrangement for low-income dwellings. Mixed Use refers to a variety of domestic, economic and productive activities carried out by dwellers. Warm-humid equatorial coastal climate defines this scheme and is part of bioclimatic design resources.

3.1 Ecomaterials

The Ecomaterials are the product of a research agreement between SENACYT (now SENESCYT) and the Catholic University of Santiago de Guayaquil (UCSG), whose objective was to provide alternative solutions for elements and construction components based on the efficient use and management of local resources as seen at Fig. 6.

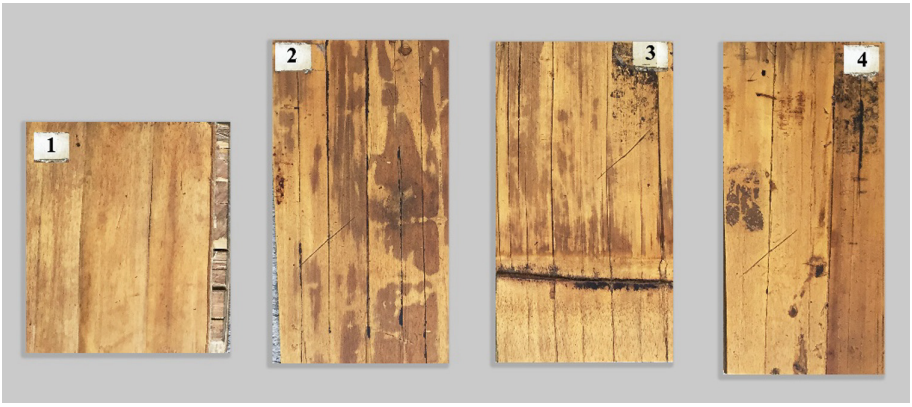


Fig. 6. Different types of ecomaterials made from natural fibers and bamboo (*Guadua Angustifolia Kunth*) as a result of the Project "Pilot plant for research, production and technology transfer in the use of innovative ecomaterials for low-cost housing construction", leaded by School of Architecture and Design (FAD) at Catholic University of Santiago de Guayaquil (UCSG). Triple bamboo horizontal and vertical layered panel (*one*); three types of bamboo sandwich-type panels: with coir fiber (*two*); with internal bamboo thread (*three*); and with internal layer of rice husk (*four*).

With this, we want to improve the constructive quality of low-cost housing, especially using bamboo [20] of the type *Guadua Angustifolia Kunth*, considered one of the three best bamboos among about 1400 existing species worldwide due to its high resistance.

Within the research process, four types of bamboo boards with dimensions of 2.40 × 1.20 m developed, which differ from each other in the manufacturing processes, orientation of the raw material and finishes. Its use is oriented to the construction of houses of social interest (VIS), as floors components, walls, division panels, coatings, ceilings, furniture, among others [20].

Over the years, research has focused on the study of other natural resources such as fibers from agricultural waste from coconut straw, banana and palm leaf fibers. This diversifies the solution options of the Ecomaterials to the different components of the dwellings.

Design for the architectural envelope and its systems of walls and roofs are fundamental in equatorial latitudes, as they are elements that receive a large amount of solar radiation. It is precisely here where the Ecomaterials play a key role to achieve optimal thermal performances in designing dwellings at Monte Sinahí.

4 Conclusions

Design of low-income dwellings must include bioclimatic criteria to respond adequately to a given climate reality. It should be designed with this focus not only the architectural envelope integrating materials and construction systems of good thermal performance, designs of windows and doors, but also spatial arrangements and zoning of interior spaces that respond to different climate scenarios.

Ecomaterials development has a primordial importance at present because they are natural and healthy products, free of chemical compounds and do not harm the environment. Its use in the design of dwelling spaces allows criteria of bioconstruction to be considered with a minimum impact on the ecological footprint, thus preserving the health of living beings and the planet.

The success consists of achieving a creative combination that takes into account technical, social and economic factors, using the existing raw material in the place and combining it with known technologies. By promoting the use of Ecomaterials and the application of bioclimatic design in the construction of social housing, it contributes to the care of the environment and the improvement of the quality of life of the inhabitants of Monte Sinahí, at Guayaquil, Ecuador [20].

Archetypes design of low-cost housing begins with the study of the social, economic and environmental context, thus characterizing the territory where the project will be built. In addition to dwellers, who are protagonists in the decision-making process.

With this knowledge, it is possible to give coherent answers integrating the architectural design, as well as the interior furniture to the social interest houses, taking into account the spatial analysis [2], ergonomic and anthropometric of the community; all as part of a systemic design process [21], where participatory design methodologies

in which the inhabitants of the sector or direct beneficiaries are part of the decision making, guarantee the sense of belonging with the developed solutions [4, 16, 22–24].

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Codesign of Public Spaces for Intercultural Communication, Diversity and Inclusion

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Abstract. The consistent phenomenon of immigration from countries with different cultures, that characterized the last decade, has changed the use of public spaces in European cities. The need to develop innovative solutions aimed at improving intercultural inclusion and mutual understanding of all citizens emerges, so that urban spaces become inclusive, safe and sustainable. This research project is focused on two main questions: (1) can design and technology enable the creation of a different way of living the public space to catalyze interpersonal interaction and to promote a shared sense of citizenship? (2) is it possible to support intercultural communication and to facilitate social inclusion through the design of innovative and interactive public spaces equipped with smart urban furniture? This paper presents three Design Orienting Scenarios as results of the research conducted by several experts, professionals and people with different cultural backgrounds during a focus groups and two different workshops where they made converge competences from design, business, engineering and social sciences to find innovative solutions for the social inclusion of migrants in urban areas.

Keywords: Social innovation · Design for inclusion · Public spaces · Smart technologies · Interculturalism

1 Introduction and Background

The current society is progressively becoming more and more complex. Indeed, the increasing number of businesses or other organizations developing international influence or starting to operate on an international scale changed how value is created and perceived while strengthening globalized economic relationships. At the same time, the bettering of international diplomatic relations and the raising of new policies for the free movement of people in widening geographical areas, such as the European

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Union, are changing the shape of our society. These changes of the global socio-economic scenario caused the emergence of the so-called post-multicultural era, which defines a society presenting intertwined effects of different phenomena: transnationalism, superdiversity, cosmopolitanism and solidarity [1]. Transnationalism indicates a social phenomenon due to the increased interconnectivity between people and the fading financial and cultural significance of boundaries among different countries. The term "superdiversity refers to the phenomenon of diversification of diversity, which consists of some current levels of population diversity that are significantly higher than before. Vertovec observed that superdiversity is distinguished by a dynamic interplay of variables among an increased number of new, small and scattered, multiple-origin, transnationally connected, socio-economically differentiated and legally stratified immigrants" [2]. It denotes increased diversity not only between immigrant and ethnic minority groups, but also within them. Cosmopolitanism refers to a shared feeling of belonging to a unique community based on an inclusive morality, a shared economic relationship, or a political structure that encompasses different nations. Solidarity refers to the ties in a society that bind people together as one based on kinship and shared values or other shared interests or goals.

The complex structure of contemporary society requires new policies able to recognize the inevitability of diversity in modern cities while supporting integration and inclusion. Such policies should adhere to the methodological interculturalism, which aims at incorporating diversity and difference into society's public culture rendering it object of affirmation. Methodological interculturalism indicates also the contact between people as the most important and appropriate way to drive integration [1].

Physical spaces can be designed to support such contact and, in the context of cities, public spaces can play a crucial role in catalyzing social encounter, also with strangers. Urban architecture already provided some examples of solutions for social inclusivity, e.g., public art interventions as shown in Sharp et al.'s paper [3]. Unfortunately, to our knowledge, there are not many examples of urban design dedicated to intercultural integration and inclusion. Although some research has already been conducted on the use of technology for the integration of migrants in new countries [4] and some preliminary work explored also the adoption of codesign techniques with immigrant teens [5], there is still an evident lack of work that focuses on intercultural integration in urban areas integrating digital technology.

As stated by De Lange et al., new technologies can enable smart cities to engage citizens and promote cocreation of new solutions [6]. We also believe that smart public spaces, i.e., public spaces augmented with new technologies, can be designed to foster intercultural integration and for this reason we started working directly with migrants to codesign novel concepts of smart spaces to respond to citizens' needs while valorizing diversity [7]. To this purpose, we started a project to explore the possibility to codesign smart public spaces for intercultural integration. The first phase was composed of two steps: a focus group and a "World Café" workshop. During the focus group, researchers and professionals working in different domains, mainly from design, political and social science and computer science, met operators and social workers in inclusion projects and integration of migrants, for analyzing together the current state of the art in urban architecture for multicultural integration, use of technology in public spaces, and design solutions for social inclusion. Thanks to this debate and exchange

between the participants, it was possible to generate the research questions to be answered during the following workshop. During this workshop, which adopted the World Café methodology, the participants (including researchers, migrants and cultural mediators) tried to identify the critical points of multicultural integration and inclusion for migrants and relative strategies to cope with these challenges (these results can be found in Rinaldi et al.'s paper [7]).

In this paper, we will present the second workshop, conducted after a few months, where researchers, migrants and cultural mediators tried to co-create different solutions to tackle the previously identified challenges to intercultural inclusion applying the strategies emerged during the previous workshops (Fig. 1). The result consists of three different concepts, depicted in Figs. 2, 3 and 4, which respectively present a nomadic gym, an itinerant escape room and a smart bus shelter. These concepts will be presented in detail in the remainder of this paper.



Fig. 1. One of the tables during the codesign workshop.

2 Methodological Approach

According to the codesign methodology the research questions were identified as a primary element of the research. The main questions were: (i) can design and technology be strategic factors in creating a different use of public spaces and facilitating citizens' interaction and sense of citizenship? (ii) is it possible to support intercultural communication and to facilitate social inclusion through the design of innovative and interactive public spaces by incorporating digital technologies in urban furnishings?

As already mentioned in the previous part, European cities are changing due the immigration of people from different countries bringing a variety of heterogeneous cultural backgrounds. There are many issues related to the integration and dialogue between cultures. Urban design plays a key role in how migrants participate in their host community and it is an important driver for the inclusion process. Promoting in

public spaces the interaction of different cultures becomes a crucial element to facilitate social cohesion and living together [8–10].

This codesign workshop aimed at investigating innovative solutions for facilitating migrants' integration and the dialogue between different cultures, through the design of innovative urban furniture and services, integrating smart technologies.

With this objective, researchers shared the design process with the other stakeholders, including users from different cultures, carrying out an activity of ideas' generation and of design concepts' development.

As Rizzo [11] and Sanders [12] wrote, this methodology have to be aimed more at identifying than at solving problems and focuses on the opportunities for innovation, emerging in the phase of ideas' generation, which will be used by designers to define innovative but plausible Design Orienting Scenarios.

The choice of codesign workshop derived from our desire to develop a project activity of a participatory nature together with the users by actively involving them, as this method allowed for designing products and services that are more useful and meaningful for people. For the development of the research, we decided to actively involve some immigrant citizens, coming from five different countries extra-UE, in the codesign workshop. In this way, researchers, expert of design, technology and social issues, were able to identify three different innovative scenarios of digital product-service systems for urban spaces, aimed at encouraging and supporting integration and intercultural dialogue.

Fifteen people participated in the codesign workshop, including designers, engineers, social scientists, professionals and operators working in the social field, educational scientists, immigrants and cultural mediators. During the co-design workshop, for understanding needs and expectations of all the stakeholders, involved and for stimulating the creativity of participants, the researchers exploited their skills and some of the tools normally used in the design discipline, such as design probes, storytelling, design orienting scenarios, prototypes, and design thinking models.

The development of project scenarios took into account the strategies, which were previously identified during the focus group, as fundamental to promote dialogue and intercultural inclusion.

The strategies we referred to are the following: (i) creating a network of interactions to stimulate intercultural exchanges between locals and migrants; (ii) educating for diversity; (iii) tackling of the gender differences in the provision of services or projects *(i.e., migrant women are wary of leaving their children in healthcare structures, and have problems of autonomy)*; (iv) working to maintain identity; (v) bringing of the different cultures closer together *(i.e., through themes such as school, work, food, dance, music and sport)*; (vi) use of catalysts, such as the linguistic tandem that allows two people of different cultures to confront each other and learn not only at a linguistic but also a cultural heritage level; (vii) creating of informal situations, which foster inclusion and direct human relationships [7].

The process adopted has been divided into three main steps: (i) the *"say"* phase, that means understanding needs and expectation of both local and immigrants; identifying the main factors of exclusion and/or inclusion in cultural heritage; exploring how different cultures use public spaces; (ii) the "*do*" phase: moving on to the discussion, collaboration, empathic relationship with the co-designers, for the generation

of ideas, concepts and possible solutions creative and summarizing insights; (iii) the *"make"* phase: discussing the insights and identifying a set of design domains for inclusive product-service systems in urban spaces, representing them through innovative and plausible Design Orienting Scenarios.

During the cognitive and exploratory activities, related to the "say" phase, participants told their experiences, documenting them through annotations, images, photographs, using different tools and methods that were made available by designers.

Once the previous phase was analyzed and the co-project brief was well identified, together with the participants, we moved on to the codesign activity: to the "do" phase.

Through discussion, collaboration, and empathic relationship with the co-designers, multiple ideas, concepts and possible creative solutions were generated. Finally, we arrived at the "make" phase, in which concepts of interactive urban place were developed and prototyped, represented by the designers in the form of three main Design Orienting Scenarios, better described in the following section.

3 Results

The workshop, which saw users involved as co-designers in the design process, led to defining and experimental prototyping some innovative, interesting and viable solutions concerning urban spaces and furnishings, in the form of product-service systems, for facilitating social inclusion of immigrants and intercultural communication among citizens.

Migrants have been given the position of 'experts in their own experience', playing an important role in developing knowledge, generating ideas and developing concepts of the products and services that they themselves will use. The ideas have been translated into three main Design Orienting Scenarios, which will play an important role in inspiration of design, as described below.

3.1 Scenario 1: Health and Wellness

The first solution is focused on sports and wellbeing (Fig. 2). Promoting good health and well-being is one of the key research areas promoted by the EU [13] as well as one of the sustainable development goals of the World Health organization [14]. In a superdiverse society, promoting health might imply additional challenges that cannot be solved through traditional interventions. This first scenario tries to address this challenge through the identification and the design of a public space installation for promoting and supporting fitness activities. Such solution could consist in a set of gym equipment to be installed outdoor in parks, squares and neighborhoods or indoor, in schools. As sport in public space could be an opportunity for socialization, this scenario aimed at identifying a common playground for younger people, both millennials and kids ac-companied by their parents. For the first target user group of this wellness installation, technology was identified as an opportunity both for socialization and for increasing motivation in engaging in physical activity, giving an opportunity to the youngest generation to track their physical performance, to compare it with other users and to challenge each other. Dance and music were also seen as an opportunity to foster

engagement in physical activity while also valorizing cultural heritage. While the opportunity to have fun and enjoy dance was considered as appealing also for parents with their kids, a possible barrier was individuated for a part of female migrants, whenever their culture would hinder them from enjoying physical activity in fitness outfits. To facilitate their participation to such activities, the identified design solution was a capsule to be installed in the public space, close to the other fitness installations. The proposed capsule would allow female migrants enjoying in fitness activities in a discreet space, with their kids and/or with other female migrants.

A digital platform will augment the capabilities of this nomadic gym providing information, about fitness classes and their schedules, and allowing registration for a selected class. At the same time, this platform can enable facilitated sharing of these events in order to motivate other people in the participants' social network and to catalyze the establishment of new relationships through the social media.

3.2 Scenario 2: Learning and Cultural Heritage

Promoting interculturalism and social inclusion implies a reciprocal understanding of cultural habits and traditions, as well as a good knowledge of local policies and bureaucratic processes of the hosting country (Fig. 3). As both locals and migrants might have difficulties to find (and often little interest in looking for) such information, the challenge of this scenario was to identify a solution to motivate people to get interested in and retain information about different cultures and about local policies. Indeed, policies and bureaucratic processes are often provided by institutions in a format that is complicated and difficult to understand even for locals, while little information is often provided about the culture of the different communities inhabiting an urban space. The solution identified for this scenario is an escape room, a social game that is particularly popular among millennials, but that is also enjoyable by people of all ages. The escape room could be realized in an itinerant format, to be moved from time to time in different public spaces of the city, such as parks, squares, neighborhood, schools and shopping centers. The content of the escape room should be varied and should be targeted at acquiring knowledge about uses and traditions of the different communities living in the surrounding of the public space where the escape room is installed. At the same time, the content should also facilitate learning of the bureaucratic processes that citizens of all communities might encounter during their daily life in the city. As entering the escape room with a multicultural team might facilitate the solution of the riddles required to win the game; socialization between different communities and learning through problem solving will be particularly facilitated. Some challenges have been identified for the sustainability of such solution: rich and varied content is required to raise the engagement of participants and a moderator is required to ensure the best experience during the game. Moreover, such installation should be easy to move to different places of the cities in order to reach the maximum number of citizens.

3.3 Scenario 3: Free Time, Work, Movement

The third scenario was intended to address a more practical need of people with different backgrounds to exchange ideas, services and skills (Fig. 4). In this case, the urban space is transformed in order to allow everyone to easily share information with other citizens, in an accessible and decentralized manner. This sharing info point could be physically materialized into either a multi-ethnic interactive totem, or a table where people can sit with real and virtual guests (for example, with chairs that integrate interactive screens in the backrest), or a smart interactive glass (for example, integrated in a shelter). In all these cases, video-messages can be shared by any citizen looking for particular skills or support or offering particular services or help. Users looking for a job or skill offer could browse the content and listen to messages left by other users, eventually meeting in person with other people sharing ideas at the info point. This solution might foster synergies among citizens and promote the inclusion of people with different needs and backgrounds. Challenges that should be taken into consideration in this scenario are a secured authentication of the users leaving video-messages, as well as a moderation of the contents left by the users. A risk to be avoided is transforming the public space into a ghetto of migrants, where locals would be afraid to gather. To this purpose, such info points should be installed in strategic places where all citizens are already gathering, for example in a park where kids can play together, in a bus stop, in a shopping center or in a school. At the same time, accessible and attractive interactive systems may lower the barriers for citizens to approach the service and to share and access such information.

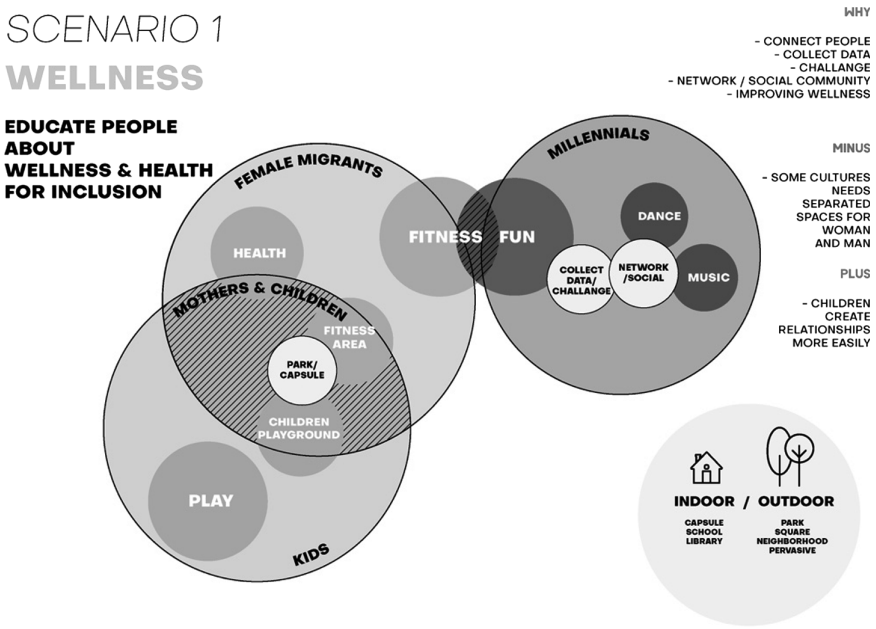


Fig. 2. Design Orienting Scenario to present the concept of nomadic gym

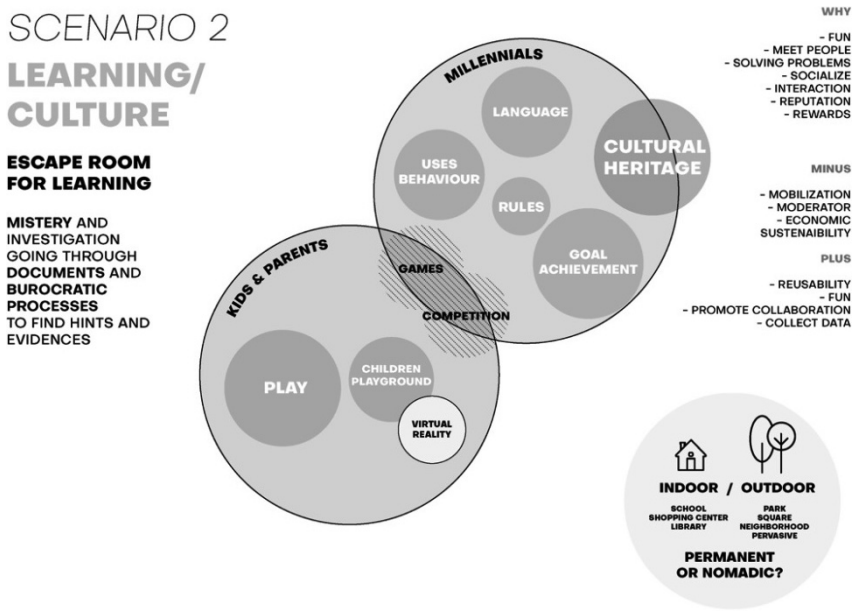


Fig. 3. Design Orienting Scenario to present the concept of itinerant escape room.

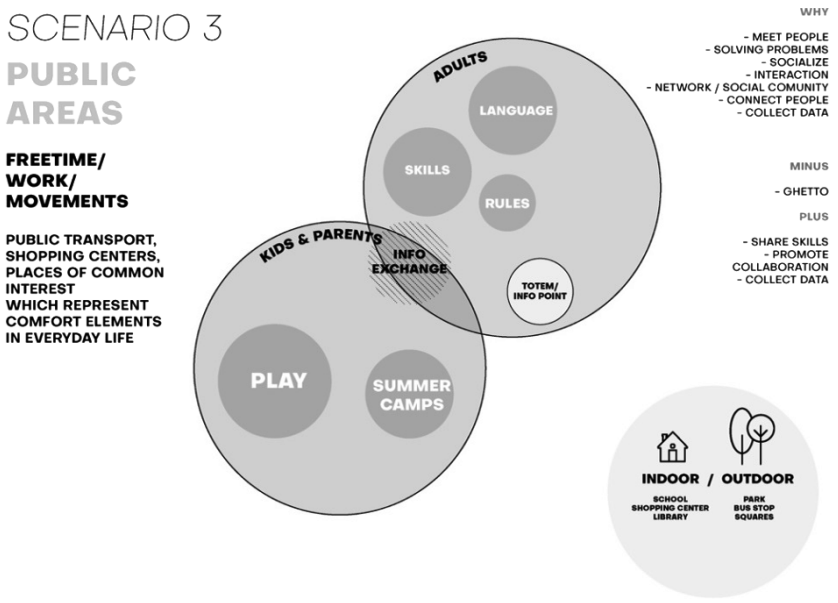


Fig. 4. Design Orienting Scenario to present the concept of smart bus shelter

4 Conclusions

In this paper, we presented the results of the second workshop adopting the codesign approach for the participatory creation of solutions that leverage smart public spaces as a catalyst for intercultural communication, diversity and inclusion.

This research has opened a reflection on the factors of exclusion that may compromise the use of and the access to urban spaces and services by all citizens, highlighting the need of a systemic and transdisciplinary design approach, which considers the intercultural factor, characterizing the contemporary cities. The use of, the access to, and the participation in the activities and services provided in urban areas may be affected by cultural, social and political factors, by economic status and linguistic difficulties of the users. Due to the complexity of the relations and the interactions of these aspects, a multi-domain and systemic design attitude is required in applying social inclusion and cohesion approaches in these contexts.

The barriers identified as the main causes of exclusion, discrimination and lack of cohesion between different cultures, even among the second young generations, are mainly four:

- Cultural barriers
- Social barriers
- Economical barriers
- Legal and political barriers

These barriers must be considered within the usability assessment and the design process of public spaces for intercultural communication, diversity and inclusion, where the main objective should be to prevent any kind of potential exclusion.

Furthermore, this means that it is necessary to adopt a systemic approach where the product-service design is a dynamic, under changeable, human-centered, open and codesigned part of the system [15].

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Development of an Anthropometric Protocol for Wheelchair Users: Guiding the Decision-Making for Designing Inclusive Spaces

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Abstract. This paper describes the steps taken toward the development of an anthropometric protocol. The protocol was conceived as a tool for the design of inclusive built environments considering wheelchair user characteristics. The process followed for developing the protocol consisted of two stages. The first one included reviewing the type of dimensions, application context, methods and user profiles within the available literature. The second stage consisted in the corroboration of order and relevance of the measures proposed as well as the measurement instruments and the way of approaching participants. This protocol considers a total of 16 dimensions including height, reach and depth measurements. The paper describes the method, measurement landmarks and the tools used to take the measurement. To guide the application of the protocol a table was developed with recommendations on the use of certain percentiles according to the interaction of the user with the environment.

Keywords: Wheelchair users · Inclusive spaces · Design guidelines · Built environment

1 Introduction

The public built environment should accommodate all users to be a facilitator of daily life activities considering the particular characteristics of all population groups. Providing easy access without any additional adaptation [1]. According to World Health Organization [2] physical barriers are a crucial aspect that hinder service delivery and interferes with the participation of people with disabilities in education, social and productive life causing a disparity when compared to people with no disabilities. Also, the WHO [2] report includes nine recommendations to help in reducing the gap for people with disabilities, among them are: reinforce and support research about disability, improve the data gathering about this condition and allow the access to all conventional services and systems.

In the Mexican national context, some efforts have been made towards creating more inclusive spaces for all groups of the population. Among them are design

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guidelines for the interior design of public buildings and exterior spaces. Some of the main references are the standards *Manual de normas técnicas de accesibilidad, Gobierno de la Ciudad de México* [3], *Criterios de proyecto de arquitectura para la accesibilidad de las personas con discapacidad* [4], *Normas y especificaciones para estudios, proyectos, construcción e instalaciones* [5], and *Recomendaciones de accesibilidad* [6]. It must be said that the documents mostly fail in providing the origin of the anthropometric data. In some cases data were outdated, or they were from other populations. This situation has been suggested to cause a disparity between the data shown in the handbooks and the current population [7].

Previous protocols reported in the academic literature has considered the characteristic of wheelchair users. Nevertheless, these works were oriented to the design of workspaces [8, 9] or to propose dimensions for other more general applications [10]. Therefore, the interaction with the built environment is not considered with an impact on the way of measuring the user. The interaction of wheelchair users with space is mediated by the wheelchair making it necessary to collect the dimensions of people, but conceiving the user and the wheelchair as a whole.

Although numerous efforts have been made to inform the design of inclusive built environments (IBE), it is considered important to continue in this direction, since there is still a lack of information and standardization for the measurement of wheelchair users for this application purpose.

The objective of this work is 1. to develop an anthropometric protocol that allows standardizing measurement techniques for wheelchair users required for the design of IBE and 2. propose criteria for percentile application in the design of IBE considering wheelchair user. Objectives aligned with [11] recommendations, to reduce the current gap in methodology and application of anthropometry by HF/E professionals and designers to create safe and effective products or environments for a wide range of users, taking steps to ensure well being and human dignity to all users.

2 Methodology for Protocol Development

The procedure was divided into two stages. First, a literature review was made to analyze the current contributions to the subject. Second, a corroboration stage was done. Through the literature review, the landmarks and method references were obtained. In the corroboration stage, the order of the measurement and application of the protocol was tested, as well as the collection of data regarding daily life activities of wheelchair users. This, to incorporate the vision of the active user aligned with the contemporary concept of disability.

2.1 Literature and Documental Review

In the literature review, official Mexican standards were consulted to identify the available information for the design of IBE for wheelchair users. Specific information about the landmarks and the measurement method was missing. Therefore the information obtained from these documents was through the analysis of the graphic schemes regarding wheelchair users in interaction with the built environment. The consulted documents are the following:

- Manual de normas técnicas de accesibilidad (Handbook of technical guidelines for Accessibility; Gobierno de la Ciudad de México, 2016)
- Criterios de proyecto de arquitectura para la accesibilidad de las personas con discapacidad (Architecture project criteria for the accessibility of people with disability; Instituto Mexicano del Seguro Social, 2011)
- Normas y especificaciones para estudios, proyectos, construcción e instalaciones, (Standards and specifications for studies, projects, construction and facilities; Instituto Nacional de la Infraestructura Física Educativa, 2010)
- Recomendaciones de accesibilidad (Accessibility Recommendations; Buenfil-Garza and Gutiérrez-Brezmes, n.d.)

Altogether these documents include exhaustive graphic descriptions of the wheelchair user in interaction with public and private spaces. Even though these are not anthropometric protocols, they allowed identifying some of the user dimensions required for the design of IBE. Which, has been translated to the proposed protocol into the appropriate landmarks and the dimensions (total length of human-wheelchair system and elbow to elbow width, see Table 2), as well as the need for the consideration of the person and the wheelchair as a system. On the other hand, some of the standards did not include the date, reference and population of the data. In other cases, the data was outdated or from other populations. Also, the criteria of data application regarding percentiles were not clearly shown.

With the objective of analysing measurement methods, a search was done in different specialized publications (Applied ergonomics, Ergonomics and Industrial ergonomics). The work related to anthropometric protocols for wheelchair users were considered to analyze the method and the dimensions included. In Table 1 a comparison of the methods, dimensions and consideration of the wheelchair is made.

Table 1. Previous protocols used as a reference for the development of the present protocol.

Author	Measurement method	Dimensions
Nowak [9]	Direct manual measurement on a special chair according to Martin-saller's method cited by Nowak [9] and graphic calculation from data. Subjects were measured without their wheelchair	Stature Eye level Shoulder height Elbow height Knee height Popliteal height Trunk depth Buttock-popliteal length Thigh thickness Shoulder breadth Maximum elbow breadth Elbow breadth Arm overhead reach Arm reach forward Arm reach down Lateral reach Arms span

(*continued*)

Table 1. (*continued*)

Author	Measurement method	Dimensions
Jarosz [8]	Direct manual measurement on a special chair according to Martin-saller's method cited by Nowak [9] and Jarosz [8] graphic calculation and calculation with an average wheelchair. Subjects were measured without their wheelchair, an adjustment was calculated by a mean dimension of the wheelchair, according to Skaradzinska cited by Jarosz [8]	Stature Eye height Shoulder height Elbow height Knee height Popliteal height Trunk depth Popliteal depth Thigh thickness Shoulder breadth Hip breadth max Elbows span Arm overhead reach Arm reach forward And the following calculated measurements Floor to vertex Floor to eye plane Floor to shoulder Floor to elbow Floor to top of thigh Floor to overhead grip reach Floor to upper grip reach Forward reach from front of wheelchair Forward reach from abdomen Lateral reach from side of chair
Das and Kozey [10]	Photogrammetry Subjects were measured on their wheelchairs	Seated stature Eye height Shoulder height Forearm height Knee height Toe height Max reach height Overhead reach Normal reach Radial arm length Maximum reach Trunk depth Bi-deltoid width Acromion width Elbow width Overall length Seat pan height

Other protocols and projects focused on anthropometry were found. Nevertheless, most of them were omitted for this study due to their focus on other populations, such as elderly people [12] or population with cerebral palsy [13], or because their descriptions were focused on data application [14], without specific information about the anthropometric measurement process.

Contributions of the reviewed authors are integrated to the proposed protocol under a systemic approach that considers and measures the user together with its own wheelchair as a human-wheelchair system [10]. Due to its accuracy, the direct manual measurement was selected among the reviewed methods. Furthermore, verification of definitions and landmarks was performed. Among the authors some of the measurements are named differently but measured in the same manner, others are proposed completely different. The work from Jarosz [8] and Nowak [9] focuses mainly on the development of workspaces, and therefore the dimensions are oriented towards reach.

In the reviewed documents (standards and protocols) height dimensions are similar by considering the user and the wheelchair as a unity resulting in some cases in measurements from the ground to the body landmark. For reach dimensions, some landmarks are similar from the graphics shown in the handbooks and the reviewed protocols, although some others and the measurement methods differ. As a final step in the literature review the International Standard ISO 7250-1:2010 [15] was consulted to verify the landmarks and instruments proposed.

2.2 Corroboration

This stage aimed to corroborate the order and pertinence of the measures proposed as well as the measurement instruments and the way of approaching participants. In this stage, a total of 14 wheelchair users participated. Eleven men and three women aged between 19 and 50, most of them had more than fifteen years of experience using a wheelchair. All participants had total or partial dexterity of the upper extremities and were active wheelchair users, having autonomy to perform everyday activities without assistance.

For the anthropometric data collection, the following instruments were used: Martin anthropometer and a Vernier type callipers (700 mm), and a measuring tape. Additionally, a questionnaire was adapted from the Evaluation of Daily Activity Questionnaire [16] including open-ended questions to assess the difficulties of the wheelchair user in everyday life. Specific results from the questionnaire had been published [7].

From this sample was confirmed that this protocol could be used to measure participants in different environments such as work or study place. The dimensions proposed corresponded to some problematic experiences in built environments reported by the participants in the questionnaire, confirming its applicability. Also, the order of the dimensions was adjusted to ease the process. In detail, a change was done in dimension Maximum vertical reach sideways to a wall (see Table 2). Initially, the dimension was extracted from the graphic information in the handbooks, although from the questionnaire to participants it was identified that the real manner for wheelchair users to reach things over the head did not match this description.

3 Protocol Description

This protocol is conceived for the application of its data in the design of IBE. The set of 16 dimensions can be classified into three categories; the dimensions strictly of the person, the dimensions of the human-wheelchair system and the dimensions of the wheelchair alone, even though the latter are not strictly anthropometric dimensions, all are necessary for the design of spaces since the interaction of the person with the space occurs in the wheelchair. The data collection method is direct manual measurement.

After obtaining the consent of the participants, it is essential to consider the following basic guidelines: (1) All measures must be taken in the participant own wheelchair, (2) Participants should wear their normal clothing including shoes, only removing jackets and other bulky clothes, (3) Measurements are taken by a group of two applicants (preferably a man and a woman for the ease of participants). One is in charge of measuring the participant while the other assists in the process and captures the dimensions in a format, (4) For all the dimensions a Martin anthropometer was used, except for 11 and 16, (5) People should not be forced to adopt postures they find uncomfortable or painful, and (6) When possible, all dimensions are measured in the right hemisphere.

Table 2. Proposed dimensions in the protocol

Dimension	References landmarks and measurement postures
1. Total height of human-wheelchair system	Vertical distance from the ground to the highest point of the head (vertex), with the subject's head oriented in the Frankfurt plane. Measuring view: sagittal plane
2. Total length of human-wheelchair system	Length from the rear surface of the human-wheelchair system to the farthest front. Measuring view: transversal plane
3. Eye height	Vertical distance from the ground to the outer corner of the eye (exocantion) with the subject's head oriented in the Frankfurt plane. Measuring view: sagittal plane
4. Shoulder height	Vertical distance from the ground to the upper side of the acromion with hands on thighs. Measuring view: sagittal plane
5. Elbow height	Vertical distance from the ground to the lowest bony point of the elbow (radial humerus joint commissure) with the arm flexed at a 90° angle. Measuring view: sagittal plane
6. Wheelchair height	Vertical distance from the ground to the highest point of the wheelchair. Not including the person. Measuring view: sagittal plane
7. Armrest height	Vertical distance from the ground to wheelchair armrest. Not including the person. Measuring view: sagittal plane
8. Handrim height	Vertical distance from the ground to the top of the handrim. Measuring view: sagittal plane
9. Highest landmark closest to the knee	Vertical distance from the ground to the maximum point of the flexed leg near the knee (upper patellar zone). Measuring view: sagittal plane
10. Toe height	Vertical distance from the ground to the tip of the toe. Measuring view: sagittal plane

(*continued*)

Table 2. (*continued*)

Dimension	References landmarks and measurement postures
11. Maximum vertical reach sideways to a wall	Maximum distance from the ground to the knuckle of the middle finger with the right arm and body leaning against the wall. A tape measure placed one-meter-high from the ground is used as a reference. The participant can hold a flat object in the palm to ease the measure identification. Measuring view: sagittal plane
12. Elbow to Elbow width	Length from elbow to elbow with hands at the top of the handrims, separating the elbows to the maximum possible point. Measuring view: coronal plane
13. Lateral reach	Length from the middle of the collarbone (suprasternal notch) to the knuckle of the middle finger, with the right arm extended laterally. For better support and accuracy, subject must have the back against the wall. Measuring view: coronal plane
14. Frontal reach	Length from the acromion to the middle finger knuckle, with the right arm extended forward and the fist closed. Measuring view: sagittal plane
15. Thorax-chair depth	Length from the farthest posterior point of the chair to the chest (mesosternal point). The chair must be against a wall and the subject leaning against the backrest. Measuring view: transversal plane
16. Thorax depth	Length from the backrest to the farthest point of the chest (mesosternal point). For this dimension, a Vernier type calliper 700 mm is used. Measuring view: transversal plane

Note: For a graphic description of the dimensions see Fig. 1.

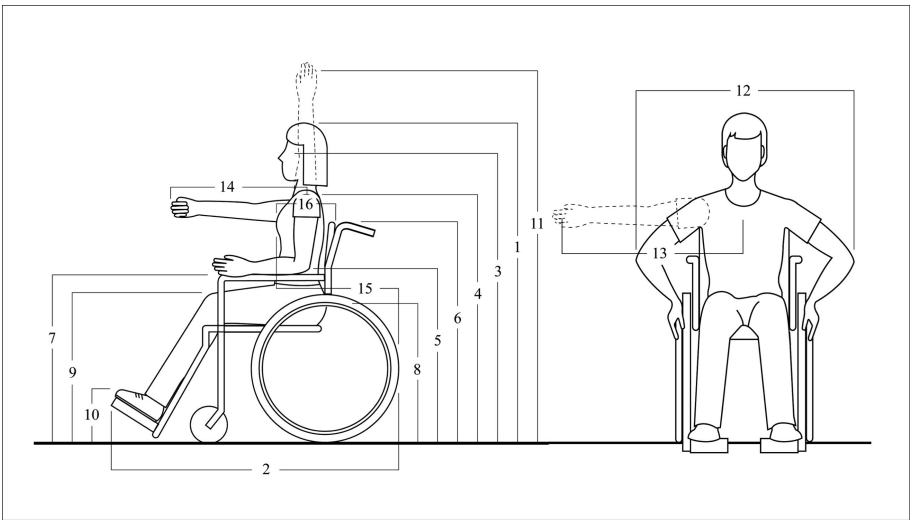


Fig. 1. Anthropometric dimensions proposed in the protocol. The annotation corresponds to the description in Table 2.

From the review of the official documents for the design of inclusive spaces, some gaps were identified. The following criteria were elaborated to respond to these gaps, considering the capacities and limitations of wheelchair users. The development process (Table 3) was nourished with data obtained from the corroboration stage with wheelchair users. The 5th percentile of the female users was considered to define the dimensions regarding reach, surfaces and sight. The 95th percentile of male users for clearances [17].

Table 3. Recommended criteria for selecting the appropriate percentile to apply in the design of public spaces considering wheelchair users.

Application	Criteria
Minimum width of the pedestrian zone	Maximum width of elbow to elbow while grabbing the handrims of the wheelchair, of the 95th percentile, multiplied by two plus clearance
Minimum size for waiting area before pedestrian crossing	Area determined by the maximum width and length of the 95th percentile human-wheelchair system
Minimum corridor width	Length from elbow to elbow while grabbing the wheels of the wheelchair, of the 95th percentile, multiplied by two, plus clearance
Minimum door width	Length from elbow to elbow while grabbing the wheels of the wheelchair, of the 95th percentile, plus a tolerance
Elevator operating controls, contact, window or button	Frontal reach of the 5th percentile, height at eyes. 5th percentile
Information guides for spatial orientation. Except emergency signals.	Eye height of the 5th percentile. (This is a general recommendation and dimensions of the signals must be considered, determining height case by case)
Maximum height for counter surface	Height at elbow in seated position, 5th percentile
Maximum sink height	Height at elbow in seated position, 5th percentile
Sanitary spaces (dimensions of toilet cubicle, dimensions of door, height of handrails)	Area determined by the maximum width and length of the 95th percentile human-wheelchair system, plus the estimation of their companion, plus a tolerance and the path needed for the use of the facilities
Height of handles	Height at shoulder in seated position. 5th percentile
Public emergency phone	Dial pad should placed at height at eyes. 5th percentile
Lifting platform surface	Area determined by the maximum width and length of the 95th percentile human-wheelchair system, plus the estimate of their companion, plus a tolerance

4 Discussion

The proposed protocol is suitable for the purposes of spaces, workstation and furniture design; it is acknowledged some measures may not be useful for other purposes. For example, if dimensions of the user or the wheelchair alone are needed. Although the data collection is easier and can be performed in several environments such as the work or study place of the participants, making data collection easier to obtain and feasible with fewer resources.

Some of the dimensions needed for the design of spaces do not appear in the protocol but, they can be inferred from the rest of the dimensions. For example, to determine the width of a corridor with circulation in both directions, the authors inferred the dimension from the measurements *elbow to elbow width* and *total length of the human-wheelchair system* (see Table 2).

Other authors [8, 9] measure the user separately and then consider the wheelchair dimensions, which results in a data set suitable for multiple purposes, but being less specific regarding the variation of wheelchair types and more complicated to obtain. The particular characteristics of each context will determine the relevance of considering certain dimensions.

As well, other protocols, for more accurate measurements, establish that participants must wear a very light layer of clothing [15], although for the nature of data application, in the design of IBE, clothing is not considering a main factor to interfere with the dimensions.

Due to resource limitations, this research focused only on wheelchair users. However, efforts to include those who use physical aids, visually impaired people and all those whose travel requirements are not considered with the current infrastructure are still missing. It is acknowledged the importance of collecting data from all user groups to inform the development of truly inclusive environments.

5 Conclusion

The development of the present anthropometric measurement protocol is a proposal that integrates the contributions of researchers, design guides, and the view of wheelchair users for the application in the context of IBE.

The insights gained from this study may be of assistance to architects, urban designers, human factors and ergonomics professionals and stakeholders to provide criteria to guide decision-making for the design of IBE.

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Designing a Pilot System for Sustainable Villages for All

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Abstract. The rapid change of the Chinese society in the last 20 years, with the biggest urbanization process ever observed, the growing economic and social gap between the remaining rural population and the much more sophisticated resident of the large cities of the coastal area of the East, has been pushing the Chinese government to intervene with several policies aimed to reduce the west-east migration. However, the different policies designed with this aim are not yet reaching the desired impact and their implementations are often not focusing on the need to preserve also the cultural heritage of the Chinese countryside. This paper discusses the applied research on the points mentioned above, focusing on design solutions for a sustainable and innovative pilot system which promotes economic and ecological sustainability, social innovation and re-defines marginality through innovation within tradition.

Keywords: Design driven social innovation · Design for all · Sustainable business · Cultural bridge · Elderly · Rural · Marginality

1 Introduction

Despite the average increase of the income per-capita and the very strong decrease of the number of people living under the poverty threshold, the inequality in China (represented by the GINI index) is still higher than that one of the most developed economies (Fig. 1).

According to the 2016 Statistical Report on Urban and Rural Construction issued by the Ministry of Housing and Urban-Rural Development of the People's Republic of China in 2017, there were approximately 2.617 million natural villages in China in 2016. The natural village (Chinese: 自然村) is a unit of daily life and communication of farmers, often belonging to the same family, but it is not a social management unit. Several natural villages constitute an administrative village (Chinese: 行政村), a rural grassroots management unit established by the state in accordance with the law, with a village committee and a party branch committee. In China there are more than 650.000 Administrative Villages, out of which approximately 5000 are recognized as traditional villages.

Any intervention to improve the quality of life and the economic and social environment in the rural areas will face a very high level of complexity.

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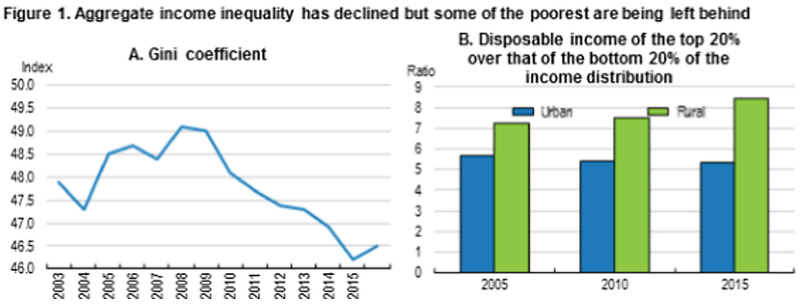


Fig. 1. GINI index trend and allocation of income in China (OECD 2017)

2 The Difficult Life of the Rural Population

The mass migration from the vast rural areas of the west to the more developed areas in the east (Fig. 2), with the resulting progressing reduction of the number of the farmers (and of the food produced by the family farms), although increased the average income of the previous farmers, now transformed for the largest majority in migrant factory workers, created an even bigger divide between the urban population and the countryside.

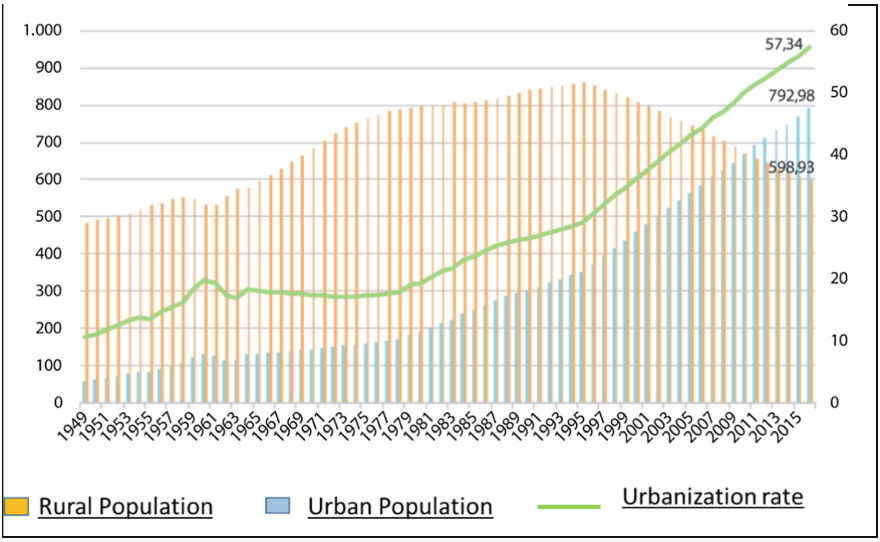


Fig. 2. Evolution of urbanization in China [2]

Furthermore, in the process of urbanization of Chinese society, two new types of families emerged, mobile families and left-behind families. There are 70 million left-behind families in the country, involving 240 million people, of which 77% are rural

left-behind families. Rural left-behind children accounted for 35.1% of all rural children, left-behind women accounted for 6.1% of rural married women, and left-behind elderly accounted for 23.3% of rural elderly.

The development of Rural China aims to focus on its diversity and cultural richness parallel to the improvement of the local living conditions and the poverty alleviation in the rural villages.

National policies, ranging from traditional subsidies based to more advanced integrating social, economic and environmental development support this vision and play a relevant role in it. The growing government investment "Poverty Alleviation" policies aim to bring the entire rural population above the poverty level by 2020 (Fig. 3).

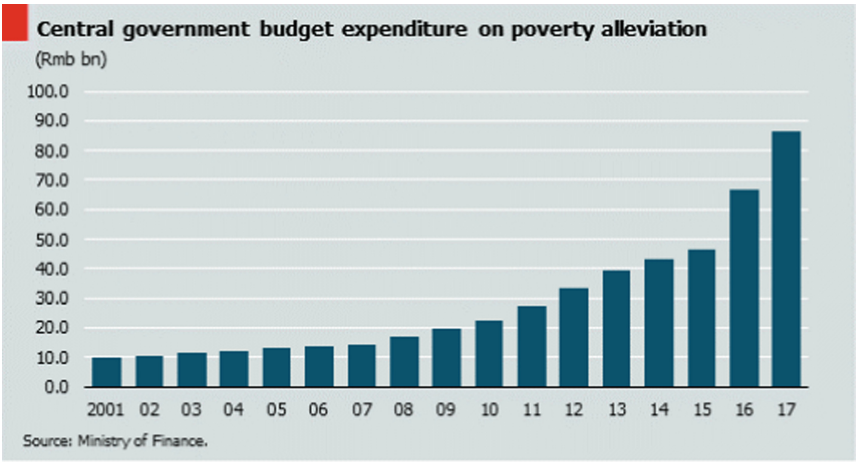


Fig. 3. China government investments in poverty alleviation are steadily growing [3]

However, one of the key components of the poverty alleviation was the resettlement, where rural residents are moved to small towns, still reducing the employment in agriculture, detaching people from their familiar environment and cancelling the cultural heritage of the smaller villages.

The "Beautiful China" campaign, launched by President Xi, supports integrated actions for a better (cleaner) environment and to recover the tradition and culture of China, which is still mostly present in the rural areas, in the original architecture and rural landscape and in the soul and the memories of the elderly.

Significant investments have been made and other were planned in order to improve the quality of living in the rural areas. As jointly stated by General Office of the Communist Party of China (CPC) Central Committee and the General Office of the State Council in February 2018, "although progress has been made, the living environment in rural China is very unbalanced with many areas in the grip of dirt and disorder. It falls far short of people's expectations and marks a key weakness in social and economic development". The three years action plan unveiled in that occasion

includes garbage sorting, toilet upgrades, residential sewage treatment and village management [4].

The "Characterizing small town" policy supports systemic interventions where design can impact social, culture, economic and business interactions.

3 Rural Elderly Issue

China's population is becoming more and more aged. In 2017, China's elderly population over 60 years old has exceeded 230 million. It is the only country in the world with an elderly population of over 200 million.

There are more than 88 million households in China with over 65 years of age, accounting for more than 20% of households in the country.

In 2013, the number of disabled elderly people in the country reached 37.5 million. It is estimated that the number of disabled elderly people will exceed 40 million in 2015. In sharp contrast to the rapid growth in the needs of family support, family capacity is weakened due to shrinking family size and time resources.

Among them, the rural left-behind elderly families and the elderly living alone are the most prominent (Fig. 4).

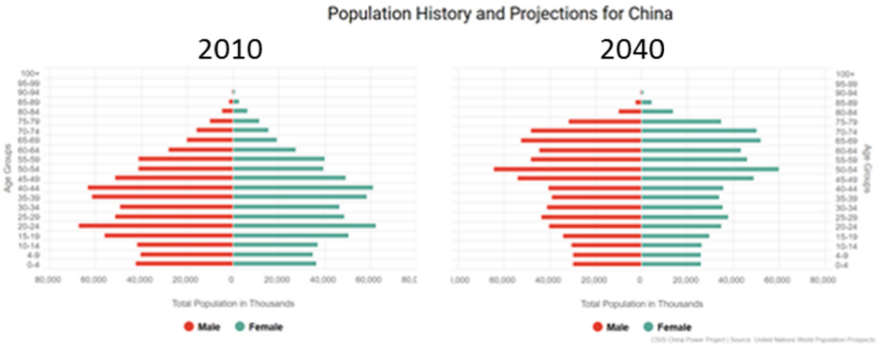


Fig. 4. Demographic composition of China in 2010 and 2040 projection [5].

One of the effects of the solitary life of the rural elderly is the dramatic increase of the rate of suicides, presently one of the highest globally [6]. Policies and specific activities aimed to slow down this process are quickly needed.

4 The Evolving Needs of the Urban Residents

The population of the urban areas is showing a strong increase of attention to health, environment and healthy food, also driven by the many food scandals Chinese customers faced in the last few years. A McKinsey research [7] shows "a decrease in consumption in categories deemed less healthy and a willingness to spend significantly

more on health and more environmentally conscious categories…….(omissis) … consumers seemed more concerned with these issues in 2015 than they were before".

This is driven by several forces:

(a) The continuously increasing spending capacity, with the expansion of the upper middle class (Fig. 5)

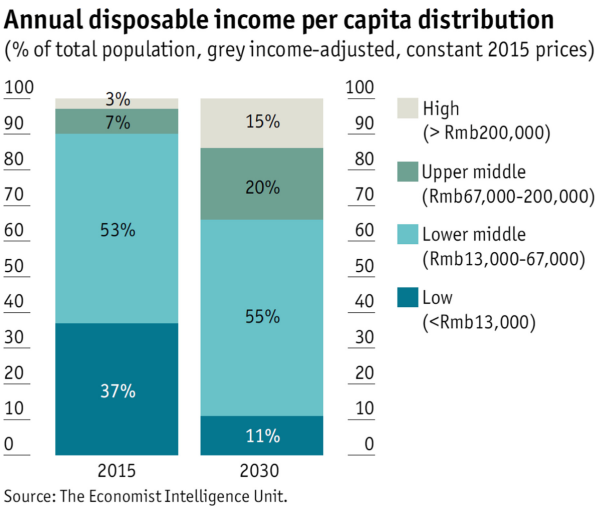


Fig. 5. Distribution of annual income in China 2015–2030 [10]

Although several cities will register a big growth of the average per capita income, the Tier 1 cities market are still foreseen to be accounting for the largest part (Fig. 6).

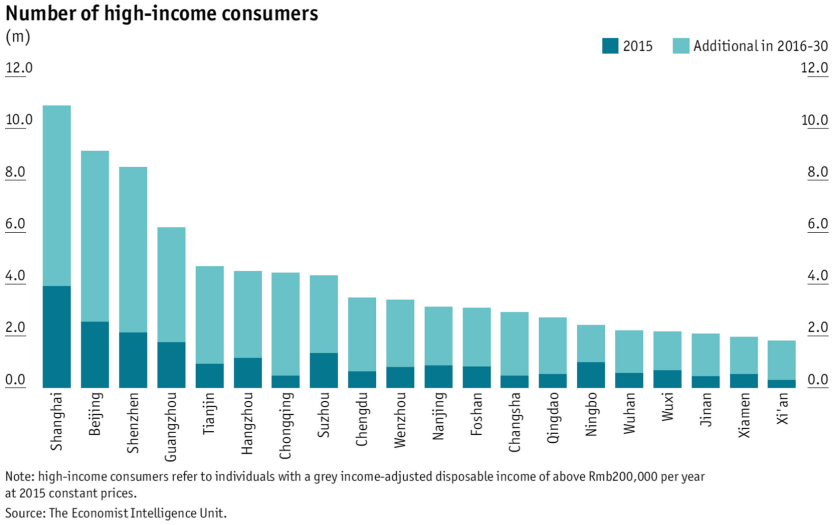


Fig. 6. The 20 most important Chinese cities in terms of income per-capita in 2015 and 2030

(b) The increase attitude to indulge in personal consumption. McKiney (2016) reports an increase of the willingness to spend to get better quality and of the attention to a better quality of life. In 2013, health care and nutrition products jumped to number 2 among 15 product categories in which Chinese consumers plan to spend more, up from number 11 in 2011 (BCG 2014). A survey performed in 20 Chinese cities in 2014 showed that 80% of respondents were not satisfied with food safety and thought the major responsible are food companies and food industry association. A recent research shows that 88% of consumers are willing to spend more in order to get healthy foods, organic and without food additives [9]. The same source reports that

- "Over 30% of consumers in the cities of 1st and 2nd rows often buy organic food. Consumers seek foods with fewer pesticides that can harm their health. Having a child will influence on how to consume the foods, parents are more vigilant about food. Families with high income are willing to pay more for organic food".
- Although the experts' projections [10] show a decline of the % expenditures in food, the healthy food does belong more to the categories of health products and healthy and organic food is often seen as a luxury product.

(c) The strong connected of food with health in the traditional Chinese culture, which expects meals to be nutritionally balanced and to use natural ingredients. From our research, in Shanghai only there is more than 15000 vegetarian belonging to one or the other organization. Wechat (the most common social network in China, with more 800 million of users) hosts more than 20 chats only in the Shanghai area, focused on healthy food/vegan/vegetarian/organic, etc. The Beijing Farmers Market has a network of 30,000 WeChat followers. International market research company Organic Monitor estimated that in 2013 the market for organic foods in China had reached about 2.4US$ billion, compared with less than US$100 million of 10 years before [11]. On top of many companies providing "organic" food sometimes supplied by rural farms, cooperatives of farmers, focusing on fair and organic farming, are starting to emerge and represent an opportunity to establish sustainable business models for small scale. This is made much easier by the e-commerce that is now the standard way of purchasing for hundreds of millions of Chinese, which generally trust more online platform than traditional shops and which is becoming the standard way to purchase food in China [12].

5 Proposed Project

5.1 Rationale

Eco and gastronomic tourism is perceived as a possible effective driving force for the development of the villages that kept traditional characteristics. The Chinese government strongly encouraged the formation of farmers' cooperative to support agriculture and agritourism. There is a growing number of projects promoting the enhancement and development of villages and small towns in China. Among these, the initiatives

focusing on the preservation of the ancient charm of villages to support poverty alleviation through tourism are the most renowned and many pilot experiences of rural tourism have been implemented. From an urbanization perspective, to improve the countryside standards of living, some small villages are merging with other villages or towns, creating clusters concentrating scattered realities into higher density residential areas, so facilitating the provision of public services. This process also helps saving agricultural land.

However, rural residents often got a limited benefit from the tourism, as they participated in tourism activities in most cases only because they were recruited as workers because their limited skills and experience prevented them from being involved in the management [13].

Furthermore, as observed by Yang and Hung [14]:

"Sustaining the success of the tourism cooperative remains difficult because of complex factors, such as management ability of leaders, attitude of other interest groups and market competition".

In addition, since it is estimated that nowadays only less than 2% of Chinese villages have maintained their traditional features, the initiatives able to account on a "heritage related tourism" are inevitably focused on a limited number of settlements. Therefore the implementation of innovative development models based on a different pattern of values is likely even more crucial for all those villages that have not preserved their traditional layout and characteristics.

The agricultural sector remains key to provide employment and income opportunities for the rural population. A gradual restructuring for the agricultural sector, from an innovative and environmentally safe perspective, is necessary to allow productivity, efficiency and farm income to increase. This process will have to involve the management of elderly which, as explained before, represent the largest population of the rural villages.

The Project aims to explore innovative ways to improve local quality of life and establish a sustainable maintenance system, creating a favorable living environment that can attract new inhabitants (whether returning natives or newcomers), and visitors.

These objectives would be achieved by increasing local farmers' income and improving local public services, enhancing and promoting the quality of agricultural products, developing innovative and energy-efficient practices in farming and building construction, and by training and capacity building initiatives in agriculture and ecotourism sectors.

5.2 Project Components

The Project will include three components:

1. Restructuring of agricultural sub-sector, through:
   (a) Technical assistance for restructuring the current agricultural production patterns, introducing new or improved systems of organic production and low emissions, pre-processing/processing technologies for agricultural products, storage and marketing facilities;

2. Strengthening of farm-to-market linkages, including upgrading of quality standards, labelling and certification, branding, product tracing, logistics, and food safety;
3. Support of existing and new farmers' cooperatives and enabling institutions, providing training and capacity building in management and business operation, and start-up investments for new and innovative technologies.

5.3 Facilities Improvement

(a) Technical assistance for residential upgrading, renovation and restoration of traditional buildings, and new buildings construction using traditional materials and modern technology with efficient energy solutions;
(b) Technical assistance for the provision of improved facilities for the agricultural sector, including new facilities for processing, storage and marketing;
(c) Subject to the availability of funds, possible technical assistance for public infrastructure improvements including wastewater treatment and environmental sanitation facilities (solid waste collection and treatment), small-scale agricultural infrastructure (such as production irrigation, drainage, field tracks), security facilities (fire extinguishing equipment).

5.4 Territorial Linkage and Urban-Rural Cooperation

(d) Technical assistance for enhancing small-scale sustainable territorial infrastructure, including restructuring and upgrading existing pathways, and developing new trails connecting settlements;
(e) Technical assistance for cultural and natural resource participatory inventory of the villages in the region;
(f) Technical assistance for drafting protection measures/regulations for landscape and architectonical integrity and consistency;
(g) Technical assistance for drafting urban planning layout for the integration of new buildings, facilities and infrastructure;
(h) Technical assistance for improving eco-tourism services and facilities, and soft mobility offer;
(i) Capacity building for sustainable cultural and eco-tourism development and community self-development (guiding local residents to conduct profitable tourism-related transactions); English-language training; training on service standards and hygiene practices;
(j) Enhancement urban-rural linkages promoting education courses on innovative/organic farming, food-related events and facilities.

The Project will be divided in three phases (1. Research and Evaluation, 2. Design and Research Implementation, 3. Project Implementation)

The project received the interest of a county in the west part of the Hunan Province and we are planning to start the research activities before summer 2019.

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Assessing Accessibility and Safety Conditions in an Urban Environment: What Do Pedestrians Perceive?

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Abstract. This study aimed to assess pedestrians' perceptions about accessibility and safety with an aim to identify factors that influence their choice of mobility in an urban environment in the Municipality of Tlaquepaque, Mexico. A survey was conducted of 299 people aged 18 to 72 years old. The study was undertaken in situ while the users were at transit on the place. Most of the participants pointed out the presence of obstacles to free access and over than 60% of the participants considered that the design of the road could imply problems to people with disabilities. In terms of safety, almost 80% of participants consider the lack of respect to pedestrians as the main fact that represents safety risks for them. Overall, the study allows recognising a series of elements of the urban space might be considered to create an age-friendly – safe and accessible - environment.

Keywords: Urban environment · Safety · Accessibility · Ageing · Pedestrians' perception

1 Introduction

Walking is an integral part of every travel chain and is an important component of one's mobility. It is recognised as the cheapest, most natural and sustainable mode of travelling [1]. In addition, walking comprises a series of benefits ranging from physical and psychological to social aspects [2]. Alfonzo [3] proposes a socio-ecological model consisting of a hierarchy of five levels of needs in the decision-making process of walking namely: feasibility, accessibility, safety, comfort, and pleasurability. This study stands on the view that a feasible, accessible and safe journey needs to be

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guaranteed before pedestrians decide walking. Lack of accessibility and pedestrians' perception of safety risks might affect their decision to walk or even their choice to use some streets [4].

The term accessibility used to refer to the relationship between a person's capabilities and demands generated by the design of the physical environment. At present, it is a term more oriented towards usability, defined as the 'usability of a product, service, environment or facility by people with the widest range of capabilities' [5]. Although accessibility has gained importance and interest to fulfil the needs of both older and disabled people, there are still some gaps to be bridged. The World Health Organization [6] highlights that, in both developed and developing countries, people think that their city was not designed for the elderly. In Mexico, previous studies have drawn attention to the presence of physical and social barriers in urban environments that prevent people from using roads as pedestrians [7, 8].

According to the World Health Organization [9], the number of road traffic deaths on the world's roads is unacceptably high. Accidents involving pedestrians, cyclists and motorcyclists comprise more than half of those traffic deaths. The rate for road fatality varies between countries by income. The risk of road accidents is three times higher in low-income countries than in high-income countries. In 2016, the number of road traffic fatalities in Mexico was estimated to be 16,725, with a rate of 13.1 deaths per 100,000 populations [9]. According to the official statistics, pedestrians account for around 29% in Mexico, but results from a different study suggest that pedestrians represent nearly 48% of the deaths associated with road injuries [10]. Pedestrians are the most vulnerable group of road users and traffic accidents involving injuries to them are a major societal concern.

The local governments in Mexico have made continuous efforts to improve accessibility and safety, especially in urban environments. However, most of those interventions lack participation from road users. Understanding people's needs for walking plays an essential role in designing a better road. Consequently, the objective of this study was to assess pedestrians' perceptions about accessibility and safety in an urban environment with an aim to identify factors that influence their choice of mobility.

2 Methodology

2.1 Site Selection and Participants

The study was conducted in cooperation with the municipality of Tlaquepaque, one of the eight towns within the Metropolitan Area of Guadalajara, Mexico. For this study, five blocks of a road in the headquarters of Tlaquepaque was chosen for evaluation. The specific road is *Juarez* Avenue from *Niños Heroes* Avenue to *Herrera y Cairo* Street comprising of shops, restaurants and tourist attractions (Fig. 1). This specific location was chosen for evaluation because the local government has a plan to improve roads in this area. The Department of Mobility was especially interested in understanding how this built environment could be improved for better pedestrian accessibility.

A total of 299 participants were involved in this study. A random criterion of selection was utilised which consisted of inviting a person every three people passing on the road at the time of the survey. Road users were included after obtaining their acceptance. Additionally, it was required to be aged 15 years old or over with sufficient language and cognitive abilities to allow them to provide informed consent and response to the survey. The age of the participants was registered by ranks between those who were under 18 years of age, from 19 to 29, from 29 to 59 and over 60 years of age. Participants were informed of the study objective, confidentiality of participating, the time needed for the survey, and the right to withdraw at any time if decided. The data were collected in three weeks in July of 2017. The intention was to cover different times of the day. Therefore, collection times were morning and evening hours during weekdays, evening hours on Saturdays and morning hours on Sundays.

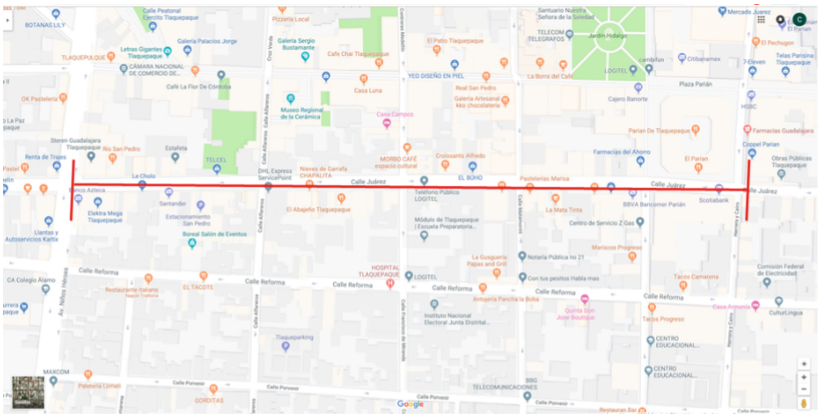


Fig. 1. Evaluation site (marked in red)

2.2 Materials

The questionnaire used in this survey was study-specific and was based on previous literature, but some questions were introduced based on the interests of the Department of Mobility. The questionnaire included two sections. The first section was to register the participants' demographics and journey characteristics. The second section aimed to collect participants´ perceptions regarding safety risks and accessibility. This section comprised a series of statements to be answered using tick boxes and two open-ended questions to enter opinions from participants. These questions had the intention to corroborate and complement what participants were responding to the closed-ended questions. A five-point scale with agreement alternatives was used for those statements. These options were: 'strongly disagree', 'disagree', 'neither', 'agree', and 'strongly agree'. The rating scale was from one to five, where one represented the negative values and five the positive ones. For the analysis, ratings of four and five were considered as positive perceptions of safety and accessibility; in contrast of one to three which were considered as the lack of these attributes. The questionnaire is shown in Appendix 1.

Data collection was conducted by three senior researchers and ten junior researchers who had training for two weeks. Two pilot studies were carried out, which served to refine the questions of the survey and to evaluate the rating scale.

2.3 Data Analysis

Quantitative data collected were analysed using, SPSS (v. 21). A process of screening and cleaning was undertaken before analysing the collected data. Some data were missing for each variable mostly due to the participant not responding to a question. Data were analysed descriptively for the preparation of this report. Qualitative data from the open-ended questions were captured and thematically analysed using Nvivo (v11). An inductive approach was used for the analysis, which means the categories identified are strongly linked to the data themselves [11].

3 Results

3.1 Participants and Journey Characteristics

A total of 299 pedestrians were involved in the survey. Majority of the participants were aged between 30 and 59 (41%), male (52%), and Mexican nationality (95%). Eleven per cent of participants reported suffering from chronic illness or disability. Thirty-three per cent of the respondents was in the place for tourism or entertainment. Forty per cent of the participants were either working (27%), or residing (13%) in the survey area, suggesting that they visit the place regularly. Ten per cent of participants visited the area for the first time. Most of the people arrived on foot (40%), by car (32%) or by bus (22%). These results are listed in Table 1.

Table 1. Demographics and journey characteristics of participants.

Participants' characteristics	Frequency (%)	Journeys' characteristics	Frequency (%)
Gender		Frequency of visit	
Female	142(48)	2/3 times per year	38(13)
Male	156(52)	2/3 times per month	51(17)
		2/3 times per week	58(20)
Age group		Daily	121(40)
Less than 18	31(10)	First time	31(10)
From 19 to 29	109(36)		
From 30 to 59	121(41)	Mode of transport to get the place	
60 and over	38(13)	Walking	119(40)
		Bicycle	12(4)
Nationality		Motorbike	4(1)
Mexican	283(95)	Bus	64(22)

(*continued*)

Table 1. (*continued*)

Participants' characteristics	Frequency (%)	Journeys' characteristics	Frequency (%)
Foreigner	16(5)	Car	95(32)
		Other	2(1)
Chronic illness or			
disability		Reason for using the road	
Yes	32(11)	Tourism and fun	97(33)
No	267(89)	Work in the area	80(27)
		Live in the area	40(13)
		Shopping	44(15)
		Other	37(12)

3.2 Pedestrians´ Perception of Safety and Accessibility

Fifty-six per cent of participants in the survey either 'agreed' or 'strongly agreed' that it was safe crossing roads in the area where the survey was undertaken (Table 2). Approximately sixty-two and sixty-seven per cent 'agreed' and 'strongly agreed' that the width of sidewalks was enough and lighting was adequate, respectively. Regarding accessibility, over 57 per cent responded that the design of the roads did not consider the needs of disabled people. Likewise, sixty-three per cent indicated the lack of rest areas in the road.

Table 2. Pedestrians perception regarding safety and accessibility (n = 299)

Statements	Unsafe and not accessible			Safe and accessible	
	1	2	3	4	5
	n (%)	n (%)	n (%)	n (%)	n (%)
Crossing roads in this area is safe	29(10)	43(14)	57(19)	77(26)	88(29)
Sidewalks are wide enough	26(9)	32(11)	53(18)	58(19)	123(41)
Lighting on this road is adequate	17(6)	21(7)	50(17)	82(27)	100(33)
The design of the roads considers people with physical and mental disabilities	65(22)	44(15)	59(20)	75(25)	49(16)
There are enough rest areas on this road (benches, shadows)	63(21)	54(18)	68(23)	67(22)	39(13)
Using this road is comfortable	6(2)	15(5)	45(15)	64(21)	160(54)
There is enough vegetation on this street	27(9)	39(13)	65(22)	73(24)	88(29)
I feel comfortable with the number of people who use this road	10(3)	19(6)	38(13)	80(27)	145(48)
The information provided by signals is adequate	39(13)	26(9)	39(13)	78(26)	108(36)

1 = Strongly disagree; 2 = Disagree; 3 = Neither; 4 = Agree; 5 = Strongly agree
*Percentages may not add due to rounding

3.3 Reasons Behind Safety Perception

Pedestrians were asked to state the main reason based on what they responded to the question regarding the extent of agreement in being safe crossing the roads in the area. Participants expressed a total of 321 reasons, approximately seventy-five per cent (239) were on safety problems. The fact that drivers do not respect pedestrians was the most mentioned negative issue (80 mentions), followed by lack of traffic lights (34 mentions) and the presence of too much traffic (31 mentions). It must be highlighted that negative reasons were raised even by participants that agreed with the statement "crossing the road in this area is safe". Positive comments on safety were led by the fact of drivers respecting pedestrians (39 mentions), followed by cars travelling at a low speed (15 mentions) and the presence of traffic lights (9 mentions) (Table 3).

Table 3. Positive and negative reasons behind of perceived safety

Positive reasons	Number	Negative reasons	Number
Drivers respect pedestrians	39	Drivers do not respect pedestrians	80
Cars at low speed	15	Lack of traffic lights	34
There are signals	9	Too much traffic	31
Presence of police officers	7	A poor culture of road safety	21
Space to cross the roads	4	Cars parked in places that obstruct the visibility and mobility of pedestrians	19
Others	8	Cars in high speed	16
		Lack of signals	15
		Lack of police officers	7
		Lack of bumps	3
		Presence of holes or obstacles on the pedestrian way	3
		Others	10
Total	**82**	**Total**	**239**

3.4 Pedestrians' Suggestions for Improving Safety and Accessibility

At the end of the survey participants were asked for any suggestions to improve this road. More than fifteen categories were raised from the thematic analysis. Table 4 shows the top five recommendations. Pedestrianisation of the road and/or widening the sidewalks was most frequently (48) suggested followed by the proposal to ban parking of cars in the street (41) and removing any obstacles on the walkway and crossing points (31).

Table 4. Pedestrians' top five recommendations for improving safety and accessibility.

Level	Recommendation	# mentions
1	Convert the current road to a pedestrian road and/or widening the sidewalks	48
2	Do not allow cars to park in the road	41
3	Remove obstacles from the walkways and crossing points	31
4	Install pedestrian traffic lights (with audio)	25
5	More signals and information	25

4 Discussion

4.1 Perception of Accessibility Issues

This research has focused on investigating the pedestrians´ perception of accessibility and safety in an urban area in the Metropolitan Area of Guadalajara, Mexico. Results indicate that over half of participants (168) did not agree with the statement of "the design of the roads consider people with physical and mental disabilities", which suggests that the obstacles might prevent or impose difficulties for these group of users. In accordance with the results, a previous study has found accessibility and usability problems for older people when using the roads in Guadalajara [8]. Removal of obstacles from the walkways and crossing points is one of the top five suggestions for improvements, which reveals the relevance of accessibility issues for all pedestrians and not only for older and disabled road users.

In addition, two-thirds of the pedestrians reported that there are not enough rest areas on the road. Spaces and furniture for resting along with enough vegetation have been suggested as an important physical factor promoting walking behaviours [12]. This finding is consistent with that of Alfonzo´s model [3] regarding the level of comfort required for walking. These facts suggest that the current state of the road may prevent some pedestrians avoid using the facility either for the lack of convenience or because some pedestrians - especially most vulnerable users - may have a self-perception of not being able to move through the road.

4.2 Perception of Safety Risks

Results in this study indicate that 57% of pedestrians (129) did not agree with the statement of "crossing the roads in this area is safe". This finding contrast with the percentage of negative reasons explaining the safety risks (75%). The difference may be explained by the fact that some pedestrians who "agree" with this statement also provided negative comments on safety. Only some of those who "strongly agreed" (88) did not provide any negative comments. Beyond these differences, the results are

consistent in showing pedestrians concerns on safety. These results may be explained by the fact that the number of road traffic injuries and fatalities is too high in Mexico. It may be due to the reason that the perceived safety is highly associated with the number of road fatalities. Perceived safety concerns have been reported previously in the context of Guadalajara [8].

At least four of the negative reasons for safety concerns are directly related to the interaction between pedestrians and car drivers. In general, the interaction between pedestrian and vehicle drivers are mediated and affected by several factors including social and behavioural, for example, compliance of rules and social norms which have been identified to play the central role compared with formal rules [13, 14]. Having ease of movement without any challenging situation with other motorists found to be an influential factor in the perception of safety. This in line with Šucha [15] who found following behaviours from the car drivers: approaching a crossing at an inappropriate speed, not yielding to pedestrians and not yielding when turning right/left at a junction, among others have a negative influence on pedestrians' perception of safety. In contrast, car drivers perceived mainly pedestrians to have the following unsafe behaviours before an accident: an infraction of some traffic rule, not respecting traffic lights and not crossing in the appropriate zones. At any case, car drivers' respect for pedestrians could be manifested by attending to speed limit, observance of the right of way and use of the designated parking spaces, also, by the consideration to pedestrians with diminished mobility which are more vulnerable while crossing the street.

Another factor described in the literature as part of pedestrian-car drivers interaction and identified by participants among the negative reasons for safety perception is the physical infrastructure, manifested in the presence or absence of signals, traffic lights, road geometry and type of pedestrian crossings [13, 16]. Furthermore, when asked for suggestions for improving safety and accessibility, participants' most recurrent answers were related to having exclusive areas for pedestrians, whether that be pedestrian-only roads or extended sidewalks, as well as forbidding parking of cars on the sidewalks. These results suggest that there is a need to improve interactions between the pedestrians and vehicle in a holistic way, including social aspects of the interaction and improving the infrastructure.

4.3 Potential Interventions

The suggestions from the participants seem to be an excellent starting point for possible countermeasures. The recommendations comprise ideas for both accessibility and safety improvements. Pedestrianisation of the road along with widening the sidewalks was the most voted idea for intervention. This means no access to motorised traffic and the prioritisation of the use of the road only for pedestrians. It should be noted that pedestrianisation has an overall positive environmental effect [4].

Interestingly, the suggestions made by the road users corroborate well with the literature and are within the international guidelines for pedestrian safety [4], which indicates that pedestrians have a good sense in recognising the problems and ability to see the solutions. Furthermore, this study highlights the relevance of including pedestrians' participation for a more human-centred design of our cities.

5 Conclusion

The overall aim of this study was to assess pedestrians' perceptions about accessibility and safety in an urban built environment with a view to identifying factors that will encourage walking as a choice of the commute. The study found that walking needs in terms of accessibility and safety are not fully guaranteed in the evaluated location. A considerable proportion of participants had the perception that crossing roads in that site is not safe, but they also pointed out that the design of the road does not consider the needs of older and disabled people. Car drivers' action towards pedestrians was one of the main reason for the negative perception of road safety. Participants suggested several recommendations that have the potential to impact positively on the decision-making for walking. Finally, it is relevant to state that more research is needed for getting a better understanding of accessibility and safety conditions of urban spaces. However, the collaboration between the road users and local authorities for developing a safe and accessible zone is even more needed for increasing pedestrians walking rates.

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Appendix 1. Questionnaire

Aspects included on the questionnaire

1. Internal control		
a. Questionnaire number:	b. Time:	c. Date:
d. Place:	e. Name of the researcher:	

2. Demographics and travel characteristics						
a. Gender_____		b. Nationality		1) Mexican	2) Foreigner	
c. Age	1) Less than 18	2) from 19 to 29		3) from 29 to 59	4) 60 and over	
d. Any chronic illness or disability?		1) Yes		2) No	Name it _____	
e. How frequent do you use this road?	1) 2/3 times per year	2) 2/3 times per month		3) 2/3 times per week	4) Everyday	5) First time
f. How did you get to this place?	1) Walking	2) Bicycle	3) Car	4) Bus	5)Motorbike	6) Other

3. User perceptions on safety and accessibility					
a) Please tell us how much you agree or disagree with the following statements:					
Statements	1 Strongly disagree	2 Disagree	3 Neither	4 Agree	5 Strongly agree
Crossing roads in this area is safe.					
Why?					
Sidewalks are wide enough					
Lighting on this road is adequate					
The design of the road considers people with physical and mental disabilities.					
There are enough rest areas on this road (benches, shadows).					
Using this street is comfortable					
There is enough vegetation on this road.					
I feel comfortable with the amount of people who use this road.					
The information provided by signals is adequate.					
Do you have any suggestions to improve this road?					

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Global Perspectives on People-Centered Design and Cultural Heritage

Understanding Visual Information Processing for American vs. Saudi Arabian Users

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Abstract. Cultural differences may affect user experiences in many different ways. This may range from having to adapt to different data formats to understanding novel directions of reading and writing. Analyzing data presented in various forms are crucial for both information assimilation and dissemination. Different information presentation methods can substantially affect task performances. To date, limited research has been reported that investigates how users from different cultural backgrounds respond to various information presentation methods while conducting visual information processing tasks. To fill in that gap, we conducted an experiment to better understand the relationship between American and Saudi Arabian users when interacting with different information presentation methods in the context of visual information processing. The specific information presentation methods investigated in the study are textual presentation, graphical presentation, and tabular presentation. The results suggest that information representation has significant impact on task efficiency for both groups of participants. However, information representation only affected the answer quality of the American group.

Keywords: Cross-culture · Visual information processing · Information presentation methods

1 Introduction

The interaction of cultural markers with technology is responsible for the differing perceptions and user experiences [1]. According to Heimgärtner, cross-cultural variables such as globalization and internationalization, can determine the layout of a system's user interface and affect its usability [2]. Systems designed for the global audience are infused with cross-cultural cues in the design process to enhance the target user experience.

User interfaces are increasingly becoming globalized and culturally sensitive at the same time, thereby advancing the development of cross-cultural applications while influencing the design of user interface. Fernandes defined the steps for designing international user interfaces. First step is globalization, which is building basic functions that can be easily modified when used in different culture. Second step is localization, which is adapting the globalized product to preferences of a culture [3].

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Processing visual information is influenced by the culture of reading and writing. Notable cultural difference that might affect visual information processing exists in various forms such as languages, measurement systems, format of numbers and dates, and the use of colors. The direction of reading and writing is another important factor. For example, Americans have a culture of reading and writing from left-to-right (LTR) while the Arabs read and write from right-to-left (RTL). It is important to understand how the cultural difference affects the way Arabs and Americans process visual information.

In this study, we investigated how users from the United States and Saudi Arabia interact with three information presentation methods while completing visual information processing tasks. The three information presentation methods examined are textual presentation, graphical presentation, and tabular presentation. We also collected eye gaze data in order to examine the visual scanning patterns and strategies. Better understanding of the relationships between cultural difference and visual information processing may help researchers and practitioners design visual contents that better fit the unique needs of people from different cultures.

2 Related Research

Integration of cultural differences into the design of technology systems is essential in users experience. Marcus asserts that a degree of cultural relativism is critical in avoiding technology bias. Most of the United States websites capitalize on visitors and their objective [4]. Mauney et al. conducted a study to define touch-screen gestures' preferences among nine different countries. Three hundred and forty individuals participated to use 28 gesture actions. The actions were recorded on a touchscreen simulator. All participants showed high-level of agreement on all proposed gestures except on symbolic gestures [5].

Researchers also compared different countries and cultures when using web-based tools and websites. In a recent study, Benaida compared Arab universities with US universities using the Hofstede's cultural dimensions. He chose three university websites from each culture. The result shows lower level of individualism within the Arab culture than the American culture. However, Arabic culture is more masculine than the American culture [6]. In another study, a new analysis technique was proposed to maximize the benefit of e-government websites. Aladwani compared British and Kuwaiti citizens' views on e-government interface quality. His technique incorporated content analysis, persuasive quality gap, and user perception. The findings showed a significant difference between the two groups in perceiving the performance of quality features. No significant variation was observed between the two groups in perceiving the importance of quality attributes [7].

In another study, Marcos et al. conducted an eye tracking experiment to determine if there are cultural differences between users from the Middle East and those from Western Europe. The study suggested that Middle Eastern users spent longer time on search engine results pages compared to European users and read more results. The results are found to be consistent with holistic cognition theories, and cultural

variations may stem from the fact that the Middle East participants were non-native English speakers [8]. As such they may have had reduced confidence and slower performances in engaging with the pages.

Kralisch et al. conducted a study to identify the role of different cultures on search behavior, specifically information seeking behavior. They recorded the navigation behavior of users from more than 185 countries. People within similar culture have the same search behavior and it might be due to the inheritance of thinking patterns [9].

Al-hamouri et al. reiterated that Arabic reading and writing styles differ considerably from the Western scripts. The authors evaluated the impact of written Arabic on the sequence of language-associated brain activations by scanning a group of Spanish speakers and a group of native Arab speakers. The result showed that the brain processing was mainly left lateralized in both groups; however, the left and right hemisphere of the brain reached similar activation point in Arabs but differently in Spanish participants [10].

Other scholars have given their input on the subject of information processing. According to Helmut, the processing of visual information is different among cultures because of the system of characters. The author specifies that Arabic consume extra horizontal space compared to English due to character variations. Arabic characters are written from right-to-left while the numbers are written from left-to-right; therefore, experts have been careful while translating an Arabic mobile application into English [11]. Better understanding of both American and Arabic visual information processing patterns is important from both the linguistic and the system application perspectives.

According to Chokron et al., writing and reading direction has been demonstrated as a key determinant of visual-spatial performance, such as facial affect perception, line bisection, aesthetic judgment, straight-ahead pointing, and movement perception. The findings show that visual information processing is largely based on the hemispheric interpretation of objects based on directional modes, performance asymmetries, and other factors [12].

3 Method

3.1 Experiment Design

In our study, we adopted a split-plot design that consists of both between-group and within-group variables. The between-group independent variable is the cultural background of the participants: American and Saudi Arabian users. Two within-group independent variables were examined. The first one is the information presentation method with three conditions: textual graphical, and tabular. The second within-group independent variable is the difficulty of the tasks, also with three conditions: easy, medium, and difficult. We developed three sets of webpages that presented the same amount of information in three different methods. Presented on each page was statistics about four health-related conditions (smoking, high blood pressure, cholesterol, and Diabetes) in four imaginary countries.

We collected data regarding the time it took to complete the tasks and the quality rating of the answers to measure task performance. The participants' subjective satisfaction and preference ratings were gathered through a post-test questionnaire. In addition, we used a Tobii X2 60 eye tracker to track the participants' eye movements to help understand the visual scanning paths when interacting with the different information presented methods.

3.2 Participants

Twelve participants from United States (the American group) and twelve participants from Saudi Arabia (The Saudi Arabia group) took part in the study. All participants in the Saudi Arabia group grew up in Saudi Arabia and were pursuing a bachelor or graduate level degree in the United States. All participants were undergraduate or graduate students from different majors. They were recruited through email announcements and flyers. In the American group, seven participants are female and five are male. In the Saudi Arabian group, two are female and ten are male. The age for the American participants was between 20 to 30 years old and for the Saudi participants was between 20 to 37 years old. All participants received a $20 gift card at the end of the study.

3.3 Scenario and Tasks

Throughout the study, each participant observed health-related information presented in different methods and answered questions based on the information presented. We selected health-related information to be our core data because people are constantly looking for such information on the Internet. For instance, the number of visitors of WebMD is estimated to be 75 million each month [13]. We created four imaginary countries with imaginary data including high cholesterol, smoking, high blood pressure, and diabetes and their occurrence rate among four ethnic groups: Caucasian, African American, Hispanic, and Asian. The volume of data presented for each country is the same. For each country, we developed three questions for each participant to answer based on the data presented. The level of difficulty of the questions varies based on the amount of information needed to answer the question. The easy questions required the participant to find the information about a specific ethnic group in order to retrieve the answer. For example, the participant only needed to track the data about the males in the Caucasian group in order to answer the following question:

"Among Caucasian males, which of the 4 health-related conditions has the lowest percentage of occurrence?"

For the medium level questions, the participant had to track the information about a specific gender. For example, the participant needed to track the data about all male ethnic groups in order to answer the following question:

"Among all male groups, which ethnic group and condition has the lowest percentage of occurrence?"

For the difficult questions, the participant needed to investigate all ethnic groups to find the answer. For example, the participant needed to track the data about all ethnic groups, both male and female, in order to answer the following question:

"Among all groups, which ethnic group and condition has the biggest difference between male and female?"

We used numeric ratings to measure the quality of answer with three possible values: 0, 0.5, and 1. The answers to the easy questions only contain one specific health condition, with a correct answer being rated 1 and incorrect answer being rated 0. For the medium and difficult question, the answers consist of two elements: a health condition and an ethnic group. Answers containing both correct elements would receive a rating of 1. Answers containing only one correct element would receive a rating of 0.5. Answers containing no correct elements would receive a rating of 0.

3.4 Information Representation

We designed the pages locally using asp.net and Visual Basic on Visual Studio 2017. Nine webpages were developed for four countries: A, B, C, and D. Countries A, B and C were used for the formal tasks and Country D were used for the training tasks. The pages for all countries consist of the same amount of imaginary data regarding heart disease- related statistics presented in three information presentation methods: textual, graphical, tabular (Figs. 1, 2 and 3). At the top of each page, a question was presented and the participants answered the question based on the data presented on that page.

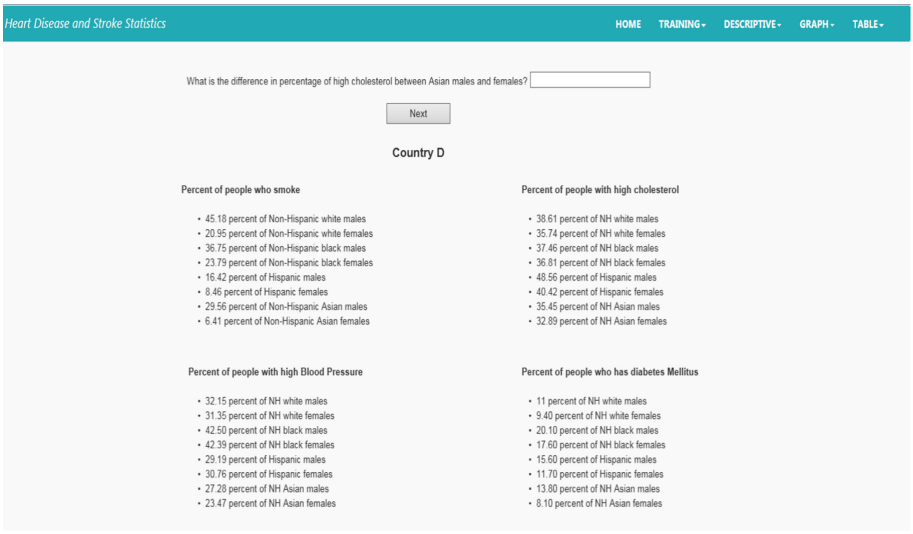


Fig. 1. Health-related data presented in the textual method

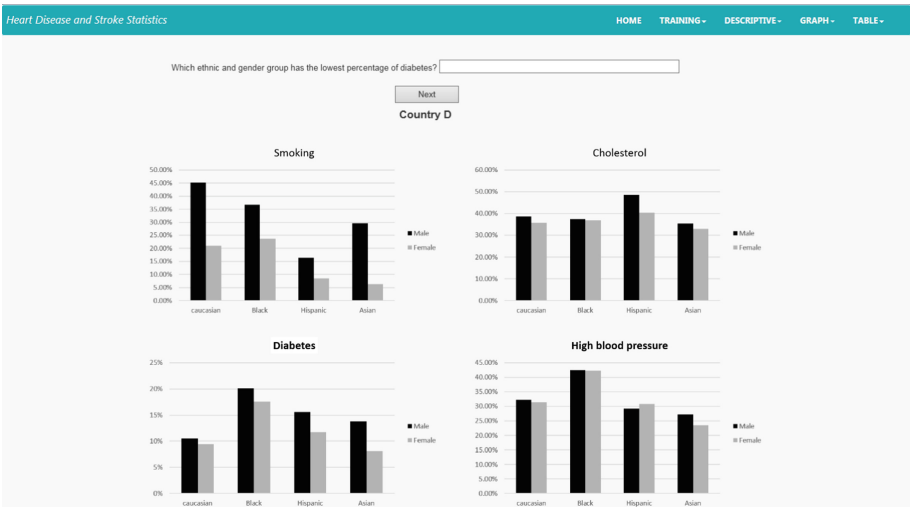


Fig. 2. Health-related data presented in the graphical method

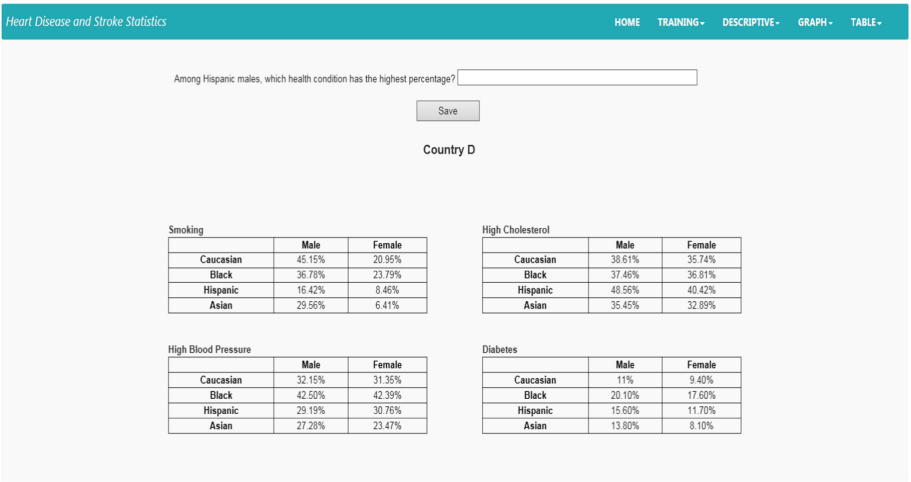


Fig. 3. Health-related data presented in the tabular method

3.5 Experiment Procedure

IRB consent was collected in writing from each participant. After the study was explained, participants completed a training session that exposed them to all three information presentation methods. Following the training session, each participant completed information retrieval tasks under all three information presentation conditions: textual, graphical and tabular. Under each condition, they viewed the data of a specific country and answered three questions (one easy question, one medium level

difficulty, and one difficult question) about the data. Both the order of the information presentation methods and the country are counterbalanced to control the learning effect. Participants completed a demographic and satisfaction questionnaire at the end of the study. Data was collected from all participants over the course of one semester.

4 Result

The data collected was checked for completeness, cleaned and formatted for analysis using the SPSS software. We completed preliminary analysis of the data using the Repeated Measures Analysis of Variance (ANOVA) test with task completion time as the dependent variable and information presentation method, question type, and participant condition as the independent variables. The results suggest information presentation method and type of questions have significant effect on task completion time ($F(2, 44) = 46.08$, $p < 0.001$; $F(2, 44) = 5.03$, $p < 0.05$). The textual method required significantly longer time to answer the questions than the tabular method and the graphical method for both groups (Fig. 4). There is no significant interaction effect between information presentation method, types of questions and task completion time ($F(4, 88) = 3.90$, n.s.).

There is significant difference between the two groups of participants in task completion time ($F(1, 22) = 11.094$, $p < 0.005$). Participants from Saudi Arabia spent significantly longer time completing the tasks than participants growing up in the United States. As indicated in Fig. 4, participants from Saudi Arabia spent significantly longer time to complete the tasks than the American group when the information was presented in all presentation methods.

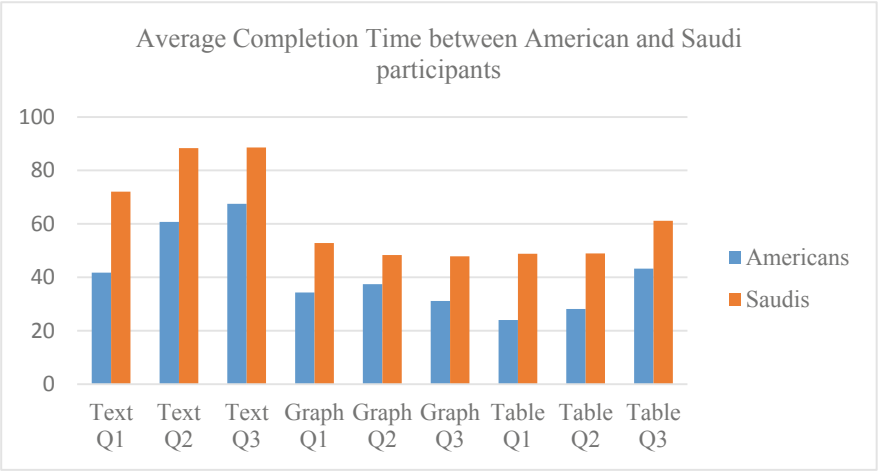


Fig. 4. Task completion time (in seconds) of both participant groups

We conducted a Repeated Measures Analysis of Variance (ANOVA) test with quality rating of the answers as the dependent variable and information presentation method, question type, and participant condition as the independent variables. There is no significant difference in quality of answers between the two groups of participants ($F(1, 22) = 1.733$, n.s.). Information presentation method and type of questions have significant effect on the quality of the answers ($F(2, 44) = 5.04$, $p < 0.05$; $F(2, 44) = 14.82$, $p < 0.001$). There is no significant interaction effect between information presentation method, types of questions and quality of answer ($F(4, 88) = 2.49$, n.s.). Participants from the United States had significantly lower-quality answers when the information was presented in text as compared to graph and table. There is no significant difference in the quality of answer among the three information presentation methods for the participants from Saudi Arabia (Fig. 5).

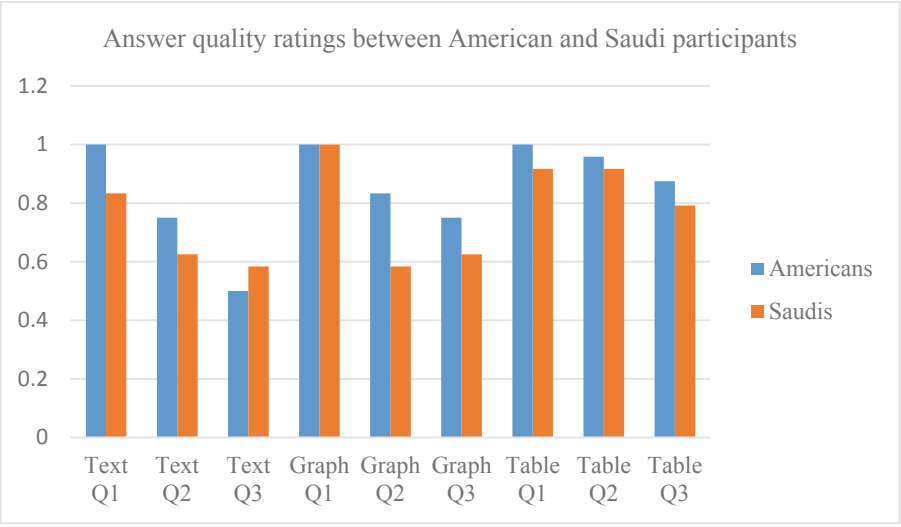


Fig. 5. Quality of answer between American and Saudi groups.

Participants from both groups showed similar patterns in the subjective preference rankings towards the three information presentations methods (Table 1). There is a close to 50% split regarding the most preferred method in both groups. 50% of the participants in both groups selected the graphical method as their most preferred method. The other 50% of the American group and 42% of the Saudi group selected the tabular method as their most preferred method.

The participants showed more consensus regarding the least preferred method, 75% of the participants in both groups selected the textual method as their least preferred method.

Table 1. Number of participants from each group who selected a specific presentation method as their most or least preferred method.

	Group	Textual	Graphical	Tabular
Most preferred	American	1	6	5
	Saudi Arabia	0	6	6
Least preferred	American	9	2	1
	Saudi Arabia	9	3	0

5 Discussion and Conclusion

We studied the influence of three information representations on visual information processing for users from two different cultures through a controlled experiment. While quality of answers between American and Saudi participants was the same, the Saudi participants spent longer time to complete the tasks. The impact of the information presentation methods on efficiency followed the same pattern for the two groups of users. That is, the textual method required significantly longer time to answer the questions than the tabular method and the graphical method for both groups. However, there was a difference in the impact of information representation on the quality of answers between the two groups. The quality ratings of the Saudi participants were similar among the three information representations while the American participants had higher ratings in the graphical and tabular formats than the textual format.

The results indicated that the Saudi participants spent longer time completing the tasks. This could be attributed to many reasons. For instance, Saudi cultures read Arabic text from right-to-left. This may result in a delay in processing the presented information from left to right. Another possible factor contributing to the lower efficiency in the Saudi group is the language barrier. Since the information was presented in English, it might have taken the Saudi participants longer time to read and understand the information. It is interesting that the information presentation methods affected the answer quality of the American participants but did not affect that of the Saudi participants. We are analyzing the eye movement data to study the visual scan patterns of the participants. We hope the visual scan patterns can help explain the differences observed in efficiency and quality of the answers between the two groups.

Our study provided preliminary understanding on how people from different cultural backgrounds interact with different information presentation methods. The results suggest that, for participants in both groups, the textual condition is the least desirable method according to both efficiency and subjective ranking. However, the results should be interpreted with caution due to the small sample size and the specific nature of the participants. All Saudi participants were students studying in a university in the U. S. and therefore, did not represent the general population of the country. We plan to replicate the study with a larger sample size in Saudi Arabia to validate the finding.

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An Application for Mobile Systems Developed with the Community Involvement. An Open Source Mobile Application Project of a Perceptive City Map

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Abstract. The paper describes the hypothesis of an applicative part of the author's research *Design for the sensitive experience* (The research has allowed the author to organize interviews and discussion with different city users and psychologists permitting the definition of parameters and categories described in this paper. Anyway these parameters are questionable and have to be implemented thru the second part of the research, thru the comparison with results taken from investigation that are planned to be made also with technological advices.). It's an experimental project aimed to create the bases to develop an open source mobile application where the *city users* can directly communicate with planners, designers and administration. The 'app' would consist in an interactive city map, a model that can be extended to any cities. In particular, the paper displays the experiment conducted within the PhD research, applied to four itineraries of Rome city. The experiment can be tested on other urban realities and it illustrates the parameters identified to map the city areas and the tools that can be used. The method adopted to monitor the sustainable-mobility, is the development of an application that has to be used especially during the planning phase of the visit, before to start a city tour, not only in the while of a walk.

Keywords: Application · Open sources · Mapping · Design with community · Well-being · Emotional map · Urban contexts · Historical city · Inclusive itineraries · Perceptive · Sensitize the people · Accessibility · Life quality · Inclusive parameters · Data collection methods

1 Introduction

A space could be defined as 'inclusive' if people don't notice the inclusiveness at the first approach. To better understand the concept, people can think about a condition in which they have everything; in this case, they can't perceive the feeling of missing something. This happens with a good design: an inclusive space doesn't make you feel

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excluded, and you don't reflect on the exclusiveness, because they just feel good. If a place is accessible people don't think that it could be built as inaccessible.

In the meanwhile, we have to consider that the aspiration towards a project "for all" (*Design for All*), is still a distant purpose. In the past it has represented an abstraction as much as today the idea of a design oriented towards a "standard" user, has to be considered outdated. The recipient of the Architectural Project and Design should be, therefore, an extended user, or at least extended to an enlarger number of people.

Nowadays, how can we do not include in our idea of 'community' the so-called "invisible" minorities which are together with children and elderly (which in Italy are no longer a minority of the population) - the physically impaired person with cognitive and sensory problems?

To design welcoming architecture or spaces and urban projects, the specialists have to consider during the design process the different user's needs, and the perceptions that the environment stimulates on the visitors.

To better understand people's needs, should be open new direct links between the community and the planners (productive connections). We have to consider, indeed, that depending on the age, necessities change, and that disability can be temporary or permanent. Some people with less perception of a sense might have developed another capability connected to another particular amplified sense. A collaboration with them can help designers in having different vision of the space and new intuitions.

In 2001, the International Classification of Functioning, Disability and Health developed the definition of 'accessible place' by moving the attention away from personal incapability, to address it rather to the living space: it's the environmental context that plays a fundamental role in the inclusion or exclusion of individuals, as it is characterized by elements inclined in "producing" disability, independently of the physical and perceptive conditions of people.

The ICF transferred the concept of disability from the notion of "*deminutio*" to the definition of "particularity" in the perceptive relationship between person and environment: it has elevated for the first time the concept of equality to a fundamental social value.

2 Design for Sensitive Experience

The research within the author's PhD thesis, in particular, aims to support the principles of Inclusive Design applying them to the stratified urban context, by favoring a line of "participated and shared" choices. The research goal is to point out that in the last decades, architects, planners, developers and designers have lost the real dimension of a design project and the related aspect of "responsibility" own of their job. A public design project can't be self-referential; it has to be designed for people well-being, to emphasize the environment, to be sustainable in all its parts.

An inclusive space is designed with the concept to be lived in by the community and to be capable to offer a comfortable environment for as many people as possible.

The research question is, "Does Inclusive Design haves necessarily to be an indoor space?" Architects and administrations consider it an impossible challenge. Yes, it is, but Designers, planners, architects and engineering started the carrier with the aware to have chosen a challenging job.

Henri Lefebvre in *The Right to the City*[1], described the need to reflect on the essential needs of men, and to the right of people in the city. We should consider the fact that everything passes through the single person, before to arrive to the plurality.

Everything comes from the individual.

The contemporary city is implicitly asking a dialogue with citizens. Because each of us should be able to contribute to the built prevention and care, to work together to take possession of the well-being and of the belonging feeling that once, was living in every citizen.

The Italian architect Giancarlo De Carlo wrote that in the past eras, when there were no magazines and books on architecture, and the architecture was represented only through painting, people were not eliminated from the scene, but they were often represented in the foreground, in the act of use the *architectural event* that was intended for them[2].

The real subject of all created objects and urban landscape is the man, and De Carlo perceived the idea that architecture was not only made up of buildings, but of people and buildings together, related in a relationship of a mutual needed.

The emotional factors arising from a context are determinant in the behaviors, judgments and choices of people. The environment and the architecture influence mind and people mood. They are therefore key elements in the development of cities and in the conservation of our historical heritage.

Citizens with physical difficulties or perceptive sensory diversity are often excluded from city life and from the enjoyment of common heritage; the research proposes to pursue a fundamental and unexceptionable principle of the Universal Declaration of Human Rights of 1948. "*Participation in the cultural life and scientific progress by the community is a right of every individual who must be put in condition to take part freely, to enjoy the arts and to participate in progress and benefit of the heritage properties*"[3].

These are the premises that lead the research. Administrations and designers should have the chance to communicate with the *city users*, citizens and tourist, but not only. The research aims to propose one of the many feasible ideas to start a collaboration helping each other, sharing information, analysis and not only proposals.

[1] Henri Lefebvre in *The Right to the City. Philosophy of the City and Planning Ideology.*

[2] Richards J.M., De Carlo G., Blake P., L'architettura degli anni Settanta, Il Saggiatore, Milano 1973, p. 91.

[3] Art. 27 (Universal Declaration of Human Rights 1948).

3 The Feasible Role of a Digital Applications in the Society

A digital application is a tool that can hold different utilities and goals.

In this paper and within the research the final users of the application are supposed to be the citizens, the administrations, the organizations, the tourists and the architects with the planners. The author proposes the development of a concrete tool that is the result of the analysis and studies carried out on the perception of citizens, children, users with sensory, motor or cognitive difficulties in urban areas. The tool is an application for mobile systems that allows the use of an interactive map of some historic center itineraries that pass thru areas of cultural interest.

The tool for mobile systems holds the potential to offer support also to people with disability difficulties in knowing the degree of accessibility and the satisfaction of other users on the perceptual quality and use of a context, before choosing it as a destination of cultural interest. Even tourists, as well as citizens, could enjoy this instrument because often they, if they present sensory or motor difficulties, feel hindered in planning a trip to the Capital.

The research is currently ensuring the development of a plan where the areas of high historical interest and their degree of inclusion are indicated, to obtain a map of users' perceptions and emotions[4].

The digital application should allow the use of an interactive map of few itineraries which classifies, area by area, the accessible levels as well as perceptions and emotions of people in the interaction between the user and the city.

The idea is to develop a tool that hold the potentiality of an open source system, to implement and to update the information (Cf. C. Ratti, Architettura Open Source). In this way it could be used by the Municipality for the information acquisition to be presented and consulted during the town council, to define priorities, to make decisions related to the street routines maintenance, exceptional maintenances, and renovation of urban furnishing.

The application shouldn't contain only objective data, but also people emotions. People can insert a feedback on a place creating a new point of feedback. The new point of feedback can be related to an emotion.

4 The Hypothesis of an Application as a Partial Result of a PhD Research with the Community Involvement

The application could also be an interesting tool for the partial publication of research results and could represent a first step towards the open source extension of the graphic drawings for the involvement of users in the mapping of the city. The author has received for two years a grants from Sapienza, Università di Roma, (2017–18 and 2018–19)[5], to develop an application for mobile systems to promote a concrete tool that

[4] G. Bruno, Atlas of Emotions, Verso Books, Milano, 2007.

[5] Research Grant del. DR n. 1052/2017 Prot n. 27698 7th April 2017 and n.278/18 del18/09/2018 within the EU Research Horizon 2020.

permit the users to live inclusively the city. The project goal is to open the application to the users' acquirements, so that the accessibility status can be implemented and constantly monitored and updated. The research is based on the information and knowledge acquired by the author thanks to the research work carried out in synergy with the Municipality I ° in the years 2016–2018 in relation to the study of accessibility of the historic center of Rome and the needs of citizens in the field of inclusion.

The tool applied to the mobile systems holds the potentiality to offer a support to all the interested people, tourist, citizens, more than everyone people with perceptive and emotional difficulties because they can be aware of the accessibility level of a path before to arrive in front of the "obstacles".

The 'app' gives the possibility to know in advance which road to take depending on the kind of tour that the person needs to do. The app can assist the user in the walk related to parameters like the pavement, the presence of natures, benches, shadows, cycle lane, urban furnishment and so on.

A practical example: The app support in the tour planning; if a user knows before starting the visit, if to take the right or the left of a sidewalk, he is not obliged anymore to cross the street various times to reach the ramp to go up the sidewalks. Even tourists with special needs, as well as citizens, can enjoy this instrument overcoming the fear of planning a visit to historical centers like Rome. At the same time the application permits to the person to publish comments and information detected, to insert an emotion in the atlas. Four colors help to distinguish the level of satisfaction of the four categories:

Physical factors, sensitive factors, well-being factors and in the end, emotional factors.

4.1 The Application's Users and the Mapping Methodology

The questionnaires surveys filled by some citizens in the frame of the researched have pointed out that they were not informed about some accessibility project that have been occurring for at least three years. The application permits an immediate update by the citizens who can be an active part of the process and not only the final users. They can easily find information about road accessibility status, suggestions about paths and itineraries and also, they can report in real time any urgent discomfort, breakdown, or also, to share nice surprised, why not.

Consulting the digital application, the urban planners can immediately define the SWOT analysis[6], have an overview of weakness and strengthens of the urban area, continually updated. It helps having an overview of the conditions, to be able to detect in reduced time possible interventions. The urban planner will be able to conduct less survey on site, knowing in advance people needs.

The map of the application, defined by different colors that characterized the area, will permit at the first approach to pinpoint the places where to go to have a relax, to avoid if you're with a person with physical impairments, where to stay with children

[6] SWOT is the acronym standing for Strengths, Weaknesses, Opportunities and Threats. It's an analysis method used mostly used in Urban Planning.

where to go if you're by bike. Institutions and Public administrations can easily find out the areas where people don't like to go or where they don't feel in comfort. The places more appreciated can be valorized and it's possible to define new connections that can link the isolated places that have received positive feedbacks.

The main users of the application are:

1. Public Administration
2. Citizen
3. Planners

4.2 How to Map an Urban Context?

This paper aims to share few Mapping advices in the urban context that consider the multisensory experience and people wellbeing the aim of the analysis. The following points are the first results of the research started in 2014[7].

The research investigates only 4 itineraries, and it's an experimentation of a tool that can be applied to a larger scale.

Note: the methodology applied and all the categories and parameters defined by this paper are the result of a study within a thesis research.

The advice is to define itineraries of max. 3 km (Miles) lengths each. The itineraries start from point A and ends to point B.

The research aims to give a contribution to people everyday life, so the starting points have to be characterized by centrality as markets, stations, parks, and public services. The itineraries give the chance to people to pass by the most beautiful and livable parts of Rome city and its archaeological paths and squares.

The first investigation is conducted every 100 m (328 ft), and then the Open Source system can be implemented by user's feedbacks.

To each point the mapping can give one or more categories information (see the Table 1 content).

Table 1. Categories of investigations

Category	Sense/perception
Category 1	Physical description
Category 2	Sensory description
Category 3	Perceptive/Cognitive description
Category 4	Emotional feedback

[7] Between 2014 and 2015 the author has attended the elective course "Inclusive Design" at the KU LEUVEN University in Belgium and she joined the research group Research [x] Design with whom has collaborate for one year (2014–15) at the ASRO Department of Architecture.
(KU LEUVEN Tutor Prof. Ann Heylighen):

– "Rent-a-Spatialist" (ERC Proof-of-Concept)
– "Mobilizing Disability experience to inform design practice" (IOF leverage Project).

Table 2. The relation between the category and the response.

	RESPONSES			
Category 1	Ideal entrance Welcoming	Accessible	Not enough accessible	Not accessible at all
Category 2	Positively Stimulated	Sometimes/or just one or few sense have been considered	Not Considered	Problem/ discomfort felt
Category 3	Understandable e inclusive	Wayfinding Sometimes Present	No Wayfinding	Not understandable
Category 4	Positively surprised	Regular situation	Not Satisfied	Feeling of Discomfort

To each category the digital application will give a written description and a color to have an immediate response on the map.

The interval investigated are ascribed by an opinion codified by a color:

1. Red
2. Orange
3. Yellow
4. Green

To define the colors in the attribution of the places on the map, supports the reading of the plan.

4.3 Mapping

Where to start to investigate the senses? The research has individuated the first part factors to consider during the mapping related to the senses stimulations. The list can be always implemented. The factors are the following, collected for each sense:

Table 3. The five senses stimuli

THE VIEW
Colors
Light/Shadows
Shapes
Degradation
Disorganized/tidy
Clean /Dirty
Brightness
Harmony in the elements juxtaposition/contrasts
Presence of green area/Nature/trees/woods

THE SENSE OF SMELL & Breath
Clean/Dusty
Pollution
Garbage bins in the open air
Factories nearby
Stations nearby
Split conditioning
Rivers, see, marsh nearby
Gastronomic activities
Presence of green area/Nature/trees/woods

THE SENSE OF TOUCH
Stimulation by porosity/shape of materials
Dust or shiny
Presence of Object designed for play/touch/ seat
Presence of shrub evergreen/smelly shrub
Presence of any natural elements to interact with

THE SENSE OF HEARING_SOUNDSCAPES
Noises
Music
Children's laughs
Presence of factories
Presence of stations/trains (elevated railway)
Level of traffic
Restaurant bar with open doors/tables outdoor
Airport nearby
Presence of natural filters (Parks- Tall trees)

4.3.1 Well Being and Emotions, Two Connected Factors

The study conducted thru the analysis of case study, the interviews, and the study of the physical environmental technology disclose the importance of people's the wellbeing associate at the accessibility of the spaces.

The following table shows how the well-being is connected to two factors, physical and psychological (Table 4).

Table 4. Beyond the five senses

Well being	
Phisical factors	Psycholocigal factors
Cold/warm perception	Socially welcoming
Humidity percentage	Presence of fences
Air conditioning flux/directions	Prohibitions
Brightness-luminance phenomena	Wayfinding[a]
Emotional factors - Individual memories - Historical collective memories - Social relations - Relax/Stress - Comfort/discomfort (conf. PANAS Scale parameters)	

[a]K. Lynch, The Image of the City, The Technology Press Harvard University Press, Cambridge, 1960.

4.3.2 Accessibility Physical Factors to Consider During the Mapping Phase

Referring to the four kind of responses (cf. Table 2) it's possible to define a first set of parameters for the classification of the spatial accessibility:

Table 5. First set of Parameters

PHYSICAL BARRIERS_URGENT PRIORITY
No ramp to reach second/first a stretch of the sidewalk
No sidewalk
Cobblestones pavements not flat
Sidewalk less large than 0,90 m (3ft) or without possibility to turn with a wheelchair
Sidewalk large but occupied by restaurant/coffee bar with tables and chairs
Sidewalk large but occupied by market boxes lot
Large roots and big holes on the sidewalk
Pedestrian crossing
Road slope more than 8%
Steps not reported
Barriers on vertical space (branch of the trees…)
No alarm alert in correspondence of sliding doors, traffic lights, obstacles…
No LOGES paths

PHYSICAL BARRIERS_MEDIUM PRIORITY
Sidewalk of a length between. 2 ft-3 ft.
Roots and small holes on the sidewalk
Very few pedestrian crossing
Pavement in gravel/ clay court (in a dry place). Asterisco per quando piove. Se il giorno prima ha piovuto, non andare.
Garbage bin at 0,90 meters height
Road slope not more than 8% (people with wheelchair and not strengthens in the arms have to be pushed by someone)
No tactile maps

PHYSICAL BARRIERS_URGENT PRIORITY
Sidewalk of 1,m
Garbage bin at ground floor level/until 2 ft.
Road slope not more than 5%
Pavement in concrete /asphalt/small crushed gravel better Ramp for each sidewalk stretch

PHYSICAL BARRIERS _MORE THAN SUFFICIENT
Sidewalk < 1,m
Road slope between the flat and the 4%
Presence of Pedestrian crossing each Regular pavements No hills- flat road …

The green defines the status of the art that goes beyond the common idea of "accessibility".

5 Conclusions

As the architect Roberto Secchi observed, at present we underestimate the effects that individualism has produced on the generation of new social conflicts. The loss of feelings of citizenship and sharing of shared values and rules for a free coexistence in the mutual recognition of all rights.

The space represents what has been before, what it is today, and holds the potential of what can become in the future.

Architects and planners must be able to plan with the awareness of the past, but listening to the needs of the inhabitants of the city to work together on the future, involving whom, will really live this future[8] (Cf. Gregotti and Wright 1945).

For this reason, the research aims to communicate to the architects that nowadays more than ever, they hold a social position. They are the bearer of a key role in the link between politics and citizens: a support for the integration and the union among the inhabitants, aid to plan regeneration in different contexts. We have to be aware of the fact that all the people constitute a community, made up of a multitude of different identities, with individual needs and stories, starting from children's involvements.

Social networks are not always the best way to communicate. Wrong messages can pass thru this virtual world, or good messages can also be misunderstood or surrounded by advertising and an infinite multitude of media messages, and become just one of the many. Nowadays we can not do without technologies, aids, media and social networks; what we can do is to use them in the best way to amplify their good effect and to find social roles.

At the same time the research is founding out the difficulties and the contradictions to develop tools able to measure accessibility factors, as well as the sensitive and the emotional ones. At least it's interesting starting from a point and propose valid methods. The paper doesn't pretend to find solutions, but the staring point of a work held in a complex urban context, that once collected to the other contemporary researches, will be able one day to certificate the public spaces and to guarantee an enlarged inclusiveness and an increased community well-being.

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Inclusive Design Practices for Natural Parks. Products and Services for Experience-Focused Solutions in Places of High Naturalistic Value

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Abstract. The research investigates the possibilities deriving from inclusive design methods in contexts of high naturalistic value. Natural parks, reserves and public gardens play a strategic role from an ecological, social and cultural point of view. Therefore it is necessary to place them at the center of a new scientific debate on methods for the study, the development and the governance of these assets. They are particular and multi-functional contexts in which today it is necessary to operate both in terms of environmental and landscape protection (ecodesign), and in relation to the evolved needs of their users (user-centered design). After a deep analysis concerning international case studies, the research proposes a new possible model of inclusiveness for design practices oriented to territories enhancement. A model capable of acting both in the metaproject phases (introducing interdisciplinarity and co-design practices) and in the properly design phases (according to the principles of design-for-all).

Keywords: Design for territories · Natural parks · Inclusive design · Integrated services · Eco-social development

1 Natural Parks as Inclusive Places. Design Models and Methods for Territories Enhancement

Starting from the evidence that the parks are protected areas characterized by high naturalistic and landscape values, the so-called "design for the territory" - in its vocation to promote initiatives for local development and for territorial protection - is the preliminary instrument to operate in these places through actions and methods

The research "Inclusive design practices for natural parks. Product and services for experience-focused solution in places of high naturalistic value" derives from the scientific activities of the II level Specialization Course "Natural capital and protected areas, planning, design and management", promoted by the Department of Planning, Design and Technologies of Architecture (PDTA) – Sapienza University of Rome. The research is coordinated by Professor Carlo Martino and Professor Vincenzo Cristallo – with the scientific support of PhD Ivo Caruso. The general aim of the research is to analyse the system of physical and intangible tools which implement, give value and new functions to naturalistic areas, through specific "integrated services", able to create connections between products and communication design.

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which promote models of widespread and inclusive planning. These models are targeted to the use and enjoyment of environmental assets by combining the ecological and social priorities with the services provided though products [1]. For this reason, the enhancement of a choral way to project by an extensive system of stakeholders (local administrations and institutions, public or private organizations, companies, researchers and professionals, private citizens) is an indispensable condition for every project with a territorial vocation. It means a project in which the territory is concretely and rhetorically co-authored and in which it is required a network of different skills. Transversal and complex skills which can concretely give value to the specific typicalities of a territory heritage [2]. This is why to design starting from the territorial point of view means recognizing and preserving the identity of a "local culture" that can generate "local products" through its "local resources", of any species. And, "local product" is everything that has a close relationship with the territory and with the community that generated it, even casually. The protection of a territorial vocation therefore becomes the starting point of any planning hypothesis which provides, depending on the case, the relocation, revaluation and reactivation of material and immaterial resources of a given eco-system. However, these are resources (skills and qualities) that must be recognized and shared. Design actions for the territory are aimed to: "read" the territory heritage, interpretate it, visualize it, share meanings and visions, promote forms of participatory planning, transform visions into feasible initiatives, design specific products and the interfaces of the services deriving from them, promote an effective communication of the whole processes. That is to say that design and its system can direct actions towards an environmental sustainability that has a strong relational and social component on a territorial scale. As a consequence, sharing becomes a form of co-definition of the project plan through cooperation actions between proponents and recipients. It is therefore important to recognize that when the goal is to introduce innovative processes on the territory - fostering the connections between places and people, the continuous learning, the enhancement of the material elements, knowledge, culture and local traditions - it is necessary to adopt an approach that supports a community-based form of project; so able to act simultaneously on strategic and services levels. Levels that, in order to generate appropriate and long-lasting actions, must consider the theme of the project of the identity of places as an indispensable value that requires constant monitoring and planning to act in the direction of development and protection of natural heritage. However, the concept of identity is often misunderstood by a pre-constituted representation of its value, considered above all as belonging, defense, opposition. Nonetheless, the objective to be pursued - also understanding the difficulty of many to adhere to a more complex and variable meaning of the term identity - is to ensure that designing identity is equivalent to proposing an updated vision of the word "localism". Consequentially it is fundamental to contemplate territory's multiform nature, its plurality of meanings referable to cultural, normative, economic and political aspects. These aspects need a circular and extended design attitude, focusing on the experiences of the last years that have pushed on themes such as the access to resources, the protection and the use of goods,

the environmental enhancement and the sustainable development. Finally, it is necessary to define an idea of a localism that has been updated in the contents by examining the value of typical resources according to a definition ascribable to the sequence of relationship between product/context/identity. Such a linking indicates that what we sometimes identify generically as territorial-environmental resources are assets to which we can recognize such complexity that can fully distinguish the area of origin and its main identifying properties. Moreover, the economic studies referring to the productions that belong to the typical resources consider the territory as a diffused company - or the environment as a systemic enterprise - and recognize in it economic models, often informal, where the originality and the quality of local products, including those of an environmental nature, is given by the particular combination of territorial resources and the typicality of the goods resulting from a specific "Productive Habitat" [3]. This "Habitat", considerable as a place composed of parts in reciprocal stability (balance of relationship and position), results in a peculiar balance between material and immaterial elements. These elements represent the structural, organizational and dimensional typicality of a given context. These arguments are even more evident if the products in this habitat can be considered as identity marks. In this case we can state that the contribution of the design can activate a process of configuration of the product/context/identity relationship acting with bottom-up strategies, with appropriate enhancement actions for the different levels of territorial identity. For this type of interpretative paradigm the design disciplines, starting from the analysis of the existing typicalities, have the task to take advantage from these initiatives of recognition and networking, turning them into competitive factors for a territorial emancipation on economic and social bases [4]. In conclusion, identity, understood as a cultural matrix of places and territories, has a crucial value for local development. It is a resource to be recognized, protected and communicated. By joining the theme of identity and the design action it is possible to increase the relationship between development and enjoyment of environmental assets, and it is possible to enhance the dynamics within scenarios of inclusive and sustainable use of local resources. Design culture, with its aim of manipulating the shape of the cultures and knowledge present in the territory, becomes a real engine of development for goods and services and helps to recognize the leading role that cultural-environmental assets have in the development of local systems. Therefore, developing the territory through the design principles means modifying the reference center of any planning activity from the subjects to the contexts. Through the use of different disciplinary levels and on different fields of action (social, economic, cultural), the action of design on a territorial scale must therefore offer solutions to increase social, economic and technological innovation processes, taking into account the specificity of local resources. This result can be pursued above all by recognizing that the "project for the territory" always plays in a general key a "narrative" role as it strives for a sort of "staging" the territory. Creating a "script" is equivalent to making a subject fit to be represented. It means to be able to portray the complexity and originality of the different components-actors that are present in the scene-territory with different roles.

2 Natural Parks as "Spaces for the Experience". Practices and Artifacts for Inclusive and Sustainable Fruition

In reference to the complex global challenges facing humanity today, nature and man turn out to be fatally interdependent. With regard to this, in the era in which is taking place what Jeremy Rifkin defines "Third Industrial Revolution", we are facing an important change of scientific paradigm, which considers nature no longer as a sum of objects, but as a sum of relations. "Old science is characterized by the values of detachment, expropriation, dissection and reduction; the new one from responsibility, integration and holism. Old science is focused on making productive nature; the new one on making human activities sustainable. Old science seeks power over nature; the new one aim to a partnership with nature. (…) The new science makes us go from a colonialist vision of nature as an enemy to despoil and force to slavery to a perception of nature as a community to feed" [5]. To have the possibility to live in a salubrious place, or to have (at least occasionally) the possibility to stay in direct contact with places characterized by a great naturalistic value, increases the quality of a person's life, and increases the quality of people's health (both from physical and psicological point of view). Moreover it has a positive impact on social skills, local economies and citizens' behavior towards the environment. Making nature simultaneously protected and usable therefore put in connection people and the environment, thus making people more aware and empathetic towards ecological issues. This condition is fundamental for the definition of the territory as a "choral work of art produced through the dialogue between living entities, man himself and nature, in the long time of history. That is, as a work that arises from fertilization by culture" [6]. The challenge (concerning planning, management and cultural aspects) can not therefore be limited to the ergonomic requirements of accessible tourism, but it must aim at creating the real conditions of sustainable coexistence between the emergencies of nature and the needs of the widest range of possible users. In this way it is possible to experience a model of inclusiveness that becomes a fundamental factor for the creation of places that themselves become "ecological tools through socialization". According to John Thackara one of the reasons why the so-called "new economy" is failing is the lack of interest in the contexts. In the book "In the Bubble", Thackara defines in the concept of "territorial patrimony"; a set of natural beauties, cultural heritages, unique specificities of the territory, social cohesion, civic sense, memories [7]. All the actions oriented to "localization" so contribute to the redefinition of social structures and relationships between resources, activities, nature and communities. Natural parks, as we said, are aimed to maintain the environmental balance of a specific place, increasing or protecting its biodiversity, and at the same time providing services (scientific, educational, touristic, recreational) to ordinary or occasional users. "Accessibility is a function of the interaction between the user, with his skills and demands, and the environment, consisting of natural resources and the organization of equipment, personnel and tools aimed at the enjoyment of the natural environment" [8]. The model of the "sanctuary" precluded to anthropogenic contaminations has to be substituted by places where ecology and ecotourism can coexist. These are places able to provide visitors with high-quality experiences. In this sense, the park can be a place in which natural and artificial factors interact; and its

fruition is managed by a "complex and articulated system of elements, interconnected or interdependent, which allows the user to tend to the targets of autonomy and self-sufficiency" [9]. The design of these specific products and services is not limited to solve problems of accessibility, interaction and usability, but includes the study of needs, expectations and behaviors of different kind of people. It is important to take into consideration the fact that the theme of diversity has been affected in recent years by a substantial re-reading. "Individuals traditionally considered disabled (of which only a part - less than 50% - are mobility impaired) constitute a significant and growing percentage of the whole population, if we consider, in addition to permanent disabled people, temporary ones, those who are not considered part of the statistics as they are not registered as disabled, those whose handicap is a natural condition (pregnant women, parents with young children, children themselves, elderly people)" [10]. This "integrated landscape" can be composed by: supports for communication and wayfinding (vertical signs, physical information panels, nowadays "augmentable" with virtual contents); furniture and equipments (seats, covers, lighting equipment, delimiting and monitoring systems, instruments for waste management, playgrounds, tools for sports or leisure); equipped areas for rest breaks and reception (so capable of foreseeing and put in connection all the functions necessary for the various activities related to welcome services for visitors, including information, programming, security, lounge or refreshment areas, logistical support); intermodal mobility solutions; permanent or temporary micro-architectures that can be more or less capable of mimesis in the context (observation towers, paths, shelters, exhibition places, research centers or structures hosting initiatives for enhancement of the territory).

Micro-architectures for naturalistic areas are particularly interesting design practices. Although sometimes presenting important sizes, they are conceived in an intermediate conceptual dimension between the sectors of building and set-up design and, often, they experiment, with a particular attention to sustainability and to integration with natural elements, constructive practices based on the standardization of the components, on the use of innovative materials, on prefabrication, on modularity, on lightness, on reversibility, on spatial adaptability. These techniques and instances are usually adopted in the sectors of exhibit and industrial design. Moreover, these constructions are real examples in which a responsible design approach can adopt the guidelines and the rules of inclusiveness as an opportunity to optimize costs (avoiding future adaptations) and to achieve a widespread approval and use deriving from the elimination of obstacles and possible conditions of discomfort, danger and exclusion. Since there are often large areas available, many of these structures are characterized by the use of suspended ramps and walkways that solve the accessibility problems of traditional towers. Long "stripes" (treetop walks) can thus elevate the visitor to allow him to enjoy magnificent bird's eye views that give the sensation of being in direct contact with nature, being able to almost caress the trees, being able to observe the landscape from a privileged and immersive position. One of the first examples of inclusive design for natural parks structures is the Clingmans Dome Observation Tower, designed by Bebb & Olson (Hubert Bebb) in 1959 and built at the highest point of the Great Smoky Mountains National Park, on the border between Tennessee and North Carolina (USA). The designer refused the exclusive use of local materials and the "rustic style" (adhering to a certain traditional imaginary) and outlined a modernist-

inspired reinforced concrete walkway that leans on cylindrical columns and leads, above the treetops, to a "circular covered terrace" from which the visitor can enjoy a 360° view. The Shark Valley Tower (1964) in the Everglades National Park, the Look Rock Tower (1965) in the Great Smoky Mountains National Park and, on a smaller scale, the Wooden Birdwatching Observatory designed by the LJB studio in 2017 in Herdla (Norway) have been designed on the same composition scheme (Fig. 1).

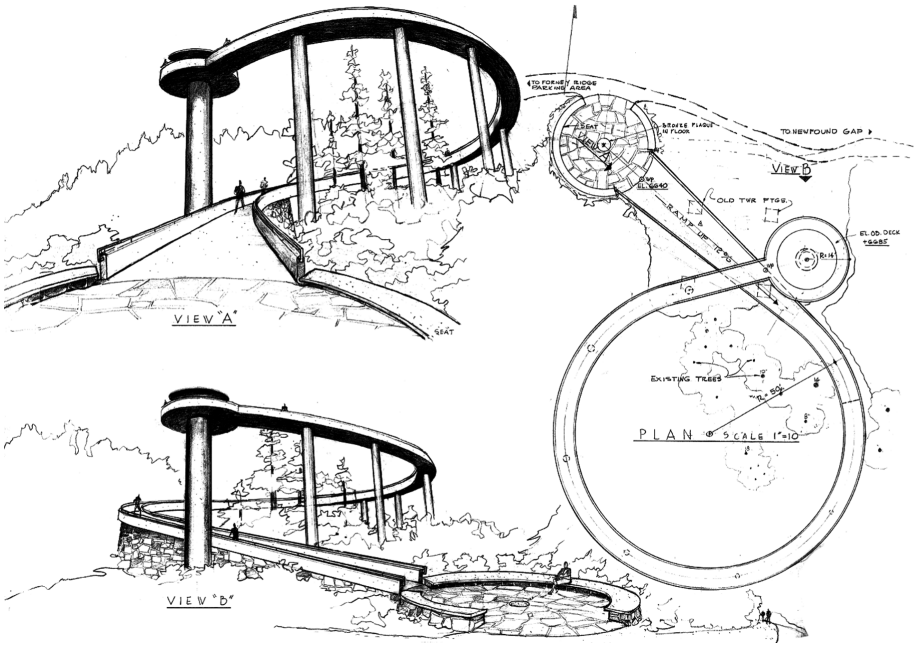


Fig. 1. Clingmans Dome Observation Tower, original drawings by Hubert Bebb, Bebb & Olson, 1959 Great Smoky Mountains National Park (USA). This pioneering project can be considered a fundamental archetype of modern observation tower strongly oriented to accessibility and standardisation of processes.

The project "A Path in the Forest" designed in 2011 by the Japanese studio Tetsuo Kondo Architects and temporarily set up in Kadriorg Park during the LIFT11 (Urban Installations festival in Tallinn - Estonia), pursues the idea of creating the possibility of a new perceptual relationship between people and the secular forest through a suspended path capable to provide alternative points of view. The project consists of a simple structure, 95 m long, and light enough to be able to anchor itself in a symbiotic way to the trees themselves, thus renouncing the need for additional support pillars. In 2012 the Tree Top Walk was inaugurated in the Bavarian Forest National Park, in Neuschonau (Germany). A wooden spiral ramp of 500 m allows visitors (even those with motor disabilities) to reach a height from the ground of 44 m. A similar case study is the Camp Adventure Park - The Treetop Experience, designed in 2017 by EFFEKT - ARUP for the Glisselfeld Kloster Forest, in Haslev (Denmark). An iconic hyperbolic

tower made of corten steel can be reached by a system of inclusive paths designed to define diversified functional segments. The user, walking through the foliage of the trees, explores bridges, spirals, aviaries, observation balconies, ramps and common seats. The Wild Walk, designed by Charles P. Reay in 2015 for Adirondack Park (Upstate New York - USA), was also conceived on the model of the "treetop walk". A large system of suspended paths that foresee various activities and create a context of strong visual impact that, at the same time, aspires to provide recreational experiences, but also to encourage people of all ages to explore and understand the surrounding natural environment through exhibitions and scientific events. In 2017 the Latvia Nature Conservation Agency launched an international design competition for an observation tower for the Kemeri National Park (Latvia). All the selected and mentioned projects (the results have been announced in June 2018) propose solutions strongly oriented to inclusivity. This fact confirms that today designers can become the spokespersons of a shared awareness according to which the contemporary natural park can be conceived as a "space for experience"; a place to experiment, to acquire information, to make discoveries, to share activities (and therefore socialize), to rediscover the pleasure of the contact with nature, stimulating virtuous behaviours (Fig. 2).

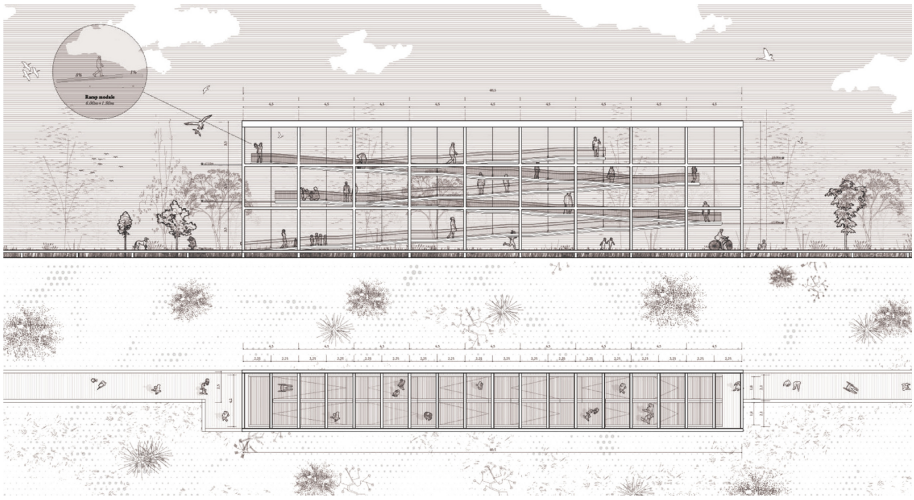


Fig. 2. Funambulist Landscape, Ernesto Urquízar Quesada, María Cervantes Lardón, 1st prize project of the International Architecture Competition Kemeri National Park Observation Tower, 2017. The observatory has been conceived as a sensorial and inclusive promenade, a multiple viewpoint to establish a continuous relationship between nature and visitors. The components of the structure are designed to be easily prefabricated offsite and to be assembled without the use of heavy equipments. It is important to note that all the awarded projects consider as key factors wheelchair accessibility, durability, ease of construction, and budget optimization.

The critical objective consists in conceiving the park no longer as a "sanctuary", a "container of wonders", or even worse as a "themed lunapark" only dedicated to recreational activities. The "park for experience" must instead be a values-amplifier, a determining instrument for the narration of the territory, for the strengthening of the local identity and of the environmental awareness of its users.

3 Natural Parks and Inclusive Services, Design Practices in Communication and Tools for Wayfinding

In the last 10 years, the international system of park authorities and the network of the numerous stakeholders involved in the management of the "Natural Capital"[1] of our planet, has shown to understand the relevance of design in the strategic project of protection and enhancement of the main heritage of humanity, demonstrating, in comparison to the past, a real "paradigm shift".

As the Italian Ministry for the Environment clarifies: "The concept of 'Natural Capital' has been instrumentally borrowed from the economic sector to indicate the value in physical, monetary and welfare terms offered by biodiversity to the human race, also in order to guide the choices of public decision-makers"[2], and it is perhaps precisely this new induced awareness that led this change. As how it happened for urban design practices [11], the "integrated tools" for parks fruition derive from innovations that have been developed in the more general field of outdoor design. From the analysis we carried out about some of the most important recent international projects, which affect the relationship between design and "Natural Capital", are emerging important signs of orientation of the "public decision makers" towards quality choices that are possible to made at various political scales. The research took into consideration good practices affecting a national level, as demonstrated for example by the systemic and coordinated projects developed in Norway, Japan and Croatia for their national parks networks; but also highly innovative specific projects affecting more circumscribed, regional, supra-municipal or local territories.

In these projects, design culture has been applied in order to contribute on different tasks: in graphic and visual communication components, in corporate-identity projects, in solutions for signages and scientific communications, in spatial and exhibit components, in the conceiving different kinds of infrastructures for both external and internal activities. Less known, or less visible, is undoubtedly the component of the project that today invests service design practices, but that are already present in embryonic ways in those projects both of visual identities and of infrastructures, designed in close synergy with the services they provide. The identity projects, for example, are today often integrated with specific digital Apps, so with tools for

[1] The term 'natural capital' was first used in 1973 by E.F. Schumacher in his book Small Is Beautiful and is closely identified with Herman Daly, Robert Costanza, the Biosphere 2 project, and the Natural Capitalism economic model of Paul Hawken, Amory Lovins, and Hunter Lovins. Recently, it begun to be used by politicians, notably Ralph Nader, Paul Martin Jr., and agencies of the UK government, including its Natural Capital Committee and the London Health Observatory.

[2] http://www.minambiente.it/pagina/capitale-naturale-e-servizi-ecosistemici.

exploring the park which provide scientific information and guidance services, as well as the design of infrastructures - towers, birdwatching cabins, etc. - it is developed with full awareness of the "performance" [12] that they can provide to their users, in terms of accessibility and hybridization with digital services.

Since the highest international institutions for environment protection conceive the Natural Capital as the set of "ecosystems which provide essential goods and services" to humanity, and since the same concept of Capital, borrowed from the economic sciences, encourages users and decision-makers to be well-aware of the value and wellbeing that derives from the natural heritage, it results that the design sciences are called today, more than before, to develop increasingly integrated solutions able to connect systems of products and services.

As previously said, this need strongly emerges from the analysis of some of the most successful projects of branding and scientific communication for national parks and protected areas. These case studies have in common that they are fully conceived as systems able to integrate the visual narration with users experiences, starting through the careful study of the peculiarities of each park or system of parks, and admitting the possibility of offering both traditional and innovative services.

3.1 Visual Identities

"Every organization is unique: its identity can only derive from its roots, its personality, its strengths and its weaknesses" [13].

As stated above, if it is possible to conceive of nature as a capital, the theme of identity design for parks must be able to make an association between company branding and place branding, and then imagine the institution of management, protection and enhancement of parks just like an organization that, to express its identity, has to be based on its specific peculiarities. The design of park identity becomes therefore more effective when it succeeds in carrying out this transposition, i.e. translating characteristics and peculiarities of supranational, national and/or local natural heritage into "visual stories" and integrating them into an overall project that offers unparalleled services and experiences.

The identity-experiential storytelling is in fact at the base of the 2015 project of Snøetta Design Studio for the coordinated identity of 44 Norway's National Parks. The logo is characterized by a squared portal, resting on the variable silhouette of a hill. It represents the visual translation of the story of a passing experience: "A portal is an entrance, or a gate, which symbolizes the transition between two dimensions; the traversing between the cultivated and the natural. The new, unifying visual identity opens a gate to these new experiences, it lowers the barriers for visiting, and facilitates the increased knowledge of our precious surroundings"[3].

Japan faced the problem of defining a national identity of the park system in 2017. The project have been developed by Yamaguchi Moeko of the Nippon Design Center. The designer cited the identity theme of the Rising Sun, the secular "logo" well-imprinted in the global collective consciousness, actualizing it through chromatic gradients that move

[3] https://www.domusweb.it/en/news/2015/04/17/norway_s_national_park_s_sn_hetta.html.

away from the full red of the national flag sun. The logo in this case symbolizes the sunrise experience, also sustained by an animation clip, with the shape of the Rising Sun in a typical foggy landscape of Japan: "The logo represents a unique Japanese landscape, the misty moment the sun rises"[4]. These two experiences demonstrate how the identity of a complex system of parks can integrate national themes and symbols with dynamic and experiential elements, able to reach a great emotional impact (Fig. 3).



Fig. 3. Norway's National Park, visual identity, graphic design, signage and wayfinding systems, Snøhetta Design Studio, Miljødirektoratet (The Norwegian Environment Agency), 2015. Photographer Øivind Haug.

3.2 Wayfinding

Wayfinding is an integral part of the communication project. If it is designed according to the logic of consistency and iteration of the identity codes, it plays a fundamental reinforcing role of the identity system and it has a significant functional role in terms of accessibility and security. In fact, the orientation and the "signaling" of predefined paths assumes a central function in a naturalistic context that offers great possibilities for the fruition of the different ecosystems (landscapes, views, etc.) so making users safe from potential risks. In the natural parks context, signaling has more than elsewhere the primary task defined by Arthur and Passini as "Problem Spatial Solving" [14], meaning the ability of the wayfinding to favor the achievement of the goal

[4] https://www.ndc.co.jp/en/works/national-park-vi_201711/.

through the resolution of a spatial problem. The most recent wayfinding projects for parks, that we analyzed in the research, have assumed all the functional constraints defined by Massimo Vignelli[5] in his manuals, such as the "Hierarchy", the "Repetition" and the "Sequence" [15], surpassing them also in favor of an extended audience. For example, the recent wayfinding project for the Parc Riu Llobregat by the Spanish studio Claese Bcn elegantly included tactile maps in the whole signage system. Fitzpatrick Woolmer in 2012 designed the signages for the Brecon Beacons National Park, in Wales. In this case the designer used the surfaces of the wooden benches as communication surfaces, so engraving tactile maps on the pieces of furniture that have been installed along the path.

3.3 Interpretive Panels

It is common practice in the functional project of parks and green areas of particular value, to provide some significant points of the paths with graphical panels carrying informations on the ecosystems to be observed, with the emphasis on the faunal and floral species present on the site. The interpretive panels are fully part of the coordinated communication project of the park, often adopting the same codes and identifying characters. These panels are particular examples of infographics. They descent from an analogical world that wanted to bring scientific information, managed with a manual approach and with a simple and informative language, to the public of visitors, often imagined as it was overall composed by children. In some of the most recent communication projects for the parks, the interpretive panels have been conceived as hybrid interfaces - analog/digital - able to increase inclusiveness of communications. So from the simple integration of tags in the graphics of the panels that refer to the online world, we witness the transformation of the same into three-dimensional tactile maps also including short braille texts, so usable by an extended range of users. Important examples are the ones designed by Atlantex Creative Works for the Canadian Fundy National Park, or the ones installed in the botanical garden of Porto Caleri in Italy.

4 Conclusions

This ongoing research demonstrates the need of a paradigm shift in redefining the "eco-social" role of parks that, if redesigned through scientific and interdisciplinary actions, can become places for promotion of health, culture of respect for nature, socialization and valorization of the territories. Natural parks can contribute to the contrast of the fragmentation of the territories and can act as a mitigation instruments between urban, periurban and rural areas. Tools of diffused ecology, economy and education, markers of sustainability and wellbeing. Design sciences play a strategic role in redefining priorities, anticipating transformations, giving identity and new meanings to places, artefacts and services, involving different actors in research-action paths oriented to

[5] Massimo Vignelli, graphic designer, in 1977 he realized, in collaboration with his wife Lella, the Ungrid project; one of the first integrated projects of corporate identity, wayfinding and communication for parks. Client: Natural Parks Service (USA).

sustainability. Design do not only has to propose "constructive practices", but "strategies of resemantization and refunctionalization" to gain true models of inclusiveness and social development. With this in mind, the design of new solutions for parks has the task of updating and redefining the rules of coexistence between nature, people and artefacts and therefore the possible degree of anthropization of nature; and planning new models of use that include new users, new priorities, new sensibilities and new awareness.

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User Interaction and Scenario-Based Experience Design for New Media Technology in Museum Spatial Experience

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Abstract. This article aims to study the interaction and scenario-based experience design of new media technology in the museum, improve people's sensibility to museum-theme space information, and facilitate propaganda and education. It mainly: (1) summarizes the expression of new media human-computer interaction techniques in the museum; (2) discusses the relationship between museum-them space shaping based on new media technology and humans' visiting experience; (3) summarizes the experience in human and museum space storyline with new media intervention. The article focuses on theoretical analysis and practical significance study from the 3 aspects. Meanwhile, it outlines the influence humans perceive in museum spatial experience.

Keywords: Museum space experience · New media technology · Interactive experience design · Scene experience design

1 Introduction

A museum is an interactive place that takes space as its medium for the purpose of disseminating information. Museums continuously grow as the humans' material and cultural lives become increasingly rich. It satisfies the needs of human information exchange in multiple fields, such as information, knowledge, technology, education, culture, as well as trade and business, while constantly driving forward human development and progress [1, 3]. The development of the exhibition space in museums is dependent on multiple elements, including space architecture, media, and exhibits.

The so-called "new media" refers to a form of technologically advanced medium that emerged relatively late and presents new forms of interactivity and connectivity in information transmission. Born out of the computer and network technologies, the new media breaks the molds of old-fashioned presentation and language of the traditional museum exhibition. Moreover, storytelling techniques in museums are no longer perpetually rigid, and in terms of the spatial expression of a museum, new media act as a kind of emerging medium of narrative expression that creates new spatial plots meaningfully and purposefully, instead of simply using those known or unknown technologies to construct the medium of space, thus influencing the "old" media and people's way of thinking, their behaviors, and their perception of the exhibits in an

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exhibition space, giving the exhibits a new form of impression expressible in its exhibition space.

The so-called spatial experience is a visual expression-based forming principle of arranging each element of space with media materials as the elements, and the principles of mechanics and modern technology as the support, in accordance with certain aesthetic rules to achieve a beautiful visual experience.

Museum exhibition design is interwoven with space, and museum design can even be understood as an artistic activity of space planning. Then, rational spatial experience and spatial interaction are the keys to determine whether the concept of museum design and the essence of design can be expressed in depth [2, 3]. The spaces of museum exhibition can be categorized into "tangible" and "intangible" spaces by enclosure, as well as physical space and virtual space by form. Hence, the arrangement of space that features the new-media-technology-driven interactive experience among spatial components in museum exhibitions should also be completed in accordance with the form, size, and enclosure of different spaces (see Figs. 1, 2).

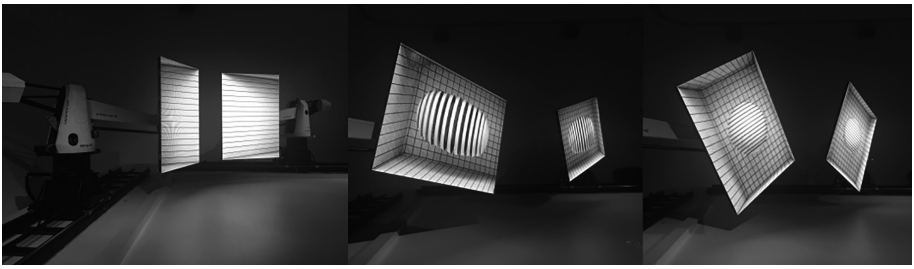


Fig. 1. Interactive new media installation of South Korea pavilion at expo 2014 milan, Italy

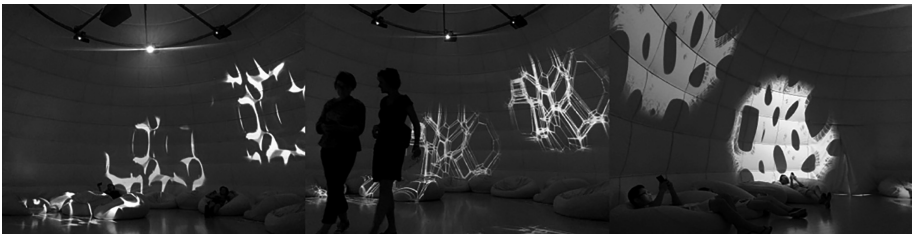


Fig. 2. Immersive space interactive experience of new media

2 Method

2.1 Forms of Expression of the New Media Human-Computer Interaction Technique in Museums

Space is a "container" of exhibits, and its nature is determined by the theme and characteristics of the exhibits in the museum. Museum space utilizes architectural entity

and new media in space to convey information presented according to the exhibition theme, through which the process of human-computer interaction experience is formed.

The use of the new media-based human-computer interaction techniques is an important tool and a necessary medium for information dissemination, and the human-computer interaction involving the new media in museums is a way of using integrated media, such as texts, images, videos, audios, dramas, interactive demonstrations, commentaries, and various physical models [4–6]. Due to the use of new media, exhibited information can exist in a new state and be perceived by the audience in a new form. The new media gives traditional museum spaces the option of digital presentation and incorporates the concept of human-computer interaction, giving rise to unidirectional, bi-directional, and even multi-directional information dissemination (see Fig. 3).



Fig. 3. Interactive multimedia installation at Shanghai museum of glass, China

2.2 New-Media-Technology-Based Exploration of the Relationship Between Museum Space Narration and Visiting Experience

Visiting and experiencing museum spaces in conjunction with the use of new media are activities that are proactive and participative in nature, while museum space is a space of information exchange where the audience input and output information at the same time in the experiential process.

The use of the new media further prompts the audience to integrate intuitional experience in the process of visiting the museum. Information reception in a museum, comes from not only the visual experience, but also from the stimulation of any other sensory terminals throughout the whole body. Only by making the audience feel the information in person can they be more able to perceive the information content, and hence complete the visit and experience process via their senses [7, 8]. At first, vision is the most important channel to collect information from that provides the most intense and clear feeling of the information, and what "seeing is believing" stresses is exactly visualization; second, sound draws the attention of people most easily, and auditory experience often can make space more mysterious; next, tactile sense is the most real, and one feels this world all the time, ranging from air motion and temperature variation to material texture and object shape, so in a manner of speaking it is the first instinct for us to identify surroundings; lastly, normally, olfaction and gustation are rarely used in medium experience and are mainly for the functional needs of daily life, but once used

properly, they will greatly arouse the memory nerve of the viewer. When all senses are selectively used in the narration of a museum space, it is highly likely to arouse plot experience featuring life memory and emotional resonance with the people [9, 10]. Therefore, in a narration design of a museum space, the purpose of exhibition design is to utilize new media technology to convey information and receive feedback, and how to utilize new media technology to constitute better content to intervene in the overall visiting route and achieve good visual effects is the focus of the studies conducted by designers (see Figs. 4, 5).



Fig. 4. Human-computer interaction device in Germany pavilion at expo 2014 milan, Italy

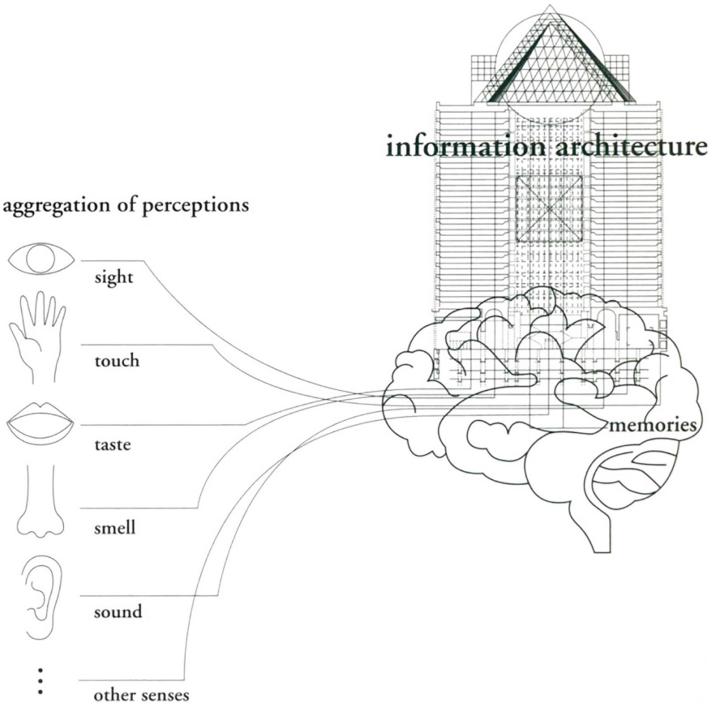


Fig. 5. The five sense organs of the human body, this is from Hara Kenya: Design in design, Shandong people press, 72 (2006)

2.3 People and Museum Space Plot Experience as Intervened by the New Media

The arousing side of plot experience often comes from thematic storytelling, personification of stories, plotting of figures, and orientation of the plot towards everyday life. Thematic storytelling is more likely to generate suspense and moving content, which is why it is best at evoking emotions of the audience. The new media convergence is manifested by the fact that traditional narration with relatively closed and complete narrative text will be gradually replaced by a loose network structure. The latter can develop a plot by expanding the scope of narrative possibility, and offers help for the expression of museum information with people's action or their interaction with others. Personification of stories makes it more vivid, because figures are the foundation to further discuss experience, conflict, and suspense. Correspondingly, plotting of figures can bring people more surprising details [11, 12].

To study the plot experience in a museum under the influence of the new media technology, we need to start from two aspects - humans' physiological dimension and psychological dimension. The experiential transition from physiological to psychological is a progressive change directed by the change in human emotion, as emotional involvement is the result or effect of watching and the result of the dialogue between the audience and the object in the museum space. Humans have a variety of emotions, such as surprise, joy, anger, excitement, irritation, satisfaction, depression, and many other indescribable emotional characteristics [13, 14]. Thus, all kinds of emotions surface in the process of information exchange with the objects in a museum by using auditory sense, visual sense, tactile sense, and even through the gustatory and olfactory organs. Mobilizing these five senses requires the human's active participation, from a supporting role to a leading role, from a spectator to a controller, but this high involvement and sense of control are hard to achieve in story plot experience of a traditional museum (see Fig. 6).



Fig. 6. Multimedia interactive experience device for Germany pavilion at expo milano, Italy

3 Results

In a museum exhibition space, new media-based exhibits and installations have been applied into the thematic expression at a higher and higher proportion, from 15%–30%, to even as high as 80%. Highly-sophisticated digital display methods have completely expanded and overturned the narrative language of traditional exhibition space, new media's display props, and installation arts, such as touch screens, projection systems, interactive systems, holographic images, and 4D cinemas, adding a new language to the exhibition space narration with increasingly diverse design approaches, influencing the speed and breadth of information reception by the audience. New-media-technology-driven information dissemination mode tends to be a way to connect those who share the same opinion and idea [15–17]. In other words, in a sense or to some degree, its forms of expression can transfer some spatial information in someone's idea to the perception of another to make the information interaction possible. In effect, it is just like the rhetorical device called "synaesthesia" in literature, which uses feelings that are originally perceptible only by organ A, to express the feelings perceivable by organ B, for instance, the ability to "see coldness", "smell color", "hear flavor", and the like. Such a figurative language is able to transfer human senses, link up, and interweave different feelings, and hence makes the information in need to be conveyed more vivid, intriguing, and perceptible. This is also an important form of the new media in museum space design.

People change from a spectator to a controller in museum space narration, and this change goes through a long historical period. From technological development, change of concept, the elevated power of speech of the audience, to the power delegation by the exhibition designer, all reflect the importance and subjectivity of the audience, namely the people in space. The audience no longer watches from afar, quietly accept, and passively approve, as they can control the theme of the exhibits or the development of the spatial plot, and choose when to quit and when to change in real time [18].

Museum space experience does not exist alone in a spatial plot. Hence, new media convergence needs to allow the audience to acquire more real feelings through perceptual experience integration and hence immersively and comprehensively feel the content of information. In the process of practicing new media convergence, on the one hand, we can make use of the characteristic of the object to lead people to think in a direction; on the other hand, we do not need to deliberately describe the characteristics of this object, rather, we should tempt the audience into putting together the form of information with abstract experience. Supplement and integration of different perceptual experience allow people to fully dig out the meaning of museum space information, while the omission of some space plot experience can make people throw away some of their long-held concepts and ideas, and re-explore the feeling that this information brings to people (see Fig. 7).



Fig. 7. Multimedia holographic installation at the museum of AC milan, Italy



Fig. 8. Multimedia human-computer interaction device at Japan pavilion at expo milano, Italy

4 Conclusion

The enhancement, improvement, or emergence of every technology endow art with a whole new mode of expression. Therefore, artists and designers are all incessantly seeking and exploring all possible technical media and materials, and trying to get new answers to change and innovate new thinking, new experience, or new artistic possibility. Hence, for museum design, innovation and revolution of science and technology undoubtedly inject critical nutrients in the continuous improvement of museum space design, making it grow and become full-fledged (see Fig. 8).

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Inclusive Participation Design Methodologies for Digital Cultural Heritage

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Abstract. The European cultural and historical heritage contains a surprising richness and variety that places it, thanks to its multi-diversity and heterogeneity, among the most interesting territories at international level. As a result of the scarcity of accessible technical equipment [1] and lack of time or availability to physically visit each Cultural Heritages, the knowledge of the European cultural heritage is not as widespread as it deserves. For this reason, a highly skilled work team with heterogeneous skills and approaches, has been created. Through the INCEPTION project, this team is developing inclusive methodologies with the aim to increase the dissemination and the knowledge of the historical cultural heritage through a web platform. The paper describes how it has been possible to model and apply some of the principles of the Human Centered Design in an international design research project in order to promote the accessibility of the digitized cultural heritage, through the involvement of institutional subjects. Moreover, the authors illustrate how co-design represents a valid method of work planning and a methodological design tool that allows a productive cooperation between different demanding profiles in the field of Digital Cultural Heritage.

Keywords: Digital Cultural Heritage · Accessibility · Human Centered Design

1 Introduction

The INCEPTION project has been applied under the Work Programme "Europe in a changing world - inclusive, innovative and reflective Societies" (Call - Reflective Societies: Cultural Heritage and European Identities, Reflective-7-2014, Advanced 3D modeling for accessing and understanding European cultural assets).

This research project has received funding from the European Commission's H2020 Framework Program for Research and Innovation under Grant agreement no 665220.

The main purpose of INCEPTION is to make understand and spread the knowledge of the European cultural heritage [2]. Thanks also to the multidisciplinary, heterogeneity and skills of the project partners, it is planned to outline appropriate strategies for the dissemination of information regarding cultural heritage to a wide and diversified audience, also trying to find solutions that are oriented towards an accessible and inclusive knowledge of it. The project therefore aims to define innovative and inclusive

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methodologies for the development of 3D [3] models of Cultural Heritage, providing information that can increase the perceived quality and interdisciplinary knowledge of cultural identity. The main objectives of the project, which are already partially developed, are related to the deployment of innovative strategies for the acquisition and implementation, through 3D models of buildings and historical contexts, of integrated data as complete as possible on the built cultural heritage, and to the proposal of specific methodologies for the semantic structuring [4] of data for Cultural Heritage, all organized through a standard open web platform for the dissemination and sharing of the harvested information.

The project, thanks also to the geographical heterogeneity of the Partners, aims to apply to nine case studies with different locations and natures, different digital acquisition tools and then, for each case, to make data, 3D models and other informations like pictures, documents, available and easily accessible for the end user.

This paper, edited by the team that is responsible for the design of the modes and tools to access and interact with the platform, focuses on the application of the Human Centered approach to the design of digital instruments and interface, like the web site. The platform is intended to be accessible for a number of user as big as possible, and to make its content available through a collection of spontaneous crowd-sourced contributions, but it also requires the availability of more specific tools, intended for experienced users, for the upload, management, validation and maintenance of the Platform.

The INCEPTION project is under development by a consortium of fourteen partners from ten European countries led by the Department of Architecture of the University of Ferrara. Academic partners of the Consortium, in addition to the Department of Architecture of the University of Ferrara, includes the University of Ljubljana (Slovenia), the National Technical University of Athens (Greece), the Cyprus University of Technology (Cyprus), the University of Zagreb (Croatia), the research centers Consorzio Futuro in Ricerca (Italy) and Cartif (Spain). The clustering of small medium enterprises includes: DEMO Consultants BV (The Netherlands), 3L Architects (Germany), Nemoris (Italy), RDF (Bulgaria), 13BIS Consulting (France), Z + F (Germany), Vision and Business Consultants (Greece).

2 Methodology

The design research shown here starts with the understanding of the needs of the different categories of users and specialized stakeholders involved, to get to the co-design of the interfaces and instruments for the navigation of the platform.

This methodological step was important to try to incorporate all the needs and expectations of the people who will use the final web/mobile platform [5].

To obtain this, two meetings of participatory work were held between the research team, the stakeholders and the users to plan together the best strategies for the conception of the structure, the organization of the contents and the interfaces of the INCEPTION web platform, through some co-design project tools, such as User Experience Map, brainstorming, card sorting and others.

The INCEPTION platform is already structured through a general system architecture. Therefore, a first prototype of the platform has been designed and developed which responds both to the first needs of users and stakeholders (previously involved in participatory days and according to the literature) and of technological and system invariants and constraints determined by software and hardware developers [6].

The first prototype was submitted to a first test through a co-design workshop [7] (held in Ferrara on 11th June 2018). This was the first event in which some strategies were developed together with stakeholders with the aim to improve the accessibility to and of the platform. The goal was not only to receive users' comments and suggestions on the current state of the INCEPTION Platform development, but above all, to have the opportunity and privilege to participate with them in the project of contents and interfaces through experimentation and re-elaboration of the opportunities offered by the platform [2].

The aim of this activity, named co-design [8], was to understand all together – designers, users and stakeholders – if the structure of the first prototype had favored the understanding of the platform and if it had managed to give concrete and tangible solutions to the needs developed during the carried out needs assessment [9]. Therefore, the activity has represented a day of participatory work which has confirmed and improved the work done up to now, integrating it with different or more inclusive investigative tools [10] (Fig. 1).



Fig. 1. View of the first co-design workshop.

The final goal that the team had set to get at the end of the first day of participatory work was not so much to deepen the requests expressed by users and stakeholders, but rather to design with them – involving and intriguing them – in order to plan a new set-up of the platform, in such a way that it also met the expectations that have not been reached yet (Fig. 2).

	Contents	User experience	Interface
Tourist and specialized users	Hyperlinks to external platforms	Storytellers to relate the real site and the virtual model	Accessibility and inclusion even to people with special needs or disabilities
	Update the models with related data and information	Possibility to print virtual models into 3D physical models	Intuitive and hierarchical interface
	Examine the model in different historic periods	Knowledge about building by showing historical events	Information available even on smartphone and by AR
Governments and decision makers	Information about events and exhibitions and info about the physical place	Bridge the gap between real and virtual experiences	Do not waste time to find data during researches
	Download models for related activities	Make users updated on last modifications of their visited models	Provide users the % of browsed elements of a visited model
	Reliable data for scientific researches	Provide augmented reality during a visit	Give users few and clear information
Technicians and professionals	Split the elements of a building in order to visualize different historic phases	Keep in memory information already visited Real-time work sharing	Private area for not accessible models and filter research bar
	Store data of previous interventions and documents available even on mobile devices	Download 3D models with different scales of details	Timeline of interventions and last updating
	Interoperability among several external databases	See missing parts of the buildings	Comprehension of different parts that compose the building

Fig. 2. Summary of the results gathered during the first co-design workshop [7]

Once the first workshop that helped the project team to develop new strategies for the accessibility and inclusiveness of the contents of the web platform was completed, planning a further meeting with the participation of all stakeholders – with different skills and approaches – was necessary [11]. The purpose of the following meeting was to discuss and reflect mainly on the tangible characters (color, font, graphic interface, contents, navigation strategy) of the web platform.

3 Second Co-design Workshop

The second workshop took place on 26 November 2018 at Art'otel in Cologne (Germany).

At the event there were about 15 stakeholders and 5 moderators to better speak to users, for a total of about 20 people involved.

The final goal was to involve all the people in a participatory work day, trying to focus the discussion on what was the most relevant, complete and accessible graphic interface for them. The purpose was not banal and obvious, since the INCEPTION platform so far designed has two main ways to access it: one is to upload (manager, institutions who has in charge the cultural sites, etc.), the other is accessing for visiting places (general users, visitors) and browse available documentation. Institutions can upload 3D models and information to increase knowledge and number of visitors. Access can be done on site or in remote.

Therefore the available material is of multiple nature and interface: navigation of BM models, photos, videos, general information with historical description and location of each Cultural Heritage.

Currently, the platform has 9 case studies:

- National Archive - Museum of Hydra in Greece (inserted in the category Museum)
- Technical-Museum-Nikola-Tesla in Zagreb (inserted in the category Museum)
- The Church of the Assumption of the Blessed Virgin Mary, situated in Mirlovic Zagora (inserted in the category categoria Historical sites)
- Istituto degli Innocenti in Firenze (inserted in the category Historical sites)
- The Saint Nicholas Chapel, also known as the church of Obergum in Groningen province in the north of the Netherlands (inserted in the category Historical sites)
- Villa Klonaridi is located in Patisia District of the Municipality of Athens (inserted in the category Heritage buildings)
- Church-Panayia-Phorviotissa in Cyprus (inserted in the category Heritage buildings)
- The Castillo de Torrelobatón (Torrelobatón Castle) is situated in the province of Valladolid in Castile, Spain (inserted in the category Heritage buildings)
- The Akropolis of Erimokastro, Rhodes, Greece

To date, users are also divided into three categories: tourists and visitors (general information); scientist or scholars (going in depth and more detailed level of information); professionals and technicians (specific login, can upload technical info checking condition assessment etc.) (Fig. 3).



Fig. 3. View of the second co-design workshop.

The working day was structured in two distinct phases. The objective of the first phase was to improve the interface and the accessibility to the platform. In a Human Centered Design approach, the people were involved in a playful and creative activity in order to allow to the different users to customize, as best they consider, the graphical interface of the INCEPTION platform navigation tools. Specifically, the discussion focused on the following "screenshots" of the platform:

- Home page (card 1)
- Geographic search (card 2)
- Most recent Models/Most complete models (card 3)
- Categories (card 4)
- Models (card 5)

In the five cards are presented almost all the tools of the platform. The specific goal of the workshop was not only to understand which color was more suitable for the background or which font was more readable, but to understand which communication strategy made the platform more intuitive and captivating for tourists or visitors, more complete, scientific and reliable for technicians. Within a playful discussion, the aim is to understand what are the latent needs; to be able to recognize what are the needs not yet expressed by the people; to understand the needs and expectations that the people have towards a web platform.

In order to do this, the card sorting [13] method was used. It was chosen because it is particularly suitable to facilitate the processes of prefiguration and shared construction through a visual and tactile experience of possible interaction tools [14]. This tool allows to represent and organize in a coherent way the functional and interactive structure of a complex web platform, focusing it on the needs of the final users.

With the aim to facilitate the communication, participants were divided, according to their knowledge and skills [12], into two different groups. In this phase, stakeholders with diversified skills were appropriately chosen. In this way the range of feedback illustrates a broad target, with different experiences, skills and needs.

Each card has been printed in large size for the two tables in order to allow a correct readability even if not very close to the main table. Each paper card depicts the current state of the platform's graphical interface (with some strengths and weaknesses).

The workshop is useful to highlight the tools and functions that a visitor might need for a first interaction with the INCEPTION platform. To do this, some cards were processed and printed, representing every single operation that the user can perform inside the Platform. On cards, there are alternative set up of different info. Groups choose alternatives, and give suggestions by scratching, rearranging the contents, explaining opinions (with post-it on images or other comments directly on paper).

Furthermore, in this phase the contribution of the moderator was crucial. The moderator, leaving free the discussion, without setting limits, obstacles or empty moments, has addressed it towards sensitive issues for the final design.

This session was very helpful to collect inputs and suggestions on Platform interface, directly testing by final users contents more suitable to their different needs.

Therefore, it was possible to elaborate a database of new and latent needs and strategic choices on how to illustrate or position some contents rather than others in the webpage.

Specifically, for example, we discussed on what was the faster and more effective navigation mode for the choice of buildings. Currently there are three different ways:

- search button
- through the drop-down menu Categories
- Geographic search

Regarding the latter navigation mode, two options (screenshot) of geographic search are presented. Below are some suggestions extrapolated during the workshop, which comment this phase of work.

- Option 1 is desirable. On the left grey column it should be helpful to have a list of different kind of information (e.g. Pop up with historic info; climate);
- In Option 2 the ring in which the picture is included is too strong;
- Dynamic pointer (hand) should address to info on building (Fig. 4).



Fig. 4. In the picture above are shown some of the different cards prepared for the event; specifically, those regarding the geographical search of buildings in the INCEPTION platform.

Once the work divided into two groups was completed, a plenary meeting was organized, where all the stakeholders examined the work carried out on the other table. This last phase of work led to the drafting of a shared final document, in which some strategies or choices were identified in order to improve accessibility to the web platform.

The second part of the workshop wanted to investigate the current and future progress of the INCEPTION platform, with reference to the observations resulted during the participatory events organized in June 2018.

A questionnaire has been developed in order to find out whether the adopted solutions were considered accessible, shared and inclusive for all stakeholders.

This document delivered to each stakeholder, was divided into two parts:

Part 1 - The first part of the questionnaire was focused on the solutions adopted to give answers to the observations which came out during the previous workshops. These observations have involved aspects that will necessarily be shown within the web platform. The document has been graphically divided into two parts. The adopted graphic and textual solution was on the top; the lower part has been left empty with the aim to provide the opportunity to write appropriate advice or suggestions. The graphic part was used by each stakeholder to suggest the navigation mode, however each user had the real opportunity to visit directly the platform through an individual PC; and therefore to observe directly the solution adopted in multimedia format (Fig. 5).



Fig. 5. Picture showing the individual questionnaire delivered to each stakeholder. Both parts are shown: the first (on the left) has been studied to understand the level of pleasantness, inclusiveness and sharing of the solutions adopted; the second (on the right) to investigate which aspects of the future platform are more shared and crucial for the involved stakeholders.

Part 2 - The second part of the questionnaire concerned the possibilities and future suggestions to be applied to the INCEPTION platform. For this reason the document did not illustrate a graphic part of real solutions, instead it contained evocative or suggestive images of how the new future platform could change and be configured.

In this part, Stakeholders are invited to express preferences on a multiple-choice chromatic scale (Green = preferable, yellow = medium; red = bad choice) on several issues emerged during the last meeting in Ferrara, to be implemented.

4 Conclusion

The participatory work days, structured in co-design workshops, have obtained important results on several aspects. Firstly, they allowed the involved stakeholders (with different sectors and specific competencies) to be able to understand other people's technical and emotional needs and therefore improve their awareness about inclusive design configurations. Secondly, they have increased the empathy between the design research and development team, the stakeholders and users of the INCEPTION project web platform. Thirdly, the applied methodologies, such as card sorting, have allowed both a fast and reliable comparison through a shared graphic

language and have made the hypothetical solution immediately perceivable, making it easier also for influential stakeholders, even though with limited technical skills, to make an aware judgement about the credibility, effectiveness and inclusion of different design solutions.

One of the most important values of INCEPTION, a project regarding the development of an accessible and inclusive web platform, is to increase the knowledge of the historical heritage (tangible element) thanks to the accurate and meticulous study of the intangible features that characterize its interface and configuration, conceived to expand as much as possible the amount of involved users.

Codesign has confirmed to be a powerful and rich complementary tool to QFD, when applied to multidisciplinary design research of inclusive public services, since it allows to verify and integrate the results of the qualitative/quantitative approach of the Japanese UCD methodology with more empathic and human-sourced informations that are delivered under the shape of participated design solutions or suggestions.

In the next few months, the project will reach the final stages until completion and delivery of all the outcomes, scheduled for May 2019. The greatest effort is now focused on the platform population by uploading all the data related to the nine Demonstration Cases, and to the final platform interface. The digital models will be enriched with documentation, attachments, videos, pictures, information, according to the main purposes of each Demonstration Case.

In addition to the nine pilots under uploading, an INCEPTION Course will be held between April and May 2019 in order to present the platform to Institutions, Public bodies, Research Centres, etc., involved in the Heritage field, as a motivation to propose Heritage digital models to be uploaded on the platform. In this way, digital models currently unknown to the public or unexploited could be shared in an inclusive way.

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User Attitudes Towards Wheelchairs: A Mexican Case Study with Special Focus on Vulnerable Wheelchair Users and Wheelchair Assistants

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Abstract. In Mexico, wheelchair users face discrimination and attacks on their dignity. To improve this situation, products that consider the needs of the whole population, while highlighting those of vulnerable groups, need to be developed. Nevertheless, little efforts have been made to acknowledge how vulnerable Mexican users and wheelchair assistants perceive this device. Hence, this research aims at gathering a deeper understanding of how the latter users feel towards current wheelchairs and where they perceive areas of opportunity. Semi-structured interviews were made to retrieve information about variables like wheelchair characteristics' prioritization, pain-points and wearing. Some of the most relevant results include the need to implement elements that consider natural body functions like sweating, and the misfit of wheelchair-user dimensioning. With these study's findings and by considering vulnerable groups, we aspire to provide insights for wheelchair design, that if satisfied, could help to create more inclusive devices and thus, more inclusive environments.

Keywords: Inclusive design · Wheelchair users · Wheelchair assistants · Older adults · Children and adolescents · Vulnerability

1 Introduction

Wheelchair users are varied and can be defined as those who already use a wheelchair or those who could be benefited by one due to limited mobility [1]. Regardless of their age, gender, place of birth, lifestyle and overall situation, these users require a dignifying mean of mobility.

In Mexico, vulnerable groups are more prone to suffer attacks that damage their dignity due to factors that as gender discrimination, low levels of schooling and low

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income. Moreover, if we add that some of them also suffer from health vulnerability and that they are wheelchair users, this situation becomes worse, translating into higher degrees of discrimination and dignity loss [2]. In order to improve and establish effective health and development programs, products that consider the needs of the entire population, while highlighting the needs of vulnerable groups, need to be developed [3, 4].

Considering these vulnerable groups and their needs when designing wheelchairs will result in greater empowerment and more participation in daily activities, this will allow them to have a more independent, inclusive and fulfilling life [1]. Also, having a proper wheelchair/mobility tool has the potential to benefit other sectors, besides healthcare, such as economy and education because of the user-society integration that a wheelchair provides [1, 4].

For this article, we have identified two further vulnerable users when it comes to wheelchair use: older people (55 years or more), and children and adolescents (0 to 17 years), which are sometimes considered in the same group [5–8]. In Mexico between 2014 and 2015, there were about 17.28 million older people and 43.5 million children and adolescents [9, 10]. Out of these, around 3.155 million and 0.307 million respectively had a disability when walking or going up or down the stairs when using their legs [10, 11]. According to [12] around 1% of the total of the population in any given country needs a wheelchair, this would mean a need of 1.19 million wheelchairs in Mexico (considering the latest official data available from 2015) [13]. As reported by [10, 14] wheelchairs were the most used technical aid during 2014 with an estimation of 1.24 million users, which, in theory, would satisfy the national need. Nevertheless several clarifications need to be made: (a) the exact amount of wheelchairs needed is not entirely precise as stated by [12]; (b) the numbers from the Mexican population stated above were from surveys with self-reported answers, therefore people that actually need a wheelchair but do not state it could be higher; (c) there is a lack of more updated data that will not be fulfilled until the next couple of years, and (d) it is not specified how these wheelchairs are distributed amongst the population. Hence some people might be lacking one, including the vulnerable population.

Also, the people helping the user that sits on the wheelchair were contemplated as key users in this study, since they can sometimes be the primary user depending on the level of disability of the seated user.

It has been documented that current aids in Mexico do not adapt to the user as they should, making them feel unsafe and uncomfortable, and this situation could worsen the quality of life of all users (including the most vulnerable ones) [15]. In addition, user experience regarding the manoeuvrability of wheelchairs has been negatively rated on a daily use basis, thus creating an opportunity to improve this device [16].

Considering the importance of designing for vulnerable groups and assistants, and the lack of information about the latter, this research aims at gathering a more in-depth understanding about how wheelchair users and assistants feel towards current wheelchairs and where they perceive areas of opportunity for product improvement. A particular focus was made on the groups mentioned before as further vulnerable to make their needs visible, and hopefully in the future, design better wheelchair proposals.

2 Methods and Materials

2.1 Participants

Four wheelchair users - two children/adolescents and two older adults -, and seven wheelchair assistants were interviewed. From the wheelchair users, three were females aged 16, 58, and 84 and one male aged 16 years. The females were independent full-time users and the male was a part-time user, in both cases, they were assisted from time to time.

Four assistants were females aged 21, 24, 42 and 57; with five, one and a half, two and 20 years of experience respectively. Three assistants were males aged 23, 31 and 74. The youngest and the oldest assistants had two years of experience, whereas the assistant aged 31 expressed his years of experience as "a lifetime". All of the assistants were providing help to wheelchair users at the time of the study.

2.2 Materials

For the evaluation, two interview layouts related to the users' attitudes towards the wheelchair were developed based on questionnaires and suggestions of [16–18]. One of the two layouts (which include open-ended and open questions) was applied to the wheelchair users that sit on the wheelchair and the other one to the wheelchair assistants. The questionnaires had the content shown in Tables 1 and 2 respectively. The slight differences between them were mostly due to the variation of the typical activities that they perform and their user condition (seated vs assistant).

2.3 Procedure

To apply the interviews to the participants, an online request via social media (to gather as many participants as possible), a visit to a public hospital in Guadalajara (Mexico), and a visit to a meeting center for older adults were done. All of the users that sat on the wheelchair agreed to a face-to-face interview at a place of their preference, except for the participants interviewed at the hospital and the meeting center. Out of the seven assistants, five agreed on a face-to-face interview and two answered an online form with the same questions. When the interview was made face-to-face, the questions' answers and any other relevant comment(s) were written by the interviewer. Else, the users were encouraged to write as many experiences as they wished through the online form. The users were not limited on their answers and could provide any extra information that they considered relevant. This freedom was agreed so they could feel in a comfortable environment, and when convenient (and if applicable), the interviewer returned to the previously made questions. When needed, questions were restructured, or sections were asked in a different order to make the interview as natural as possible to the user, mostly to children as suggested by [22].

For the first seven interviews (two with seated users and five with assistants), the questions were answered in their vast majority and the answers provided information about the participants' feelings, preferences and areas of opportunity. Plus, the questions elicited valuable feedback that was not considered on the questionnaires (like challenging scenarios for the users). Nevertheless, users seemed uneasy at the end of

Table 1. Seated user interview's sections and the correspondent data that was retrieved from them.

Section	Data retrieved
0-General data	Age, sex, studies, residence (city/town), time for which the user has used the wheelchair, the reason for using the wheelchair, and type of user*
1-General wheelchair data (as a product)	Type of wheelchair, equipment of the wheelchair, and element-related issues (e.g. seat, wheels, backrest)
2-Wheelchair use	Whether the user was trained to use the wheelchair and how, difficulty of performing daily activities (e.g. eating, showering, sopping), and pain related to body parts when using the wheelchair**
3-Wheelchair perception	Liked and disliked aspects of the wheelchair, whether the wheelchair was adapted to the user's body and if user felt identified with the wheelchair, importance and current users' wheelchair rating of features like comfort, stability, ease of use, safety and price***
4-Suggestions	Any other suggestion that the user could think of to improve the wheelchair

*User types based on the National Accessibility Scheme by [19] and [20]. **Body map based on the Nordic questionnaire's section that evaluates the anatomical areas and that has been used in different populations [21]. A scale that ranged from 1 (little pain) to 5 (intolerable pain), with the option of 0 (as no pain at all) was used. ***A 5-point Likert scale where importance was rated from "Very important" to "Not important", and their wheelchair status was rated from "Very good" to "Very poor" was implemented.

the interview. Furthermore, the term "robustness" and the question "Do you consider that the wheelchair represents you or do you feel identified with it?" needed additional clarifications since they were somewhat confusing. Therefore, to make the interview less confusing and with a faster pace for the other participants, Section 3 (in the seated user interview, see Table 1) and Section 4 (in the assistant interview, see Table 2) were reframed in order to be better understood by a broader population and to shorten the interview. Those sections were specifically chosen since they posed the most extended duration and were the most tiring when the participant was answering. To do so, preference evaluation methods that do not require a significant amount of cognitive effort and that minimize the artificial rise of the evaluation score due to over-enthusiasm were considered so the children and older adults could answer with ease. The format of the *Again-Again* tool that is part of the Fun Toolkit was considered to substitute the 5-point Likert scale. This tool gives a magnitude of preference, shows areas for development, and still provides open choices when compared to other methods like *This or that* [23, 24]. At the same time, the sub-section that reflected the importance of some of the wheelchair's features was left out since it measured the same variables as the sub-section rating the current wheelchair's features and users were tired of answering both. Besides, users tended to get confused and answered the first sub-section as if it were the second.

Table 2. Assistants interview's sections and the correspondent data that was retrieved from them.

Section	Data retrieved
0-General data	Age, sex, studies, residence (city/town)
1-General questions regarding the assistance	The time that the person has been assisting users, assisted people's profile*, the frequency of assistance and location (indoors/outdoors)
2-Wheelchair use	Whether the user was trained to use the wheelchair and how, movements performed when assisting (e.g. lifting the person or allowing them to place their hand on the shoulders), and pain related to body parts when using the wheelchair**
3-User relationship	Daily coexistence issues, user resistance to sit on the wheelchair, and solutions proposed
4-Wheelchair perception	Liked and disliked aspects of the wheelchair, whether the wheelchair was adapted to the user's body and if user felt identified with the wheelchair, importance and current users' wheelchair rating of features like comfort, stability, ease of use, safety and price***
5-Suggestions	Any other suggestion that the user could think of to improve the wheelchair

*Based on whether they were children, young adults, adults or older adults (55+) [5, 8]. **Body map based on the Nordic questionnaire's section that evaluates the anatomical areas and that has been used in different populations [21]. A scale that ranged from 1 (little pain) to 5 (intolerable pain), with the option of 0 (as no pain at all) was used. ***A 5-point Likert scale where importance was rated from "Very important" to "Not important" and their wheelchair status was rated from "Very good" to "Very poor" was implemented.

The interview was also shortened by removing questions and options that were found to be repetitive, or that could be answered with another question. For instance, the word "robustness" was related to stability. Thus it was removed, and "stable", which was less complex, was kept. Terms like "aesthetic appearance" were replaced to more comprehensive ones like "beautiful". Also, the question "Do you consider that the wheelchair represents you or do you feel identified with it?" was restructured as "Do you think that the wheelchair reflects your personality?". When possible, this subsections: (a) causes of using the wheelchair, (b) equipment of the wheelchair, and (c) part-related issues, were left to be answered by the interviewer (when it was apparent or visible) or a carer/supervisor that could answer to avoid the user's fatigue.

2.4 Data Analysis

The retrieved answers were analyzed and grouped in terms of similarity and repetition. After that, general variables that described the answers were established. Answers that involved numeric scales were averaged and prioritized. The questions that remained the same over the whole study were grouped with no distinction. When needed, clarifications were made about whether a question or section belonged to a specific questionnaire version. The early version of the survey, which corresponds to the first seven interviews, was referred to as "EV". The latest version of the survey, the refined version after the first seven interviews, was referred to as "LV".

3 Results

The results were divided into two parts, one for the seated users and the other one for assistant users due to each interview's structure. Tables 3 and 4 show the results for the wheelchair users and the assistant users' interviews respectively.

Table 3. Results from the wheelchair users' interview.

Variable	Results
Training	None of these users was trained on how to use the wheelchair. However, one user said that she used videos as a way to learn how to manoeuvre the wheelchair
Pain zone	The lower back was considered as the place where they felt the most pain with a mean score of 4.50 (SD = 1.00), followed by the upper back and shoulders with mean scores of 3.75 (SD = 2.50) and 3.5 (SD = 2.38) respectively
Difficult activities	Showering was considered the most challenging activity to perform. Moreover, although it was not previously considered, getting in and out of the wheelchair was also mentioned as a challenging task
Element- related issues	The lack of a break that assures a complete wheel stop and forgetting to place the break were considered as risks that could lead to accidents. Three out of four participants had issues with the break during the last year, making it one of the most problematic elements alongside seat and backrest wearing and the opening of the fabric's weave
Equipment and features	The four wheelchairs could fold. Three wheelchairs had a cushioned seat (in one case it was added after a while), of those, one had an adjustable footrest, and another one included a cushioned backrest. Footrests were one of the elements that in occasions resulted so inefficient that the users opted not to use them or even removed them since their feet kept on sliding
Adaptation	Opinions were divided on whether the chair was adequately adapted to their body with positive (n = 2), moderately positive (n = 1), and negative (n = 1) ratings
Experience	When asked about their experience while using the wheelchair that they were currently using, answers tended to go to extremes depending on their experience and expectations of the device. This was accentuated with the answers from the "EV" questionnaire. For instance, a user stated that her experience started negatively in a public hospital where wheelchairs were not even available and when she finally got her wheelchair (which was borrowed and previously used) the experience was further degraded. She even stated that it made her look older On the other hand, there was a case where the objective was to use it as little as possible since the user only saw it as a tool. Hence the relationship wheelchair-user was not as dependent and the facilitation that it provided were above any negative consideration. Still, comfort, cheap to repair, portability and easy to maintain and transport in public transportation were features that were poorly rated. It was also commented that a fixed seated position was tiring, and for one older adult's case, it even resulted in blood circulation issues
Shared priorities	Participants highly agreed on the need to improve the seat, since it was not comfortable and it became too hot during summer

Table 4. Results from the assistants' interview.

Variable	Results
Training	Four assistants were trained on how to use the wheelchair and worked as full-time assistants, taking care of various user profiles including adults (n = 3) older adults (n = 2) and children (n = 1). Three of them were trained with demonstrations, oral explanations and written instructions. The other one was trained with demonstrations and oral instructions only. Three assistants acknowledged the demonstrations as the best training method, and one claimed the theory and practice combined as the best
Pain zone	The lower back was considered the place where they feel the most pain with an average score of 3.07 (SD = 1.30) followed by the neck and knees with an average score of 2.14 (SD = 2.12) and 1.86 (SD = 1.77) respectively
Adaptation	Three assistants agreed that the wheelchair was not adapted to their bodies, with remarks as it being designed for the person that sits on it, but not for the person that assists. Two stated that the wheelchair was somewhat adapted to their bodies, and two said they were adapted correctly (one of the wheelchairs was customized to the assistant). The lack of proper adaptation compromises the manoeuvrability negatively
Experience	Heavy wheelchairs (e.g. steel vs aluminium) were harder to manoeuvre. The fact that the wheelchair allowed them to move the seated users (the wheelchair accomplishing its most basic function) was valued. Still, the wheelchair's features barely accomplished an overall rating of "average", with a weighted mean score of 3 out of 5 in the "EV" and 2.25 out of 3 in the "LV"
Shared priorities	Greater adaptability was highlighted, both for them and for the people that sit. It is interesting to note that although aesthetic appearance was given little importance, it was rated between poor and average in both the "EV" and the "LV". One assistant expressed that, although this is not important for them, it is for the users. The latter comment matches the seated users' opinions which expressed comments referencing the aesthetic appearance as important but rated their wheelchair appearance poorly

4 Discussion and Conclusion

Wheelchair users and assistants find value in the services that the wheelchair provides, mostly in the one concerning the mobility of users. As [25] have suggested in product usage, the facilitation of the wheelchair's goal (getting a user from point A to B) elicited positive emotions. This happened even when the wheelchair had many opportunity areas that were clearly stated by the users. The idea of "having this wheelchair is better than having none" was very latent. Still, this device should be improved. The need for a better seat and backrest design that considers natural body functions like sweating or even urinary incontinence must be complied. Similar to [16], discomfort in the seats were reported by the seated users. Failure to tackle this problem could lead to severe problems, including sores in the users' bodies and even more discomfort, thus hindering the possibilities of a better realization of daily routines [1]. The wheelchair's breaks and footrest are also elements that need to be redesigned. The

breaks tend to fail, and when the user is on the move, they most likely either make a full stop that is too abrupt or they do not work at all. For that reason, the implementation of progressive breaks that can be used to lower the speed and that can make a full stop when needed (e.g. when the user moves from the wheelchair to the bed) is suggested. For the footrests' case, structures that can be put away, but that do not wiggle while moving the wheelchair should be made. Overall, the wheelchair should be less static and more dynamic when it comes to part adaptation. Even if an element were to be designed considering anthropometric features, if it is fixed, it will most likely cause discomfort to the user. For instance, a low backrest would be good for active wheelchair users so they can manoeuvre the wheelchair with ease. However, even so, there are moments where their need is to be static, in this case, a high backrest would work better. The consideration of materials that diminish discomfort due to weather conditions (like heat or rain) is essential since the beginning of the designs. It is relevant to note that these weather conditions vary from place to place and from time to time. Thus material and design proposals that do not represent a significant cost for the user would be ideal.

Unfortunately, seated users did not receive any training, although it has been reported that these users would appreciate it and could potentialize their abilities and lower the possibilities of injury [1, 16]. In agreement with [1], training programs should be more widespread so the users can have a more independent and safe life.

5 Future Work

Although the selected population aimed to retrieve meaningful information through qualitative data, to have a representative sample of the Mexican population using a wheelchair further work is required. This paper represents the initial step of more extended research. Despite certain uncertainty related to the adequate representation of patterns, which is regularly recognized for population samples, the recommendation for future research is to select a larger adequate sample of the population to reduce the possible errors and generate more accurate knowledge. On this side, the authors suggest, as convenient for future research, to consider further vulnerable conditions that affect seated wheelchair users. This, based on the suggestions reported by pregnant women, which advice that the wheelchair does not project their ability to have a suitable pregnancy, and later on to take care of the child. This is a group that has been highly stigmatized and even labelled as "irresponsible" when they are not [26]. For that reason, their needs, attitudes and opportunity areas to improve the wheelchair should also be taken into account. Mostly in places like Mexico where literature about them is scarce.

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Inclusion of Children with Down Syndrome Through the Creation and Use of a "Learning Object"

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Abstract. This paper addresses the inclusion of children with Down Syndrome in school environments. It is based on the work of one of the authors developed as a Master dissertation in the area of Communication Design. The research integrates the study of the problem in context, with the participation of practitioners involved in the education process of these children. Framing the context implied studying not only this specific pathology but also the used learning-teaching methodologies, communication and interaction design principles and practices among other issues. Moreover, it was made a comparative critical analysis of three case studies of learning objects/systems to acquire knowledge and guidelines to support the creation of a learning object that would favor these children (aged between 5 and 7 years old) inclusion in regular schools. The result was an interactive printed book to mainly support reading and speaking activities in a playfull and shareable way. This book was evaluated by experts and was after improved through a design iterative process.

Keywords: Inclusive design · Down syndrome · Children's teaching-learning process · Interaction design

1 Introduction

Trisomy 21 (T21) or Down Syndrome is a chronical condition that imposes several challenges not only to children that have it but also to their families. It is then necessary to invest in order that these children can mature their neurological functions, practice daily routines and consequently learn and develop themselves.

By having a proactive behaviour towards their learning processes one can contribute to a fairer world, a better and more equal society, free of prejudice and one that constantly pursues information and knowledge to fight all types of exclusion situations.

In this particular area of education, we have chosen the age period between 5 and 7 years old since this is the moment children initiate their learning process as well as they reinforce their social interaction and engagement.

To avoid the difficulties children with Down Syndrome have in their scholar environment it is mandatory to submit them to continuous stimulation and to make them feel equal and included.

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The creation of materials that will help all children including these ones to acquire the competencies to read and to better speak, to execute daily tasks among other things in a playful and enjoyable way was the challenge we committed ourselves with having had the help of educators and after a field study that included the observation of two schools environments and the study of existing materials supporting these children development.

2 Scholar Integration vs. Scholar Inclusion of Trisomy 21 Children

Inclusion and integration are two different things. The first concept has a broader definition and signifies a total and unconditional insertion of the person. On the other hand, integration implies a partial and limited insertion of a person. In this particular case it means that the difficulties are on the part of children with "impairment" that can be integrated in the normal education system, but only when their characteristics allows it [1].

So, the option is to include, meaning to embrace, understand and reach and that is what we propose to these children: to proportionate them the same experiences that a child with a typical development has, "to accept the different and learn with him". To include is "to abandon stereotypes" [2] and to be happy to do it.

Learning is a process that requires interaction of the individual with the world; being so it is determinant as Bassani proposes [3] to assume T21 children school's inclusion as something natural and desirable since this way one can contribute to the improvement of their self-esteem and support their social development.

Although T21 children can experience some frailties and limitation while learning, the pedagogical work to develop with them must respect the rhythm of each child and to guarantee an adequate stimulation of his/her abilities since it is insufficient to just place the child in a suitable environment [4].

Thus, inclusion means a directed work based on the potentialities the child has instead of his/her weaknesses.

As Castro [5] acknowledges through several inclusion practices of these children in school environments it has been demonstrated that it is possible to stimulate in meaningful ways their abilities having a natural coexistence with the differences.

The inclusion gives a T21 child the possibility to interact with "normal" children through a collaborative apprenticeship process that allows a better quality of general development as well as of language ability.

It is also important to attain that the development of T21 children is better succeeded in ludic environments since it is easier for them to take advantage of a pleasant experience while learning important contents.

3 Role of Game/Ludic in the Teaching-Learning Process of Children with T21

Children are born with the potential to learn but learning occurs as a function of all the experiences children have during their development so, to have a stimulating childhood with appropriate play linked with each of the development phases will contribute to a healthier, integrate and complete personality's shape [6].

Since birth children experience an instructed world that starts with gestures, looks, words, drawings until writing is approached and reached. As Silva [7] states, to live this process through ludic activities proves to be the better option for T21 children's learning and development.

Consequently, the stimulation of T21 children through playful activities and gaming permits these children to access the necessary development of concepts such as identity, autonomy and in general terms allows them to discover the world surrounding them [8].

Friedrich Froebel (1782–1852) was the first educator to value toys and games as important elements in teaching-learning processes assuming that ludic activities allows the children to build up their imaginary world being the toy the vehicle of their self-expression [7].

Since then the ludic has been used to the development and education of children with special needs since "in classroom it is a facilitator of practical knowledge in group or individual activities" [9]. Despite that fact it is crucial to understand that educating by the use of ludic activities it is not "use packaged lessons so the student can consume it in a passive way" instead it is a conscious and planned act to seduce children to engage with the pleasure of knowing, of wanting to learn in a truthful assumption of the real meaning of "school" as a "place of joy, intellectual pleasure, satisfaction and development" [10] (p. 8).

4 Designing an Inclusive Teaching-Learning Object

4.1 Designing Interaction

A designer has an important role and an ethical responsibility towards people since through his/her actions and projects he/she determines their exclusion or inclusion in terms of their daily activities [11].

Being so, to create solutions to diverse problems is to design a complete and enduring answer that magnifies users' abilities and not their limitations, facilitating the acquisition of knew knowledge and helping the development of psychological functions [11, 12].

One of the ways of facilitating development is Interaction that serves the purpose of connecting and promoting development. It has to do with interactivity that gives respect to the result of interaction itself plus the result of the action of one of the parts involved in some event that presupposes a reaction.

As proposed by Casaca [13] the concept of interactivity must be used to improve the relationship a user has with an object, so it can create new opportunities of use and

interaction what is reflected on the quality of the object that can become more attractive and useful to the user.

Design process is supported by experience and constant iteration among the various process phases, so the designer can create the better answer to a given problem. It is then a flexible process, adaptative and open to transformation along its development [13].

In the case of a printed object one must create a narrative in which time and space are manipulated so the information is not entirely uncovered giving space to user's motivation to access the whole of it. In terms of printed objects, the disclosure can be guaranteed by the construction of folded elements, overlapped parts, that appeal to the curiosity of the reader and pulls him/her to act with it [14]. When an object presents interaction elements it excels other objects that only have plane pages since an interactive printed object gives "a closer and customizable dimension to its user having physical, tactile and manipulability characteristics that react to user's participation" [14].

4.2 Analysing Case-Studies

To support the design of an interactive printed object to support the teaching learning process to all children aged between 5 and 7 years old it was necessary to analyse existing solutions in the market. Three case studies where analysed and their strengths and weaknesses where acknowledged. Criteria used to select the case studies where the focus on the teaching-learning process of children with any kind of cognitive impairment.

The first case-study was a computer game entitled "Games of Mimocas" and it is targeted to children with mental deficiencies. It is an educational software to be used in a precocious intervention, so these children can have a better inclusion in school. It is a programme that allies education and entertainment increasing children's motivation towards learning and it is adequate to group activities.

The second case study was an activities' book addressed to parents of T21 children to help them along the development of their kids.

Finally, the third case-study was a method "The 28 words method" that departures from the general to the particular and that has good results in T21 children's apprenticeship although it is not targeted to them.

Regardless age target and the themes being approached these three case-studies allowed us to perceive positive aspects of educating tools and materials as well as aspects to be improved and enhanced. They served as inspirational material to the interactive object created (book + cards) that combines characteristics of them adding new and improved ones.

4.3 The Teaching Learning Object

As proposed by Hansen [15] inclusive design is the creation of products and environments used by all without the need of adaptation or specialized design.

A product should be designed to function in different contexts but more than that to make them part of the inclusive system it integrates. That brings us to Hansen [16]

definition of inclusive environment, one in which each user, independently of his/her abilities can live everyday life comfortably, with efficiency and security, without being limited by a bad design. Nevertheless, it is proved that in many cases it is impossible to offer a "one size fits all" solution, so, some individuals will always be excluded. Bearing that in mind it should always be part of a good design thinking process the goal of creating a product and/or service that fits the needs of the large majority [16]. An inclusive design approach that understands a product or system as part of a wider system of products and services comprehends the mental switch in design thinking that Atkin [17] synthesizes in a methodology that provides guidance to designers while developing their inclusive design solutions. In the case of an inclusive design approach one can either have an user-centred or a participatory methodology since both focus in users in the structuring of the design/research process. The process we focus on this paper is a user-centred one.

The main goal of the designed interactive kit (book + cards) was to contribute to a better performance of all children (including T21 ones) in terms of Reading and writing. The option was to do it based on activities that would captivate and deliver to children conquest and joy sensations along their learning process. The interactive book can be used autonomously but it is recommended its use together with cards (being more challenging for that reason) and it as a strong presence of images and daily words.

The focus of the developed solution was never the condition of specific children but instead the fact that all the children can learn and overcome difficulties achieving good results.

As previously said the designed kit (book + cards) is based on some elements of the case-studies mainly on the "28 words method" – in which we have 28 words whose syllables allow children to write other words – but also on the "Global method" – a more personal method using words that are more common on children's day-by-day life.

One of the premises of the project was that each word should relate itself with the proposed activity, so children would understand it easily and would have a joyful activity to perform.

The solution was an interactive kit with a main object – a book – that is used with 5 sets of cards – lowercase words; uppercase words, images, syllables, letters – that will allow not only to learn how to read and write but also some daily activities like make shoelaces (see Fig. 1).

Being an interactive kit children have to cut, draw, glue, associate, feel, build, to pair, all activities that are available in the kit never limiting the way of using it and above all supporting the attempt-error approach in each of the tasks.

In what concerns language this one was adapted to the target ages (5 to 7) and complemented with the use of colours, patterns and drawings to facilitate the concept and ideas dissemination.

As previously said besides Reading and writing the kit enables children to work fine motor through the use of textures, fittings and insets etcetera (see Figs. 1, 2, 3 and 4).

One of the main advantages and goals of this project is the fact that children can repeat the activities as many times as they want until they have a 100% assimilation of what they are learning and experiencing. Also important is the fact that each activity can have multiple answers.



Fig. 1. Images of the interactive Kit (book + cards) with some of the activities as well as of the cards that are to be used complementarily to the book (author, 2018)

4.4 Evaluating the Interactive Kit

The interactive Kit was evaluated by a group of experts – related with education, T21 pathology, therapists – so we could have feedback regarding its usefulness and impact on children's teaching learning process. This evaluation is essential since "the identification of flaws and problems is of extreme importance because it represents the first step towards the optimization of the object" [13].

Specialists had the opportunity to test the kit, to compare it with existing solutions, to propose improvements and adjustments and an iteration on the design process was done. The suggestions were implemented, and a new prototype was created. The final Kit was received by the expert panel with enthusiasm being described as an excellent tool to support the teaching-learning process since it has highly positive levels of usability.



Fig. 2. Images of the interactive book – using band-aids (author, 2018)

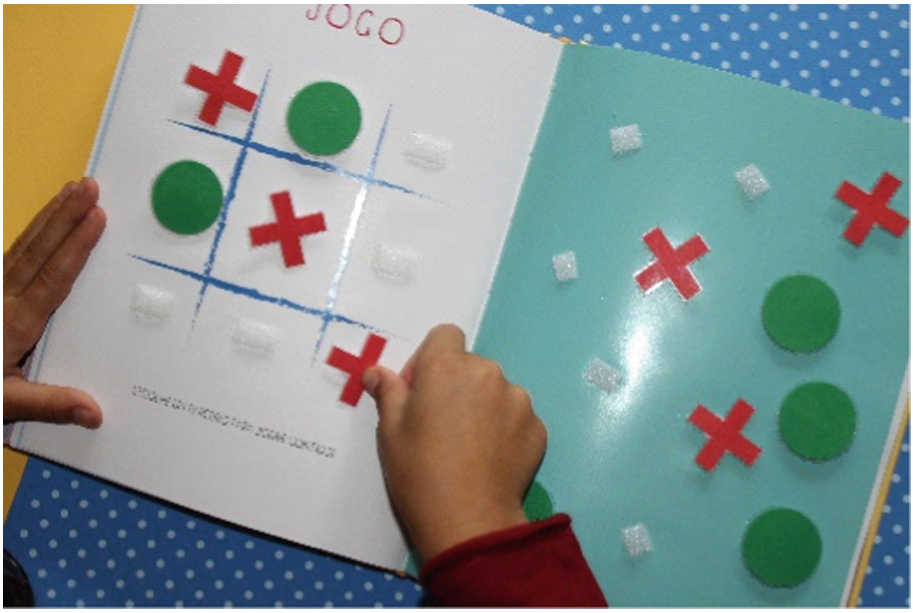


Fig. 3. Images of the interactive book – playing the rooster game (author, 2018)



Fig. 4. Images of the interactive book – climbing the stairs (author, 2018)

5 Conclusions

An overview of the themes and audiences focused in designing in an inclusive approach show us that the more common ones are related with elderly and disabled people, and that the contexts of the problems are usually related with the needs of mobility, security, personal basic needs (eat, drink, sleep, dress) health and education.

However, the children group of users is an interesting and important one to be tackled "since they are the future of the nations and working with them in an inclusive way one hopes to create a consistent intervention in societies developing awareness and an effective commitment of young generations with this approach" [18].

Inclusion in the education context is a challenging task especially when we are working with young children because the ethical implications are higher as well as the responsibilities. In the current hyper-complex world, it becomes extremely critical to guide children's development aiming that they will become sensitive, empathic and knowledgeable human beings.

Inclusion practices do facilitate that goal being accelerators of collaborative behaviors, citizenship awareness, and empathic predisposition. It also allows to experience the differences as something positive and rich.

The creation of this interactive kit made clear the need of more tools and equipment supporting inclusion. It also demonstrated that interactivity helps the teaching-learning process of children for the reason that it raises children's attention, enthusiasm and commitment to the process.

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Design of a Wheelchair for Low-Income Countries, the Second Stage of a Project

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Abstract. In the first phase of the project, it was reported in a previous conference communication, the manufacture of two low-cost wheelchairs developed under this platform, both proposals designed in European countries (Spain and Italy). Following the constructive drawings and instructions available on the open-source platforms, both chairs were manufactured as close as possible to reported instructions. In their manufacture process, both wheelchairs presented some problems, in the construction and during the user testing phase, we report these kinds of problems in the first stage of the project. In the present stage, we start from models manufactured and tested with users, with the aim of improving the product design, since, one of the characteristics of the products designed under the open-source scheme is its ability to be modified and adapted to local needs, materials and production processes.

Keywords: Wheelchair · Product design · Open-source platform

1 Introduction

People with disabilities make up one of the most marginalized groups in the world. These people have worse health outcomes, obtain lower academic results, participate less in the economy and have higher poverty rates than people without disabilities. The figures released by the WHO reflect that 70 million people in the world need a wheelchair, but only 5–15% of them have one. One of the principal causes of this is the high cost that for low-income countries implies the acquisition of a wheelchair. With this information, the low-cost wheelchair design project was launched in 2017 under the open-source platform at the Universidad Panamericana at Guadalajara, Mexico.

The objective of the project is the design of a low-cost wheelchair under the criterion of the open source platform, which will allow its manufacture by any interested party with a minimum of technical knowledge, materials, and tools.

For a product to be considered open source, needs to meet the following parameters:

(a) Free redistribution: The product design must be freely given or sold.
(b) Construction plans: They must be free and easy to understand.
(c) Derived works: The redistribution of modifications must be allowed.

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(d) No discrimination against persons or groups: No one can be left out.
(e) No discrimination of areas of the initiative: Do not exclude commercial users.
(f) Design distribution: The same rights should apply to everyone who receives the design of the product.
(g) The license must be technologically neutral: Do not require acceptance of the license through access by mouse click or other specific means of support of the product design.

2 Project Development

In the first phase of the project, it was reported in a previous conference communication, the manufacture of two low-cost wheelchairs developed under this platform, both designed in European countries (Spain and Italy). Following the constructive drawings and instructions available on the open source platforms, both chairs were manufactured as close as possible to said instructions. In their manufacture, both chairs presented various problems, both in their construction and during the testing phase, we report this kind of problems in the first stage of the project.

In this second stage, we start from the models manufactured and tested in the field, using as a base the model of the chair built in wood, because the latter proved from its construction to be more robust than the Spanish proposal made from PVC pipes (Figs. 1 and 2)



Fig. 1. User testing the wheelchair proposal made with PVC pipes, this model is economical and complies with being very easy to manufacture, however, it is very unstable and fragile, as well as it is complicated to maneuver by the user.



Fig. 2. A user is performing the test on the wooden chair; it seems that the feet are very flexed, as well as the lack of rim to push the wheel among other details.

The manufacturing phase of the chairs was carried out with the aim of improving the design of the same since one of the characteristics of the products designed under the open-source scheme is their ability to be modified and adapted to the needs, materials and local production means. We focus particular emphasis on improving the structural strength of the chair, as well as the use of materials, in order to optimize costs as much as possible, as well as to improve some ergonomic aspects that during the test with users, they showed as areas of opportunity. The overall objective of the project continues to be that the cost of the chair does not exceed USD 80 per unit and that it is feasible to be produced with simple tools and local materials anywhere in the world.

On the other hand, work continued on the search for more proposals to make comparisons, finding several proposals at the global level, some of which are well documented [1, 2], such as the model called "Free wheelchair mission, Gen 1" [3] which reports a cost of only $ 59.20 USD per unit including shipping to anywhere in the world (Fig. 3).

A consideration of this model is that part of the use of a commercial plastic chair reinforced with a metal structure. The proposal resembles the so-called "Kigali chair project", developed by Clara Romani in 2014 [4], where not reports the cost of the wheelchairs (Fig. 4).

A problem with this type of proposals is that they provoke reactions of displeasure in some people considering them to be of low quality in the short life cycle. In Mexico in 2012, the Government of the State of Sonora donated this type of chairs and received sharp criticism, both of the receivers of the chairs and the general public [5, 6]. The



Fig. 3. "Gen_1" is a multipurpose wheelchair design for use in rugged terrain. Free Wheelchair Mission Project (2001).



Fig. 4. Two wheelchairs designs from "Kigali chair project" developed by Clara Romani, this initiative has implemented in Rwanda (2014).

same situation of rejection of wheelchairs was experienced in the Argentine Republic in 2014 [7]. This type of reaction to using elements that the public considered "Economic" and adapted as is the case of the plastic chair, although the resistance of the chair that serves as the basis for the product is proven, it is natural, so we must be cautious in the development of our proposals and take into account the quality perceived by users and the general public, understanding by perceived quality that the user believes that the product has (Fig. 5).

This perceived quality can be equivalent or not to the real quality of the product because it is a subjective perception of the client. Also, although it may be influenced by "physical" aspects of the product, it is also affected by intangibles [8], hence the inclusion of this type of chair makes the product perceived as of low quality, which together with "the exclusion and ignorance have been fed back into a vicious circle: the tendency to link people with disabilities with negative stereotypes reverts to the reinforcement of their exclusion". [9], This means that strengthening the differences



Fig. 5. Adverse reactions have occurred in the past on Latin American countries where used wheelchairs based on plastic chairs, considering as offensive to the dignity of the disabled.

between individuals has resulted in scattered, fragmented and decentralized societies, where the confinement to the isolation of persons with disabilities suggests not only a lack of social cohesion but a possible tendency towards the (growing) suffering of the individual with a disability.

On the other hand there is also a design proposal that does not incorporate prefabricated elements, but instead uses the new 3D printing technologies for the manufacture of parts of the chair and that gives a better appearance and functionality to them. An example of this type of proposal is the HU-GO project, developed by the architect Hugo Riveros [10], and where different components manufactured in a 3D plastic printer are used.

A problem with this type of solution is that this type of reproduction technology, although it has spread rapidly throughout the world, is still inaccessible to the majority of the population, which limits this type of solution (Fig. 6).

Considering the previous issues, we worked on the design of the chair "Too wheels", both in its first version as the version of sports chair badminton that have recently developed (2017) and which we have also made a model for testing [11] (Fig. 7).

The first aspect that we worked in the chair was the stability, since, the original chair is connected to the lateral panels by screws covered by tubular aluminum, which has two consequences. First place, the notably increase the weight of the chair, since, We consider in excess the number of screws and second, it raises the cost of it since the aluminum tubular is expensive and only fulfills a decorative function.



Fig. 6. "Hu-Go wheelchair", a proposal developed by the architect Hugo Riveros made with different components manufactured in a 3D plastic printer.



Fig. 7. Badminton wheelchair recent developed by "Too wheels project".

For this, we chose to make a 1/2″ welded steel structure that is occult under the plywood cover. This structure in addition to providing greater rigidity to the chair as a whole makes it lighter than the original (Approximated 11.5 kgs. of our proposal against 18 kgs. of the original project) (Figs. 8 and 9). The distance of the front wheels was also modified to improve stability. Regarding the badminton wheelchair, the chair made following the instructions of the designer, obtaining the product shown below (Fig. 10).

It should be a remark that this chair considerably increases its weight (26 kgs) and uses too much material (4 sheets of MDF wood), so we consider that a re-design of it is easily possible, if compromising its stability or integrity.



Fig. 8. Comparison between the wheelchairs, showing (left side) the number of aluminum tubes and on the other hand (right side) the simplified steel structure.



Fig. 9. Detail of the structure of the redesigned wheelchair.

In all cases, users have tried the chairs and have reported a series of areas of opportunity that we are about to implement in the design of our chair, these observations are:

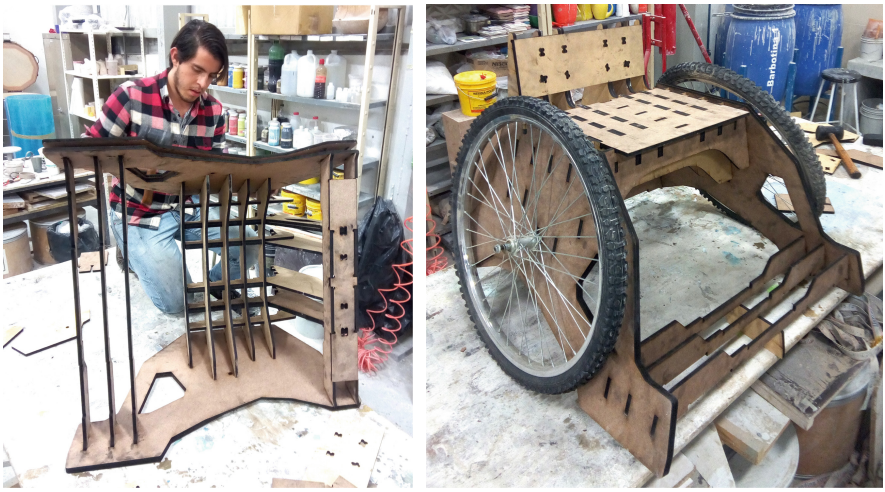


Fig. 10. Reproduction of badminton wheelchair for evaluation purposes.

(a) The axle of the wheels must be placed a little further back to allow better movement of the user's arms.
(b) The front wheels must be ahead of the current position, as well as have a smaller distance concerning the center.
(c) The backrest of the seat requires more depth for greater comfort and the possibility of accommodating cushioning.
(d) Include at all times the outer ring for a push, the proposals are not to the liking of users without this piece, because, the wheel collects dirt and water that end up in the hands of the disabled.
(e) It should include a brake system for the wheels that block the movement since the user to move from the chair to a fixed surface (toilet bowl, stationary chair, etc.), must be able to push himself from the wheelchair without is displaced by accident.
(f) As much as possible, try to tilt the wheels at a negative camber angle to improve the stability of the chair.

3 Conclusions

We have developed a proposal for low-cost wheelchairs, based on the previous design of the "Too wheels" proposal, considering that, is an open-source product, the model can be re-designed as long as they are substantial improvements and always giving credit to the original author. Likewise, we have saved material in its manufacture, which makes the chair more economical, it has increased the stability and rigidity while we have managed to lower the weight of the said chair. The users report that the use of the new proposal gives them confidence and they report a series of possible improvements that we have listed previously and which we are working to present the final result in the next International Conference to receive criticism and comments from the public assistant.

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Media Convergence in Information Transmission in Museum Space

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Abstract. Museums are important places for people's access to historical and cultural information. Therefore, people's experience and perception of information content shall be the main orientation of museum design. By using multiple media to build the exhibition space and interface, designers aim to form varied spatial effects and thereby combine educational functions with entertaining activities. The research content is divided into three parts: 1. An overview of the collisions between human and spatial scenarios in museums; 2. Observation of the expression of human-computer interaction technology in museum information transmission; 3. A brief description of the relation between media convergence and the spatial visual effects experienced by people in museums. In this paper, based on the aforesaid three aspects, the author unfolded a comprehensive discussion and explored the application of these theories in the design of information transmission in the narrative space of museums.

Keywords: Museum spatial plot · Interactive technology and information dissemination · Media convergence and spatial vision

1 Introduction

The multi-dimensional space of museums constitutes the flow of the discourse in the entire spatial plot. A plot discourse refers to not only the comprehensive experience of the audience, including their understanding and the recalling of their personal memory, while "reading" the information flow presented in the museum, but also the space that the audience see and feel when they are in the virtual world composed of the spatial plot under the theme of the museum. Field of vision is not always an integrated and closed system; while in reading, the shift of readers' field of vision is a natural and flowing process, which is not subjected to a paragraph or a chapter. Therefore, the reappearance of a space is not a composition of numerous unitary scenes, but a mixed and refined spatial complex consisted of a series of flowing scenes which cover multiple factors of the discourse, including those of geographical and spatial-temporal natures. The composition of spatial plot is reflected in the intertwined quotations [1]. The connotation of spatial plot is derived from the origins of the thousands of cultural activities under the theme of the museum. Therefore, the spatial plot is transformed

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through the media into visible and appreciable information, which is finally passed on to the audience. The thematic discourse of a museum is realized by the presence of media, and the convergence of these media causes the discourse composed of the spatial plots to be infinitely open and even infinitely contradictory. This not only results in the generation of multiple interpretations of the spatial plot, but also the changes in the narrative style.

Media convergence bestows the space an extended impression and produces a multidimensional effect. Such convergence makes people feel that the space is reachable and touchable, despite the lack of any boundary. The feeling of extension and multidimensionality in the space are also embodied in the numerous fragmented and scattered scenes. For example, Archive Dreaming, an immersive art installation created by Refik Anadol, facilitates not only the search and classification of nearly two million documents in SALT Galata art museum, but also the real-time rendering of the corresponding images (see Fig. 1). With Archive Dreaming, space is seemingly composed of hundreds of thousands of visual data. When the data is broken into numerous individual spaces, the concept of boundary will cease to exist. Such shocking immersive space enables people to feel that they are encircled by books as the space becomes multidimensional and relatively virtual. The real-time interaction between people and visual data elements seems to closely resemble a conversation between people and space.

2 Method

2.1 Spatial Plot Experience in Museums

A plot design should attract people's attention; otherwise, it may be difficult to spread. Social development has increased the ease at which people's attention is being diverted from one thing to another. When we walk on the road, advertisements and posters along the road are probably just the complementary cloaks for a spatial scene, whose content cannot be distinguished one by one. We always do not realize that certain hotels or restaurants are located on the road we pass through every day until they are spoken of by others. When we play a video, we often close its window after ten seconds when we don't find it interesting. The audience's attention always shifts this quickly. The first impression or the first feeling always determines whether the entire communication process is smooth or not. While when we successfully draw people's attention, the attraction of the plot is the factor that helps us to focus their "concentration" on our subject for a longer period of time [2].

Therefore, to think about the museum plot experience from the perspective of space enables the information of space construction to be no longer single and separated but coherent and logical. Spatial plot, which plays an important role in museum information dissemination, integrates and transforms mass media of communication. James Carrey also expresses similar opinions in his lecture on the transmission view and ritual view of communication "Media ritual is a kind of activity held based on the themes of major media and relevant fields, which makes 'media as the access into the core of

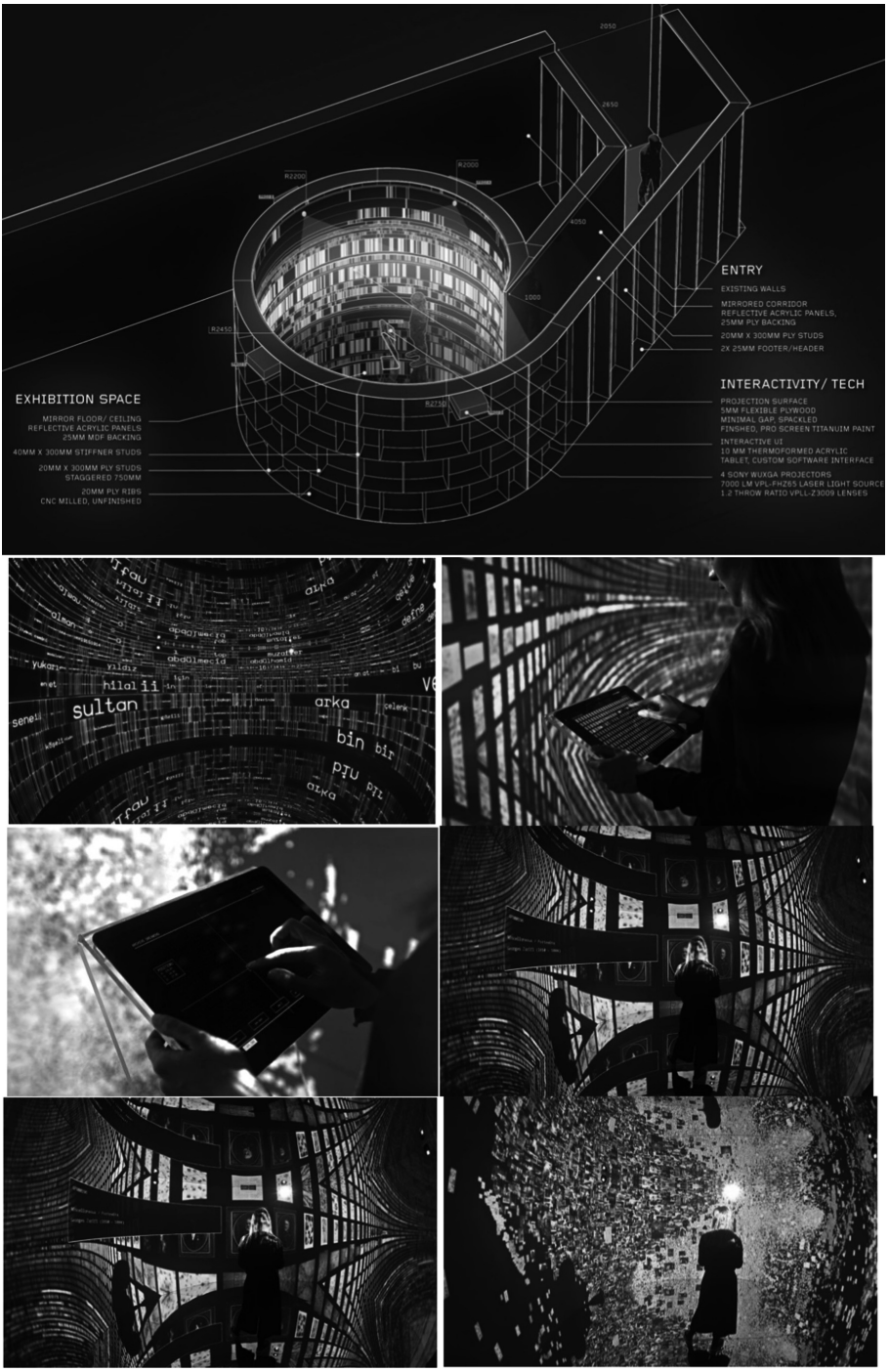


Fig. 1. Archive dreaming – building relations and drawing alt-history with machine learning

society' This values, which is hidden in the communication process, is intensified and rationalized [3]." therefore, the spatial plot experience of a museum becomes particularly important in the interactive experience at the museum.

2.2 The Mode of Conversation Between People and Multimedia Spatial Experience in Museums

In a museum, media convergence can improve the sense of reality and the sense of immersion of spatial experience, which enables the museum to leave a deep visual impression on its visitors. With the upgrading of media technology, new patterns are created in the museum experience design [4]. "Media convergence" becomes a positive developing trend of museum spatial experience. In general, media convergence promotes technology revolution, enriches the perceptual experience, and realizes the free choice of space and time, as well as the exchange between the subjects and objects of experience. However, "media convergence" is neither a simple superposition of media forms nor the development of technology, but the result of multiple attempts and practices conducted by the museums led by new media technologies for the purpose of maximizing the effect of experience by virtue of the advantages of media [5, 6].

2.3 Interactive Technology and Information Dissemination Modes in Museums

The role that the audience plays in museum information dissemination always depends on the following elements: whether the content draws attention; whether the information continues to arouse interests; whether the information is useful; and whether the audience takes action in response to such information. If the information does not draw attention, information dissemination will be impossible; if the information is not in accord with the audience's knowledge and believes, the transfer cannot proceed; if the audience receives information, but do not take action, the transfer will not achieve the expected results [7, 8]. Therefore, a successful museum information dissemination may be swift or circuitous and complex. In the research on the effect of communication, Aristotle focused on the communicators and explored how they persuaded others; while Cartwright researched the information receivers and had deep interests in the change of receivers during communication. The author thinks that it will be easier to draw a conclusion if the audience is taken as the main subject of research.

2.4 The Influence of Human-Computer Interaction Technology on Museum Information Dissemination Mode

Human-computer interaction technology under the background of media convergence is a channel and approach of museum information dissemination. Even with the continuous information flow in a museum, the audience can participate actively, while also perceiving and experiencing the information they are interested in by playing fun games or interactive games, which transforms every individual audience from being a passive receiver to an active participator. Given the support of the development of new media interactive technology, information dissemination can be realized in various aspects, including spatial arrangement, plot design, symbol guidance design, and

participation promotion. Human-computer interaction technology should be applied to museum planning, instead of just high-tech production field. After the mutual infiltration and integration of the elements in various aspects like culture, history, and exhibits, the mainstream transfer mode, which adapts to the development of contemporary museums, can be finally created [8].

Museum spatial discourse information dissemination mode should be open. Every media plays its own role in spreading information. Other than spreading the content, the media itself also disseminates information. *Thousands of Miles of Mountains and Rivers* is a silk-based watercolor created by Wang Ximeng, a painter in the Northern Song Dynasty, which is also his only creation. Before being transformed into a human-computer interaction immersive art exhibition, it lies in the Palace Museum quietly. There are always numerous visitors waiting in line for having a look at this scroll painting with a thousand-year history. Nowadays, people "revive" this great creation in another way by integrating art with new media. *Thousands of Miles of Mountains and Rivers* is an about 12-meters-long scroll. In the picture, lies elegant terraces, pavilions, and spiraling smoke, which harmoniously combine motion and stillness. Every stroke of the green hills and clear water depicts a spatial image that, in Guo Xi's words, is "stoppable", "viewable", "traversable", and "livable". Only after appreciating the details inch-by-inch, can the audience explore the underlying secrets. Such "instantaneous change of scenes during motion" is tactfully represented again using the traditional brush and ink technique in conjunction with the new elemental integration of points, lines, and planes via the new media. As the audience walks along, the scroll painting unfolds gradually. When the audience places themselves in the painting, they are not only starting a dialogue with science and technology, but also communicating with the traditional art. The interaction between light-and-shadow and digital technology enables the traditional works to step out of the conventional two-dimensional plane, but also making itself compatible in three-dimensional spaces with an upgraded and more perfect light-and-shadow experience. The multidimensional world of sense makes *Thousands of Miles of Mountains and Rivers* into an audio-visual festivity as an aerial photo, building a connection between the audience and the exhibition through the former's senses. The presentation of the special techniques inherited by the cultural relics and the spiritual connotation of Chinese culture via modern science and technology media convergence just embodies the new narrative mode of spatial discourse. *Qingming shanghe tu* (*Ascending the River during the Qingming Festival*) that was painted by Zhang Zeduan and exhibited in the China Pavilion during the Shanghai World Expo, is another artwork "revived" by similar means (see Fig. 2).

2.5 Results

Spatial scene and spatial exhibit are displayed in front of the audience via media. In the traditional museum exhibition design activity, old media is just regarded as a necessary tool for displaying the appearance of exhibits, whose independence is not explored at all. In the exhibition spaces of contemporary museums, new technologies provide us with great possibilities of spatial expression. Media convergence, as a technique of exhibiting the major visual elements in space and displaying thematic features, has become increasingly common nowadays [9]. The series of visual and symbolic image

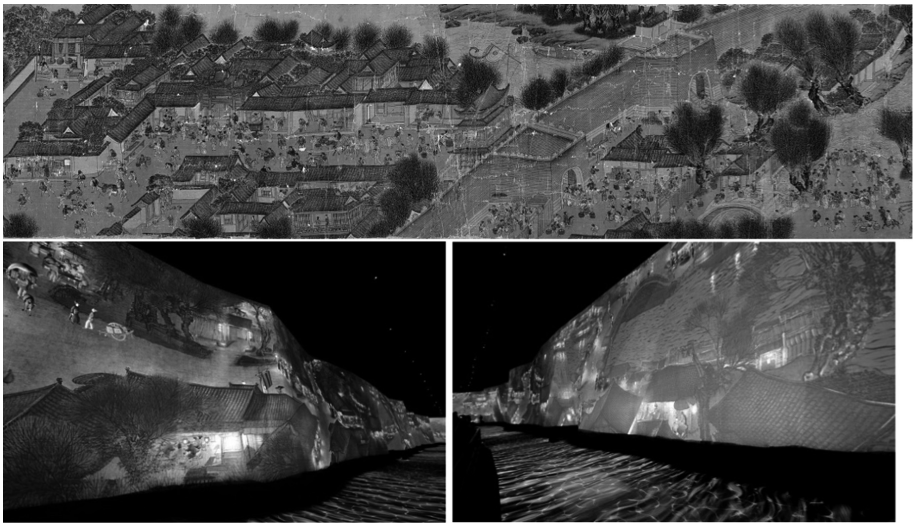


Fig. 2. A multimedia display of the riverside scene during the qingming festival at the China pavilion at the Shanghai world expo.

elements extracted from the theme of a museum exhibition is displayed through certain spatial arrangement methods via media convergence, where the change of light, the dynamic images, and hybrid-dimension spatial effect achieve an incomparable visual effect that other spatial elements cannot.

Audience's attention is the emphasis of museum design. Media convergence can expand space, or even make the space multidimensional through optical illusion, so as to "revive" the objects in the museum space and exhibit them by new means of expression. Moreover, when taking the cross-media narrative as an approach, it is necessary to take the audience's need for spatial experience into full consideration, exploit the special disadvantages of each media so as to make contributions to the narrative of the main story of the museum and enrich the information to be disseminated. In a museum information dissemination, promoting the audience's participation by symbols can finally develop the mainstream visual forms of space that can well adapt to the development of contemporary museums.

3 Conclusion

Media convergence sparks a great revolution in museum information dissemination modes and spatial plot expression by interactive technology, network technology, and communication technology in the new era. It is not a simple technology integration; it is a diversified and three-dimensional mode of transmission on the premise of the development of new media technology that is developed under the guidance of the audience's needs and the museum's thematic information. It also has to be considered based on the actual temporal and spatial criteria, after which the execution is to be

implemented by the guidance of symbols and through information dissemination and interaction, so that the information offered in the museum can ultimately be spread in conjunction with the experience of entertainment.

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Design for Inclusion for Apparel and Textile Design

Formation of the 3D Virtual Models for Clothing Fit Assessment Applied in Human Factors

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Abstract. The aim of this study is to reveal the inconsistency of virtual model formations manually created by individual technical designers and to identify effective ways of referencing human body dimensions to develop a prototype virtual model in the industry. In this experiment, the technical designers were asked to create two virtual models based on two types of size charts. The results of the experiment show that the problems of inconsistency were associated with the different perceptions by each technical designer on body dimensions and body proportions based on given charts. In addition, the problems were caused by automatic adjustments in the 3D virtual fitting software program. The limitation of adjustable size scales existed in pre-programed built-in features in the program. The result of this study will provide fundamental and referential materials to enhance and supplement virtual modeling technology.

Keywords: 3D · Virtual model · Clothing · Fit · Size · Technical design

1 Introduction

The advancements of 3D technology have changed the way products are produced in various industry sectors. In the apparel industry, the 3D virtual fitting technology is emerging as a new paradigm of changing apparel manufacturing process [1]. In addition, in global outsourcing, the expectations of 3D virtual fitting technology is gradually rising as the new solution of quality control issues. The garment fit issue is a significant challenge in the stage of apparel manufacturing in collaborating with manufacturers that are located overseas [2]. For clothing fit assessment, sending photos of sample garments by email is a typical method. Although some companies communicate with manufacturers through web-based meetings, it is still difficult to handle the fit issues. These communication methods cause the increase of production lead time. As a potential technical solution, a virtual clothing fit assessment using a 3D virtual fitting software program has been introduced. A virtual clothing fit assessment allows manufacturers to save time and cost on producing multiple sample garments by replacing the actual production. Accordingly, expectation of the apparel industry for a virtual clothing fit assessment has led to demand for developing a 3D virtual model similar to human body type and dimension for accurate fit assessment. In previous

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studies [3–9], creating a virtual model for virtual garment simulation has been explored using sizes of dress forms or human bodies scanned with a 3D body scanner. This way of creating a virtual model might not be appropriate for apparel companies due to the high cost of the equipment. For the 3D virtual fitting process, formation of a 3D virtual model is an important first step in that manufacture's use of the model for clothing fit assessment. In the industry, technical designers usually create a virtual model by using built-in features in the 3D virtual clothing fitting software program. The built-in features allow technical designers to manually create virtual models. However, consistency of the virtual model formation created manually by individual technical designers has been questionable [10, 11].

Thus, the aim of this study was to investigate two scenarios in creating a 3D virtual model by individual technical designers. One is about size consensus of each technical designer's virtual model formation with same body measurements. The other is how consistent the individual technical designers' works are when given two different types of size chart. The investigation will be followed by the suggestion of the effective ways of referencing human body dimensions for technical designers to develop a prototype virtual model in the industry.

2 Methodology

Technical designers were asked to create two virtual models for the one size, which is size 8, by using 3D virtual fitting software program to find the inconsistency of virtual model formations manually created.

2.1 Participants

A focus group for this experiment consisted of twenty-five Korean technical designers who have experiences with using 2D/3D CAD systems in the apparel industry; Korean apparel industry has many apparel companies that cooperate with brands which are located in the U.S. and Europe.

2.2 3D Virtual Fitting Software Program

For 3D virtual model formation, CLO software program was used, which is currently used widely in a garment development and fit assessment process by technical designers in the Korean apparel industry (Fig. 1).

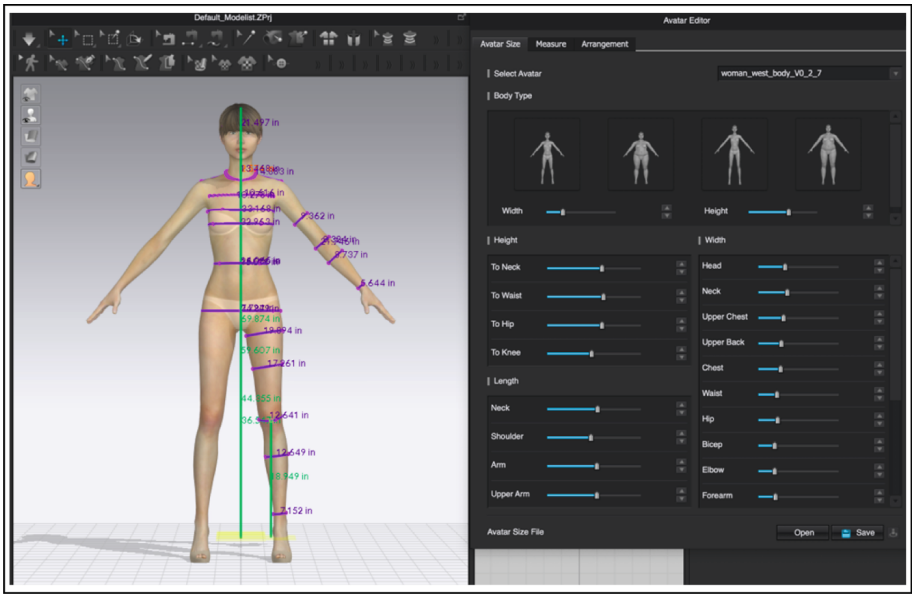
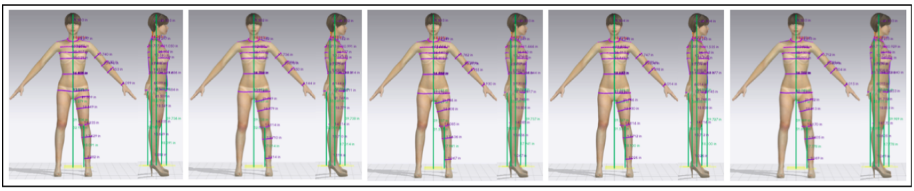


Fig. 1. Manual virtual model

2.3 Sample Size

For references of human body dimensions, we provided (1) a long size chart with 38 measurements from ASTM D 5585 standard (height, weight, bust, waist, high hip, hips, mid-neck, neck base, armscye, upper arm, elbow, wrist, thigh max, thigh mid, knee, calf, ankle, center trunk, crotch length total, cervical height, waist height, high hip height, hips height, crotch height, knee height, ankle height, waist length front, waist length back, across shoulder, cross back width, cross chest width, shoulder length, shoulder slope degree, arm length (shoulder point to wrist point), arm length (center back neck to wrist point), bust point to bust point, neck to bust point, scye depth) and (2) a short size chart with 11 measurements (bust, bust point, under bust, waist, high hip, low hip, waist to floor, back neck to waist, front neck to waist, arm, above bust) from a technical size chart. Accordingly, the technical designers were asked to create two virtual models: Model A-based on the long size chart and Model B-based on the short size chart (Fig. 2).



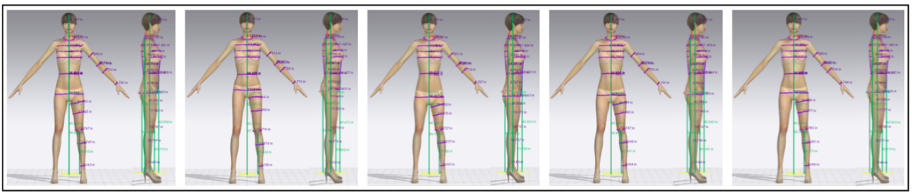


Fig. 2. 3D virtual model formations by technical designers

2.4 Data Analysis

The two virtual models were analyzed with descriptive statistics and t-test.

Descriptive statistics was used to examine size consistency of virtual models created by two types of size chart. T-test was performed to identify effective size chart on creating virtual model formations, comparing size differences between each size chart and virtual model formations.

3 Result

3.1 The Size Comparison Between Virtual Model Formations by Two Types of Chart

Consistency in Size. When technical designers created virtual model, Model A based on the ASTM standard (long size chart) shows that average standard deviation 1.4 and maximum SD 4.22. The average of dimensional error difference from ASTM size chart is −0.34 in. and the dimensional error range is between −3.92 and 0.71 in. When technical designers created the other virtual model, Model B based on the technical size chart (short size chart), results show that average standard deviation 1.98 and maximum SD 8.19. The average of dimensional error difference from the technical size chart is −0.16 in. and the dimensional error range is between −2.54 and 1.02 in. (Table 1). The findings show that body dimensions of virtual models are created differently by different users. When comparing the standard deviation of Model A with Model B, the standard deviation of

Model A is lower than the one of Model B (Fig. 3). In comparing the dimensional errors between Model A with Model B, while the average and range of dimensional errors are larger in Model A than Model B, the dimensional errors in Model B shows more inconsistency (Fig. 4). Therefore, the results show that virtual model formations from long size chart are more consistent than those from short size chart.

Table 1. The standard deviation and the dimensional error range

	Average SD	Max SD	The dimensional error range (inch)
Model A (long size chart)	1.4	4.22 (elbow width)	0.711 (high hip width) ~ −3.922 (cross back)
Model B (short size chart)	1.98	8.19 (hip height)	1.019 (thigh max width) ~ −2.544 (hip height)

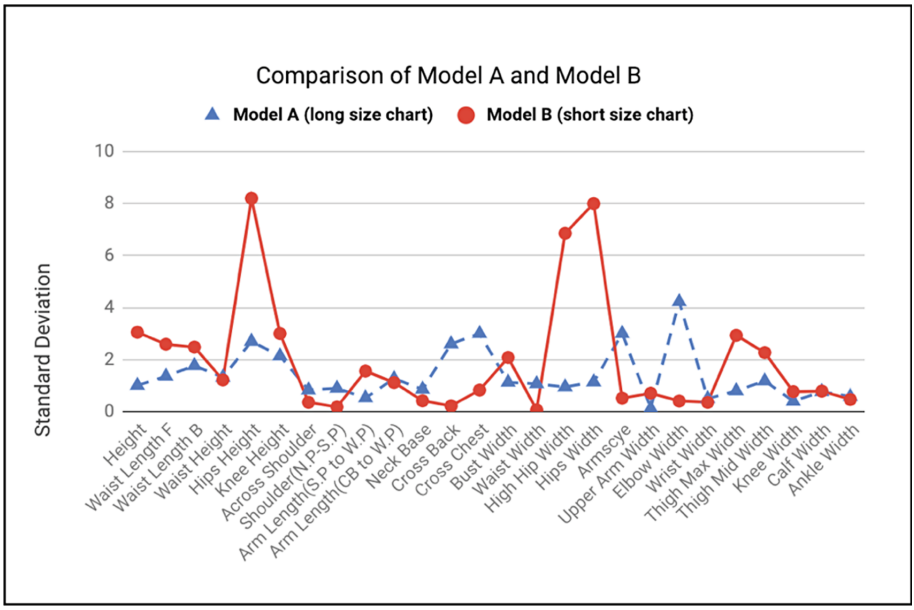


Fig. 3. The size consistency of Model A and Model B

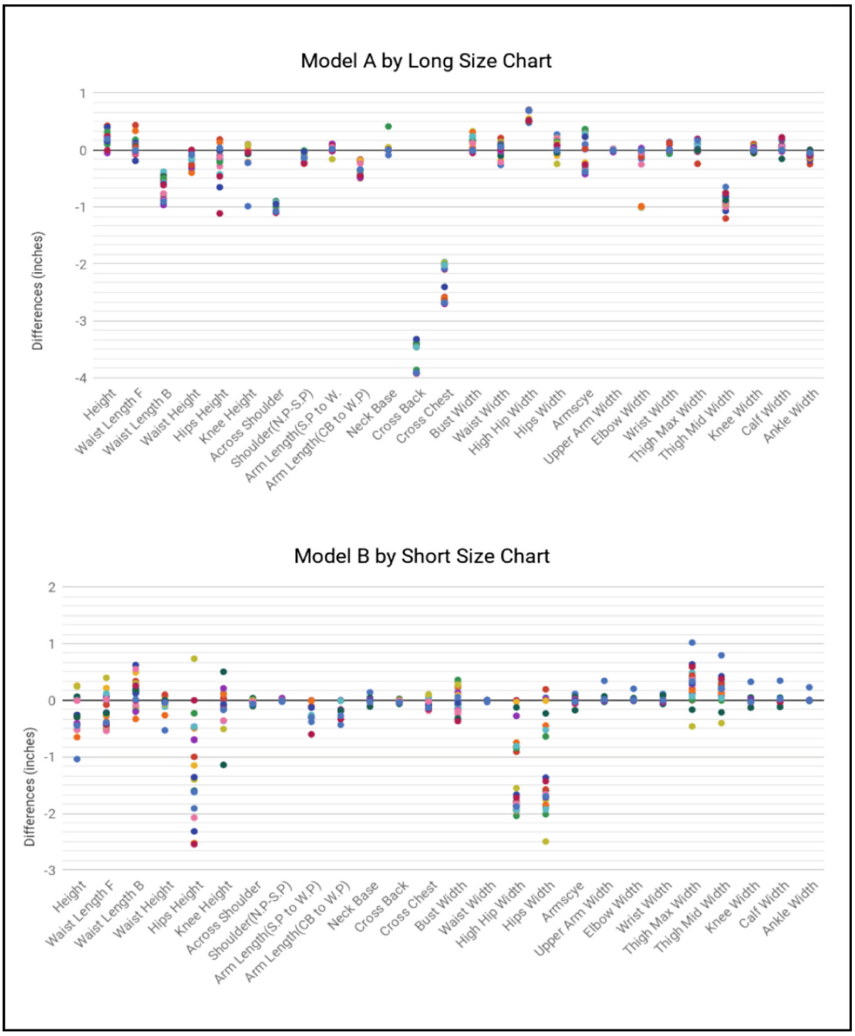


Fig. 4. The dimensional error differences of Model A and Model B

Differences in Size. Apaired t-test was performed to compare differences in size between Model A and Model B. When the same size (size 8) was given, results show significant differences in all body dimensions except for cross chest and armscye ($p < 0.001$) (Tables 2 and 3). This means that the amount of the information given on body dimensions to the technical designers has an effect on a virtual model formation.

Table 2. The size differences (height and length) between virtual model formations by two types of size chart

Height/Length	Mean(SD)		t-Value
	Model A (long size chart)	Model B (short size chart)	
Height	65.20(1.01)	72.70(3.05)	−112.751***
Waist length front	14.29(1.36)	15.88(2.59)	−24.633***
Waist length back	15.59(1.77)	17.47(2.48)	−28.072***
Waist height	39.86(1.32)	45.50(1.22)	−162.765***
Hips height	31.83(2.70)	36.04(8.19)	−25.201***
Knee height	17.93(2.14)	20.00(3.00)	−31.873***
Across shoulder	14.13(0.83)	13.82(0.36)	17.403***
Shoulder (neck point to shoulder)	5.00(0.90)	4.64(0.18)	20.036***
Arm length	23.52(0.53)	24.66(1.56)	−32.03***
Arm length (center back to wrist)	30.72(1.27)	31.50(1.12)	−21.347***
Cross back	10.96(2.60)	10.52(0.22)	8.659***
Cross chest	11.20(3.00)	11.31(0.83)	8.659***

***p < 0.001, **p < 0.01, *p < 0.05

Table 3. The size differences (width) between virtual model formations by two types of size chart

Width	Mean(SD)		t-Value
	Model A	Model B	
Neck base	14.27(0.86)	15.05(0.42)	−38.157***
Bust	35.09(1.13)	35.56(2.08)	8.659***
Waist	27.00(1.07)	26.50(0.07)	24.272***
High Hip	35.11(0.95)	33.86(6.85)	8.307***
Hips	37.55(1.14)	36.46(7.99)	6.498***
Armscye	15.31(3.00)	15.31(0.52)	0.061
Upper arm	10.75(0.13)	9.31(0.71)	97.944***
Elbow	9.48(4.22)	8.28(0.41)	14.207***
Wrist	6.01(0.50)	5.75(0.36)	26.233***
Thigh max	21.77(0.80)	20.69(2.93)	17.678***
Thigh mid	18.86(1.18)	17.88(2.27)	17.989***
Knee	14.13(0.40)	12.76(0.77)	78.104***
Calf	13.64(0.77)	12.76(0.79)	43.116***
Ankle	9.05(0.58)	7.17(0.47)	143.079***

***p < 0.001, **p < 0.01, *p < 0.05

3.2 The Difference of Body Dimensions Between a Size Chart and a Virtual Model Formation

According to the t-test, while the sizes of 50% of virtual model formations are different from the ones of the technical size chart, 57.7% of the virtual model formations are significantly different from the ones of the ASTM body standard ($p < 0.05$) (Tables 4 and 5). This results show that more differences from the body dimensions with the long size chart are made than the short size chart while the consistency between virtual model formations is greater than the short size chart. In the Model A, body dimensions of the virtual model formation display low standard deviation ($SD < 1.00$) with a significance level ($p < 0.001$) of t-Value in the following dimensions: across shoulder, shoulder (N.P-S.P), high hip width, and ankle width. This can be interpreted that there is a limitation of adjustable size scales in inputting dimensions on the body parts and automatic adjustment function causes dimensional errors while creating virtual models.

Table 4. The dimensional difference (height and length) between size chart and a virtual model formation

	Model A			Model B		
	Long size chart (inch)	Mean(SD)	t-Value	Short size chart (inch)	Mean(SD)	t-Value
Height	65	65.20(1.01)	10.075***	72.95	72.70(3.05)	−4.014**
Waist length front	14.25	14.29(1.36)	1.403	16.079	15.88(2.59)	−3.745**
Waist length back	16.24	15.59(1.77)	−18.365***	17.361	17.47(2.48)	2.198*
Waist height	40	39.86(1.32)	−5.492***	45.544	45.50(1.22)	−1.901
Hips height	32	31.83(2.70)	−3.063**	37.248	36.04(8.19)	−7.219***
Knee height	18	17.93(2.14)	−1.628	20.11	20.00(3.00)	−1.796
Across shoulder	15.13	14.13(0.83)	−60.159***	13.85	13.82(0.36)	−4.581***
Shoulder (neck point to shoulder)	5.13	5.00(0.90)	−7.253***	4.638	4.64(0.18)	0.526
Arm length	23.5	23.52(0.53)	1.55	24.881	24.66(1.56)	−7.069***
Arm length (center back to wrist)	31.06	30.72(1.27)	13.483***	31.651	31.50(1.12)	−6.606***
Cross back	14.63	10.96(2.60)	−70.456***	10.535	10.52(0.22)	−4.230***
Cross chest	13.63	11.20(3.00)	−40.690***	11.38	11.31(0.83)	−3.940**

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

Table 5. The dimensional difference (width) between size chart and a virtual model formation

Width	Model A			Model B		
	Long size chart (inch)	Mean(SD)	t-Value	Short size chart (inch)	Mean(SD)	t-Value
Neck Base	14.25	14.27(0.86)	1.078	15.054	15.05(0.42)	−1.032
Bust	35	35.09(1.13)	3.984**	35.57	35.56(2.08)	−0.261
Waist	27	27.00(1.07)	0.17	26.5	26.50(0.07)	−0.885
High hip	34.5	35.11(0.95)	32.215***	35.213	33.86(6.85)	−9.675***
Hips	37.5	37.55(1.14)	2.218*	37.647	36.46(7.99)	−7.306***
Armscye	15.38	15.31(3.00)	−1.089	15.324	15.31(0.52)	−1.242
Upper arm	10.75	10.75(0.13)	−1.81	9.288	9.31(0.71)	1.511
Elbow	9.75	9.48(4.22)	−3.212**	8.27	8.28(0.41)	1.584
Wrist	6	6.01(0.50)	0.684	5.746	5.75(0.36)	0.32
Thigh max	21.75	21.77(0.80)	1.023	20.406	20.69(2.93)	4.766***
Thigh mid	19.75	18.86(1.18)	−37.592***	17.695	17.88(2.27)	3.996**
Knee	14.13	14.13(0.40)	−0.261	12.763	12.76(0.77)	−0.141
Calf	13.63	13.64(0.77)	2.092	12.763	12.76(0.79)	0.113
Ankle	9.13	9.05(0.58)	−7.265***	7.164	7.17(0.47)	0.935

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

4 Conclusion

This study provides evidence that the sizes of manual 3D formation are inconsistent. When individual technical designers made virtual sample size model with manual 3D formation, the body dimensions of each virtual model created by the individuals are not consistent. Also, the models are inconsistently created regardless of having long or short size chart of the body dimensions. The inconsistency is partially caused by the different perception by each technical designer on the body dimensions and body proportions based on the given charts. When provided a short size chart to build virtual models, the inconsistency of the sizes is more significant than a long size chart.

On the other hand, when provided a long size chart, the problems are associated with functions for 3D virtual modeling in virtual fitting software program. Automatic scale adjustment and limitation of adjustable size scales cause more difficulties while adjusting a built-in feature pre-programed.

In conclusion, manual 3D formation would create an inaccurate virtual sample size model. This indicates that with the manual formation, there is a high chance that garments with imprecise size and fit will be produced by unreliable fit assessment.

Currently, in the apparel industry, accurate fit and size are essential and should be measured consistently which, in turn, leads to satisfied retailers and customers. Thus, further research should be performed for providing anthropometric references and guidelines for technical designers to have consensus of the sample size model. Further, the developers of 3D virtual technology should improve the limitations of functions for 3D virtual modeling.

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Apparels for Comfort. Knitting for People

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Abstract. In garment and fashion design human and technical factors to take into account are multiple, and are reflected in numerous aspects of the product, process and relationship. Comfort of the objects to be projected and produced are an essential element that in many cases is left aside, favoring the aesthetic aspect and social representation. The knitted textile material is a peculiar element which, because of its characteristics, has reserved a prominent place in the field of fashion design and is characterized by the possibility of creating its own textile surface. Knit material, like any other textile surface, includes and promotes a material and immaterial culture representative of the social and communal world. This paper intends to argue and approximate the different characteristics provided by the knitted textile material to the needs of the users and in particular the possibility of co-creating clothing adapted to the needs of the users.

Keywords: Apparel design · Co-design · Textile design · Knit design · Comfort

1 Introduction

The relationship of users with their own clothing is profound. Textile materials have a history of thousands of years and are part of different levels of our experience and way of living. The comfort of clothing, together with the aesthetic issue, is one of the main elements taken into account when choosing a piece that is increasingly representative of our way to be and well-being. Given that, comfort itself should be understood as a comprehensive issue that manifests itself at the material and immaterial level, its approach must be careful, broad and take into account the objective and subjective aspects of the user and the subject of study itself.

In recent years material developments have evolved rapidly and accompanied the new technologies, allowing users to meet the needs of the users in search of materials that better adapt to their daily needs, more agitated and with higher standards in aesthetic and functional terms [1]. The new possibilities and challenges offered by the new technologies, such as the knit material associated with new products and new structures capable of ensuring greater user comfort and high functional performance, are placed in the textile area. The knit material, due to its intrinsic characteristics, presents high levels of elasticity and consequent adaptation to the body, allowing a high increase in thermal comfort, taking into account its better capacity to allow an

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easier dissipation of body heat. Since ancient times the knitted textile material has been used to make garments that need to adapt their shape to the body.

To talk about knit is to touch different concepts and variables that, working together and mixing constantly, offer multiple products and structures that are constantly being reinvented [2].

2 The Environment of Knit Material

As an ancient craft, present since 1000BC, knitting was originated from hand knotting or twisting of yarns using hand fingers. The word 'knit' originates from the old English term 'cnyttan', and from German 'knütten', developed to modern term knot. Hand knitting rapidly advanced from fingers, to the use of hand tools – known as pins –, into a skilled and complex craft where, by the fifth century AD, knitted objects such as socks are recorded, combining fashioning, seaming, and circular knitting together with patterning techniques simultaneously [3]. Cross loop knitting (or cross-knit looping) – a single-needle technique – dates back to the 2nd century AD, being found in objects made by civilizations like the egyptians, romans and Scandinavians. Pattern knitting, known in Arabia and India from the 9th century, is introduced in the 13th century in Iberia and southern Italy [4]. As said by Schoeser [4] and Steele [5], the development of knitting has been responsible for the most striking and fundamental changes in textiles and clothing since 1600.

This deep connection with the consumer is one of the strong abilities of the knitted textile over the last decades, and the use of knitted textiles has been increased year by year since the seventies, due to the spreading of the practice of sport and the introduction of specific materials for sports activities. According to Sinclair [6], knitwear will have a massive growth in the fashion industry, related to its intrinsic relationship with casual dress, active wear and sportswear, crescent trends in our society. Recent statistics of the European Apparel and Textile Confederation (Euratex) show that in 2015 more than 1/3 of the fashion market was made of knit garments.

Knitting and knitting can probably be considered as one of the most creative options within the entire fashion and apparel production system given the possibility of offering multiple choices and variables placed in the hands of designers. Due to its constructive characteristics, the designer is allowed to create the textile substrate where it can intervene directly and in a much simpler and direct way in the production of the knit itself, without having to intervene vertically in the textile line, as with the production of orthogonal materials. The construction of knitted textile materials exists essentially in two ways: as a warp knit or as a weft knit. If the warp knit is essentially used for the production of more technical and industrial materials, the weft fabrics are the ones that have more application in apparel and fashion, being able to present with different variables within two primordial types of construction and that depend on different Technologies: Circular knit jerseys more thinner and used for interiors and "V" bed knits mainly for external use, being thicker and heavier (Fig. 1).

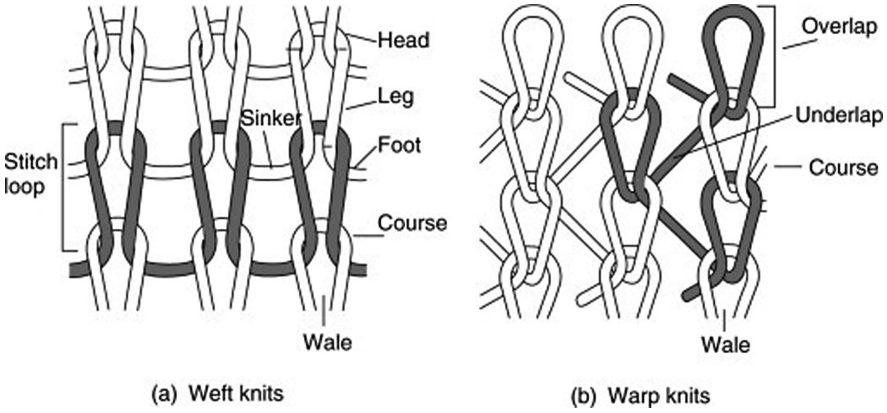


Fig. 1. Weft and Warp knitting structure. https://www.sciencedirect.com/topics/materials-science/knit-fabrics [retrived 15/02/2019]

The production of knit substrate for garments technically obeys the rules for the construction of the weft knit which allows the production of the substrate by interpolation of a new loop of knit from the ring formed in the previous row and that is constructed with the use of a single thread. This textile construction which in general terms is considered simple allows a direct intervention of the designer in its production and the choice of the type of yarn and its finish, color, diameter, yarn effect, composition, etc., is a much simpler choice of rather than intervening in an orthogonal textile row (web and weft) where the processes are much more extensive and complex and where the production and availability times of the materials in question are much longer.

As pointed out by Lindsay [7] referring to her Master Thesis, Jack Lenor Larsen in 1961 described machine knitting as the next industrial revolution, with the possibility of overlapping orthogonal textiles (wowen textiles) in terms of production speed and economic results.

Still far from this reality, Larsen was able to perceive the great potentiality of the knits that had their greater paradigmatic development with seamless technology. Spencer [8] refers that seamless technology knits on spiral, passing from one needles bed to the other working sequentially selvage needles and thus creating a tube. The process of creating garments for the upper part of the human body, refers Black [9], is to knit one tube for the body and two for sleeves, and join it together starting from under the sleeve. The result of the upper body knit garment will be also un unique tube, using the similar garment conception used by centuries for the Norwegian traditional knitting sweaters, with a traditional circular yoke.

In this sense, taking into account that in the production of this type of material the designer can have total possibility of creation and intervention in the production of its characteristics, the parallelism with *haute couture*, where in many cases the textile material used is a poetic construction of the seasonal inspiration is inevitable. In knitwear, the design becomes a basic step in a long industrial chain that starts from the

development of new fibers, from the recover of the past ones and comes to the innovation on machines that are now allowing new manufactures more and more often [10].

The production of knitted textile substrates allows an infinite and independent creative possibility combined with high productive capacity, greatly enhancing the possibility of personalizing the textile substrate and consequently of the pieces created that may have a high level of communication of brand values. There is a natural interaction between craft/making, design and new technology, refers to Sissons [11]. Knit gives the designer the possibility to work on the textile structure and at the same time to work on the garment form and function. As reported by Quinn [12] textile surfaces are more than just the façade, but are a curious layer of aesthetics and identities, and a contentious site of exploration and resistance.

3 User's Factors

The human factors involved in the design and production of fashion and apparel are multiple and of different origins. The user/object relationship is a relationship that is based on different stages and involves multiple levels of perception and involvement. The relationship of users with the object of clothing is made not only by the contact with the physical object but especially with the aesthetic and social representation that this object represents and to which it may be associated and consequently represent the user himself.

Despite the great importance and involvement of the aesthetic and social mechanisms of clothing, which gratify and participate in the construction of the psychological well-being of the user, the issue of physical well-being becomes more and more important and contributes to the psychological well-being and the increase of self-esteem, and the garment can be defined as a multisensory interface that communicates constantly with the outside world.

The comfort of the clothing we use on different occasions is increasingly taken into consideration and is one of the determining factors for the end user. In reality comfort is usually measured by its opposite, that is by the level of discomfort that any object or situation may cause the individual. In this sense, Chappells and Shove (2004) [13], says that comfort can be defined as "a feeling of contentment, a sense of cosiness, or a state of physical and mental well-being." In this sense, Sontag [14], Oğlakçıoğlu and Marmaralı [1] and Kamalha [15] add that the main areas of comfort can be summarized as follows: psychological comfort, sensorial comfort and thermo-physical comfort. Psychological comfort can influence the user in their relationship with others and in the way their interpersonal social network can perceive the values that the user wants to communicate. In this sense, it is a matter that, linked to the object of study, is projected to the outside and will help in the construction of greater security of the individual with its social structure. An example of this can be considered the typical motifs of the "fair isle" knits that soon identifies a group of individuals with the small Scottish island. There are small geometric motifs that are repeated throughout the surface of the textile and are often worked in stripes of different and contrasting colors. As stated by Steed [3] knitting has always been the method for expressing oral history, facilitating community engagement

and expressing deep personal attachments. In a society where the individual seeks to be heard, knitting emerges as a powerful social and political tool.

With regard to sensory and thermophysical comfort, these two areas of comfort are related more to the individual and less to his social network. The sensorial and thermophysical comfort will eventually be more connected to the user's senses, being more related to the textile material and the garment. The possibility of wearing a comfortable piece, which does not create great thermal oscillations in the entrance and exit of specific environments and that are comfortable in the movement of the user in its interior may be priorities for this area of comfort, being, more and more, today are a necessity to be taken into account by the multifaceted uses of the garments we find on the market. Sportswear, which had a great development of materials from the 70's of last century, with its more comfortable garments, is influencing more and more our everyday clothing, which we require to be practical, due to our overactive life. Knitting, because of its adaptive and comfortable capabilities, has always been used in active wear and sportswear. In the future, refers to Sinclair [6] we will see a growing migration of high-performance knit textile surfaces - used in both of these areas - to everyday life.

4 Design for People

The adaptation of the product of fashion and clothing to the users is often an empirical task that, through advances and retreats, adapts to the market and the needs of the possible customers who, season after season, wait for continuous innovations and proposals of renewed communication codes with its ecosystem. The elements that form part of this equation are multiple and of different levels, ranging from styles and materials, colors and structures, details and volumes, references and significances, hierarchies and recognitions, honors and approaches, among others. The continuous mixing, remixing, alteration, adaptation, forecasting, etc., of these and other slopes and variables are the center of the fashion product that has the capacity to reinvent itself constantly, even if it is found in terrains that are not stable and constantly in balance between the objective and subjective, between material and immaterial, between concrete and abstract, between fashion and tradition, between the individual and society.

Despite all the possibilities presented by the direct actors in the process, we must take into account indirect and subsidiary actors who carry out the activities necessary for the implementation of the product on the market, have specific and specific needs that must be taken into account. It is a multifactorial, interdisciplinary and complex process where the objective needs of the different actors are associated with the subjective ones, in a continuous change of positions and commitments with the aim of presenting a product that satisfies a high number of consumer needs to whom the product or service is directed.

No doubt that design is the discipline that more naturally predisposes as an intermediary of these issues, presenting methods that can help reduce distances between different positions and especially between user and fashion product/textile. Design, subject to different areas of knowledge, combines quantitative and qualitative work

methods, subjective and objective, active and observational, etc., which allow the exploration and application of methods and methodologies that provide collaborative work among the different areas disciplinary measures that contribute to the production of the textile object.

Co-design and customization are two typical examples of end-user collaboration in the production processes of the textile products themselves, which for some time have been equated by design teams and companies in order to reduce the distance between those who use and those who make product to its source of revenue.

Although there are different definitions of these concepts, we can broadly agree with those presented here. The co-design process can be defined as a process where user needs and preferences are the basis for the development of the entire design process, improvements and innovation [16, 17]. To Zamenopoulos and Alexiou [18], co-design means that people come together to conceptually develop and create things that respond to certain matters of concern and create a (better) future reality.

This need, already identified by Toffler in his 1980 book The Third Wave when a consumer participates in co-design and at the same time becomes a co-producer of the product he consumes, can be defined as "prosumer" [19, 20]. By customization we can understand the adaptation of a product made available to consumers for a possible adaptation in the technical design phase and the physical production of the service article [21]. Different definitions can be adopted for the development of actions and methods that in general terms differ little from each other, as in the case of tailored product, consumer driven design, made to measure, made to consumption, among many others.

The knit material is a textile structure that has specific characteristics due to its majority of the technology used in its production. While it is true that for the production of any material the technology used in its production has a major influence, for the knitting sector this symbiosis has always been essential and in many cases the new products implemented in the market as fashion products were the result of great advances technological developments. We can state here many, but taking into account the knit/comfort aspect that is the focus of this article, the possibility of seamless knit production has allowed the implementation of a new paradigm for the sector that is still far from exhausting its possibilities. As referred by Spencer 2001 apud Peterson (2016) [22] complete garment technology, also known as the seamless garment technology, was introduced on "V-bed" flat knitting machines in 1995, having evolved form developments in the 1980s. V-bed machines have two needles beds, on a position of an inverted V and equipped with needles. This methodology, initially based on existing technology, allowed the development of garments with different shapes but without seams, which in some cases may represent a problem because of the friction and thickness that may increase the levels of discomfort and in severe could provoke scares on the user's skin surface. The whole garment is made directly in the flat knitting machine without post cutting and sewing processes (Legner 2003 apud Peterson 2016) [22]. At the beginning of the 21st century, another innovative technology for knitting became a reality and a productive one. "Seamless" or "no seam garments" knitting technology allows the production of knit garments that fit the body and use a limited number of seams, usually reserved for hem finishes or hemming applications. This technology was developed in the 80's of the XX century, when a lot of leather shoes

were used directly in contact with the skin of the lower limbs, minimizing the use of socks. For this reason, the Seamless technology has been adapted to clothing so as to minimize the ever-increasing decline in stocking markets and to apply the techniques and logics of tubular and three-dimensional fabrics, adapting itself to the production of interior and exterior knit which could be used as any other type of knitted garment, with remarkable increasing levels of comfort for the end user.

The technological possibilities make this type of clothing an example of customization and adaptation to the different needs of use, since it presents infinite possibilities of technical development of the product used different textile structures in the same piece, being able to adopt different levels of compression by zones, application of different intensities of the substrate also by zones/areas at the surface level and in particular, being able to produce finishes that very little interfere in the interaction with the user. This technology is prepared to be able to produce individual pieces adapted to the users producing knitted garments in a mass customization optics. The disadvantage of the high prices of these equipment continues to be a factor that still prevents the large diffusion of these technologies for small shops and small businesses where, despite everything, the competition is also still in the price competition base.

5 Conclusions

If the fashion and clothing product remains one of the central elements of the individual's relationship with the social and professional environment, design processes need better vertical and horizontal integration to help design products to be more representative of consumer needs and its media. The possibility of user participation in the design process can be done in different ways, all of which allow a better efficiency in the interpretation of user needs, increasing the market penetration capacity of brands and designers, decrease in production of garments that, season after season, fill stores of not sold or rejected clothing by consumers for not responding to their needs. The poor sustainability of the garment industry needs to apply co-design strategies in order to produce better and more sustainably, sparing resources that are still wasted today because they do not have a close relationship with their final users.

Participation in the production of the knit garments by the authors themselves may represent the most complete and real scenario of co-design, and may include and extend to the adjacent methodologies of "design by user", "inclusive design", among others, knitted fabric provides this kind of joint production, adapted, customized while providing high levels of comfort and adaptability of the material produced.

With the integration of technological systems, processes, methods, etc., the act of creating products is no longer to be fragmented to become integrated and thought as a joint problem, promoting the interconnection between producer and user and meeting the real material and immaterial needs that make the fashion product a true product of communication and individual expression.

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Performative Approaches in Designing Costumes: Ergonomics in Immersion and Storytelling

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Abstract. The case studies explore experimental practices and approaches to design based on costumes that lead to the characters' construction and of the plot itself and thus contribute to the immersion of performers and spectators into corresponding fictions. Semiotics and somatics gather in a visual vocabulary based on textiles, colors and garment shapes that tell stories, taking spectators to plausible universes or situations contextualized scenically. Participatory design is considered, with costumes as working tools for performers and directors. User-centered design processes that include the moving body as the mill of a costume's definition promote a staging under construction that turns the plot into a metaphor of the costumes' facets. This brings new symbolic and theoretical frameworks for both performing and designing. Thus, ergonomics is central in the creative process, implying original designs for these staging practices with no preliminary grounds and that rely on costumes as triggers for acting.

Keywords: Performance · Costume design · Ergonomics · Immersion · Storytelling

1 Theoretical Framework

This study aims to understand the interactions between the human element and other elements in a performative context, under an ergonomic framework related to how the body and body expression can be extended by that exchange. It is an approach based on practice that is, nevertheless, "theory-focused, on concepts which imply experimental approaches to performance art that explore body perception through costumes' plastic potentialities and even its constraints" [1].

Costumes are enablers in performance, due to their somatic relationship with the usage of the body as a means of expression, therefore "our quest is to understand the actor on stage and the identities he enacts in costume" [2]. But embodiments in characters imply also the immersion in narratives they belong to, leading us to consider "performances in witch costumes are made to convey specific stories to an audience while moving the spectators emotionally and transform the actors psychologically" [2]. Here, the role of the director gains importance. The choices of a director on the conceptual elements of the narrative complement the visual language telling and the

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interaction he aims. The design process needs to follow that up, because costumes express an emotional interaction between the character/actor's performance and the storytelling: "Design outcomes had to support in some way the understanding of audience engagement with (…) [the] performance and, if possible, increase that engagement" [3].

Clothing functionality and cognitive readings by the performer are linked to his self-expression and self-image, and also, "this self-image and self-expression tend to be read by spectators not only as an outer display, but also as an inner identity and emotion (…) they blend together with the performer's actions, (…) connecting the artistic expression with the clear notion of [his] selfness. In this process, communication is obviously involved" [1]. But costumes can play a narrative role both in compliance with the characters and other elements of the storytelling and set design, depending on how they are contextualized and emphasized: "The set is the frame and the context for the costume designer's work. (…) Without light the world that the designer makes for the performers and the audience is lifeless" [4]. Thus "A good costume 'tells' the audience about the status, relative wealth, age, profession or trade, attractiveness, temper and underlying psychic state of each character" [5], but they can tell much more about the story if used and framed appropriately, when "the visual effects help place the work in a context, give the characters depth and rigor, and underline and support the emotional content of the work. The nature of devised work lets a designer work with the director and performer to build the characters and the place of the story" [4].

In a designer's perspective, several materials and their combination can highlight or blend the costume and character in the scenic surrounding space and light: artifices like the thorough choice of transparencies, reflection, oversize volumes, neutral colors, can all allow mimetic relationships. Besides those, the perceived quality of fabrics, such as softness, coldness or warmness, can convey sensations to the spectator that he relates to the character's personality. Throughout the play, a costume can then perform a narrative or interactive role, depending on its fixed or dynamic features. Its possibilities of change and interaction can be achieved both with or without the use of smart and technological artifacts, although some art directors support that the use of smart approach is unnecessary: "we believed that fundamental questions about interaction and engagement could still be asked without recourse to 'smart' systems and materials" [3].

Smart textiles or smart design can include microcapsules, LEDs, optical wire, light sensitive prints or sensors in the costumes, textiles or props. These can add smell, light, shapes and color, which can change during the play and be interactively triggered. These changes can be partial or transform the costumes completely. They can be triggered by other characters/actors, by spectators, or by inner factors like scene lighting or sound. A costume change will have narrative intentions, assuming part of the storytelling. A costume can metamorphose during the play, into two or three different characters. These characters can be present simultaneously or be emphasized one by one. In any case, there is a unique set of visual vocabulary in the stage and light design that aims to reinforce the characters' personalities, actions and their fates in the plot. Emphasizing main moments of the scenes contribute to the spectator's immersion: "Spectators may experience interactions as secretive, expressive, suspenseful or

magical, depending on the visibility of interface manipulations and their effects, which each may be hidden, partially or fully revealed, and amplified" [6].

Nonetheless, the actor's body, its expression and posture, together with the costume, plays a main role in the character's construction, namely in its personality. The starting point is the body the actor aims to embody: "Performance practice has also been questioning the usage and reading of the body, (…) the imagined body as the starting point of the performer's acting (…)[and] changes in body can as well be done by fashion, being fashion also deeply related to the notion of the self" [1]. Costumes can be involved in the performance creative process and that is even more valid in smart costume design, due to the evinced somatic characteristics and new relationships with the body. Seemingly, "actors should have sufficient time to train with the interactive features and rehearse while wearing the costumes and possibly should also be included in the creation process" [6]. The user-centered methodology used in the costume design process relies on the actors' interference with costumes even from the very beginning, since their inputs are crucial to get to a point where actor, costume and character become one and only.

In live performance, an interactive costume can expand the expressiveness of the body: "A wearable art itself can be an expressive media platform and when it is worn by a performer, it elevates expression of body language" [7]. Art directors fiercely defend or deny the use of smart approaches in performances and play narratives, but both agree that "performing art can be an ideal platform for the wearable media as it provides creative expression for both wearable artist and performers" [7]. Some say that its use impoverishes the role of actors and directors in the making of the storytelling, turning it less authentic for relying more on external processes, rather than on the actor´s body expression, posture and projection. What is certainly true is that directing with «smart» or «non-smart» artifacts differs a lot. Connotations can be given to formal elements of the costumes and setting and the open nature of costumes, often present in simple forms, seems to suggest new possibilities of interpretation, rather than impose boundaries in their meaning. By this way, they become important storytelling elements for creating this close relationship with the plot, and do not necessarily need to be «smart»: "Instead of 'smart' textiles and computational wearables engaging audiences through technology, it seemed that the open nature, or thingliness, of the costumes had a powerful and complex effect on the relationship between performer and audience" [3]. We therefore consider that besides the conceptual approaches, there is a strategic balance between pros and cons in the core of the production related to human, technical and financial resources.

Costumes can also be given attributes linked to the scenic environment they inhabit. They can symbolize a prop or an object and they can stand for themselves alone in terms of meaning: they might become something else but the character, in the fictional space of the play. Their shapes, colors, textures and volumes convey metaphors that can trigger a particular narrative role in the spectator's scenic imagery. The same stands for separating parts of the costume, making them autonomous props in the scene. The performance becomes a dialogue between the physical elements in space and the new possibilities of acting with them, which in the end needs to make sense in the narrative. A mentally and physically trained actor can foresee it, but it takes a lot of rehearsing for testing their true potential, since "an improvisation (…) needs precise rehearsal to happen, and no one

may know until strength and skill have developed further, whether it is actually possible. If it is, perhaps it will be incorporated into the narrative" [4]. Furthermore, interactive or shared costumes that involve the acting and that promote the interaction between actors and spectators imply a performance practice allied to a staging process under construction, where those relationships are pre-established in a certain framework. It is, nonetheless, a performance practice led by costumes but also actuated and defined by the chance implied in the duration of the interaction, promoting the creation of new meanings, because "the work revolves around the notion that each body and each body memory, gesture, deliberate and multiply [the] framed staging of the self in performance [and thus] leads to another layering of communication as bodily inscription" [8].

The ergonomics of a costume can then be more functional when linked to gestures or actions; more cognitive when promoting emotions and immersion in the realm of a certain production; more narrative when performing different roles or gaining attributes with new features and contextualization in tune with the storytelling. Semiotics can then play an important role in carrying the spectator through symbolic metaphoric spaces (including post-human) that costumes may suggest, proposing secondary levels of «meaning» telling, because "towards a reading of inhabiting space by wearing costumes, we need to consider the act of wearing in the impact on others, as a decoded language. Hence, a performer (and a costume designer), by deliberately choosing a signifying object for his performance is alluding to a certain social interpretative dimension" [1].

2 Case Studies

The case studies described below were held in 2014, during the exploratory design phase of the PhD research project title "Design of Dynamic and Interactive Costumes for Performance Art", based at CIAUD Research Centre, developed by Alexandra Cabral (the first author) and supervised by Carlos Manuel Figueredo (the second author), together with Cristina Carvalho. The costume design is by the first author.

2.1 Costume Design for *Little Thumb* Theatre Play

The first case under analysis portrays the costume design process for a theatre play by Seara – Companhia de Teatro de Beja (theatre company in Beja, Portugal) directed by David Silva, based on Charles Perrault's *Little Thumb* tale, which started from a financial and human resources restricted set. With three actors for nine characters (Little Thumb, Lumberjack, Lumberjacks' Wife, Lumberjack's Sons, Giant, Giant's Wife, Giant's Daughters, and another two Little Thumbs), the actors enrolled a complex performative context where they assumed three different personalities each. They could not leave the stage to change clothes neither undress them, but they had to transform their costumes and assume different personalities in every garment change, in front of the audience – involving it, rather that distracting it from the plot.

The stage design was limited to a table, a black background and light projections, meaning that the costumes had a narrative role not only in compliance with the characters they represented but also with other elements of the story, as we will see. Before the limited space and the imposed nearness between actors, they faced

movement constrains, being the scenic space defined both by their location on set and their confined action fields.

Connotations were given to formal aspects of costumes through acting, which was essential to define the characters' psychology and physiognomy. Early prototypes were requested for improvisation purposes (Fig. 1, top left) although initial instructions had been given by the actors and the director, related to gestures, manners or stature, as well to technical features, such as pockets for carrying props. There was therefore a balance between a pre-established idea of how characters were meant to be and what costumes could allow in terms of presence and body movement.



Fig. 1. Rehearsing with prototypes (top left); using a costume to represent a light in the dark (right); using boots as the reins of a chariot (bottom left). *Little Thumb* theatre play by Seara – Companhia de Teatro de Beja, directed by David Silva. Costume design by Alexandra Cabral.

Conceptual elements in the narrative were strongly linked to a complementary visual language, according to the director. The *Rubik's Cube* imagery had to be present in the color blocking related to the character's changes. There were other references like the layers in a samurai's costume, Oskar Schlemmer's *Triadic Ballet* (1927) geometry and the simplicity in Malevich paintings. The design proposal was therefore based on monochromatic costumes with some hints of color (from the other characters' attire, which could not be hidden) and textures associated to narrative aspects, such as the pleating in the Giant's Daughters' dress, symbolizing them dying horizontally

(lying on their own beds), or the vertical pleating in the Lumberjack Sons' trousers, representing the trees in the forest they lived in.

The characters had a color correspondence, according to their griefs and sorrows, destinies or personality traces. The Lumberjack's Sons were dressed in green, due to the forest trees; the Giant's Daughters were dressed in red for dying with their throats cut; orange represented the Lumberjack being antsy; purple was related to the Lumberjack's wife sorrow or idea of death associated with the loss of her kids; blue was as cold as the Giant's nature; white, considered a pure color, belonged to Little Thumb's costume.

There was also a color code given to some aspects of the narrative, so that the costumes could also represent something else apart from the characters. Yellow represented the light in the dark, coming from the Giant's house, thus the Giant's Wife had a yellow dress (Fig. 1, right); before the absence of a physical door on set, her panel skirt could also make a door's turn. The Giant's boots were used to resemble the reins of a chariot (Fig. 1, bottom left). Therefore, shapes, colors and metaphors were hand-in-hand and anticipated the spectator's imagery on the narrative.

The décor had the contribution of the always present costumes that filled the spaces, either on the top of the table or bellow it and sometimes on both. The action in the woods was carried out underneath; the action inside the houses was done on the table top. There were also light projections in the shapes of hats and crowns, indicating the passage from boys to girls (the Lumberjack's Sons vs the Giant's Daughters), guiding the spectator in the quick changes between them and anticipating the tragic moment of one of them dying.

The user-centered methodology used in the costume design process was based on letting the actors interfere in it by wearing prototypes, manipulating them and giving feedback on their usability during the rehearsals – but observing directly how they moved was important to correct mistakes missed before in the costumes' characteristics. Nevertheless, the initial possibilities of the costumes were already tested in small scale (1:25) prototypes that predicted what movements/passages from character to character were possible. Even so, it was important to check if the attired could provide a smooth convincible passage between characters to the audience. And since fastenings were also a little difficult to accomplish by the actors, extra rehearsals had to be done for the actors to practice over and over, until they would perform the passages without stumbling – and those could be then perceived «magically». We can see the transformation from Little Thumb into Lumberjack on stage in Fig. 2.



Fig. 2. Transformation from Little Thumb, in white, into Lumberjack, in orange, on stage (rehearsal). *Little Thumb* theatre play by Seara – Companhia de Teatro de Beja, directed by David Silva. Costume design by Alexandra Cabral.

Each actor had to perform two different characters apart from Little Thumb. There was, nonetheless, one «main» Little Thumb character, therefore two of them could be semi-present, that is, from the hip up. A few steps were needed to achieve the transformations, such: as moving panels sideways (transforming trousers into a skirt – Fig. 3, 1.1–1.2); dressing some parts upwards (turning a hemline into a turtle neck, blouse in Fig. 3, 1.1–1.2); unzipping and pulling some pieces down, revealing white pieces underneath (Fig. 3, 1.3 and 2.3); throwing them to the back and over the head, turning a skirt into a top (Fig. 3, 2.1–2.2) or changing from one vest to another (from the orange one to the red underneath, Fig. 3, 3.1–3.2).



Fig. 3. Costume's transitions: Lumberjack's Sons/green (1.1); Giant's Wife/yellow (1.2); Little Thumb/white (1.3); Lumberjack's Wife/purple (2.1); Giant/blue (2.2); Little Thumb/white (2.3); Lumberjack/orange (3.1); Giant's Daughters/red (3.2); Main Little Thumb/white (3.3).

The actors needed for this play had to be highly skilled and focused, since they could have to move and speak independently during the transformations between characters. The costumes' color blocking minimized the chances of them getting mistaken, being each color related to a certain character. The shapes and textures of each costume were different, also helping the actors to embody them. Besides, the pace factor related to each transformation differed. All these small details mattered in memorizing the steps needed for the costumes' manipulation.

The light design of the play emphasized the central moments of the scenes, meaning that the transformations were not always highlighted, therefore the actors had to memorize how to perform their gestures with almost no light. But the focus on the actor under a low-key lighting helped engage the audience, immersed in the performer's ability to embody constant change into different characters. The costumes

encompassed a somatic effect: after a while, the spectators could predict which characters would appear on set, although they could not guess properly how the transformations were done, as they were carried out rather quickly.

Considering the importance of these costumes in the staging process, it can be said that there was co-creation in the staging of the play itself between the costume designer and the director – costumes somehow simultaneously constricted and emphasized the acting process, thus nourishing the director's vision. There was no end for the play and the costumes contributed with the solution: the show was about misery and it was convenient to have three Little Thumbs bowing and begging to the audience. Besides, and as mentioned above, costumes also represented physical elements of the scenic environment (such as houses, trees or lights). In sum, costumes established a broader relationship with the plot, contributing positively for revising the way the narrative was constructed, and of course, the way the story could be told.

2.2 Costume Design for *Epidemia* Theatre Play

Epidemia was a theatre play by David Silva, performed again by Seara, about the new digital technologies and their «epidemic» usage, being the characters an iphone and an ipad. The plot highlighted the dependence people have on this kind of gadgets, making them lose touch with reality. The director had particular requests regarding the direct relationship between lighting and costumes, making them resemble the electronic devices. They had also to be easy to dress and undress on stage.

Transparent and shiny fabrics were used to make the costumes resemble screen surfaces. To emphasize the technological sensation, they had some volume and distance from the body, allowing light projections to fill into the «gaps», adding the impression that costumes were embedded with their own light. Altering between opaque and transparent parts also added the impression of depth in that distance. Moreover, their neutral colors allowed the stage lights to be incorporated, creating a consistency in the décor. Everything was flooded with light of the same color, since costumes could «change» color along with the scenery (Fig. 4).



Fig. 4. Costumes transformed by the light design. *Epidemia* by David Silva, performed by Seara – Companhia de Teatro de Beja. Light design by Paulo Santos. Costume design by Alexandra Cabral.

The technological resemblance in the costumes made the audience and the light designer wonder on the presence of an actual electronic technology in them. This led us question how we can make-believe in performance practices through materiality. Performance practices comprehend both strategies, technological and non-technological, being the choice itself a purely strategic decision that considers conceptual and logistic dynamics, according to the global design of the theatre play. The use of technology, electronic in this case, would represent more investment, both financially and collaboratively. As the staging occurred outside at night, the need for a technologically advanced costume was not relevant, because the impact of the lights on the costumes were enough to create a good visual impact. Immersion in the narrative would then be assured. This analysis emphasized the spectators' point of view on the visual grammar and narrative coherence of the play and into what extent the costume design would follow their expectations.

There is a semiotic facet in this theatre play that carries the spectator along the symbolic metaphoric spaces the characters live in. There is some human reminiscence in the costumes, the characters still had arms, legs, heads. They were humans turning into gadgets, or gadgets becoming human-like entities. This dichotomy suggested that post-human dimensions were being brought up. By resembling LED screens and accepting the stage lights with brightness, it was as if the characters were in a mimetic relationship with the background, belonging to a virtual space. Therefore, the light design was leading the acting, with the help of costumes, which were placing the actors «somewhere else». This was also possible to achieve due to the setting: it was a façade from a building, which gave enough room to the action space and established a scale relationship with the small characters. Plus, it was the façade of a church, adding some celestial connotations to the virtual existence. There were only a few props on stage that linked the characters to the real-life setting; a bench was connecting the characters to their mundane existence.

There was no co-creation or collaboration between the actors and the costume designer in this production, but costumes were used in advance to test the possibilities of the light design. All conceptual facets were discussed with the director alone and the experience was rather fruitful because the play exposed how much meaning can be added to a performance, when the visual solutions found for it meet the spirit of the time, being this a play based on very recent technological developments. The costumes had a significant narrative role in the realm of the production.

2.3 Costume Design for *Miss Fruits Go to School* Educational Project

Donas Frutas Vão à Escola (Miss Fruits Go to School) was a draft-project presented to Buzico! Produções Artísticas e Agenciamento Lda. (Lisbon, Portugal) destined to be implemented in primary schools to teach kids to eat more fruit. The director's demands, in this case, were the fruits being peeled, separated and cut, depending on the variety and, most important, with pieces that could be carried around by the child spectators. The banana had to be peeled, the grapes needed their seeds to be shown and the apple should have a slice cut out (Fig. 5).

The project itself had an apparent simplicity, but it was grounded on a few ergonomic topics to be sorted out regarding the users and also the spectators, who could take part in the narrative as collaborative actors – not to mention that the organic matter in the fruits could be correlated to the human body. Apart from peeling a fruit being also undressing in a certain extent, fruit and body alter with time, adding some elements to a possible improvisation in acting and possibilities in design. For example, the fruits being prone to change could lead to an apple oxidizing, making use of LED circuits linked to microprocessors and sensors to create that illusion of a slice being separated from its mother piece.

A few stories could be told, like a monkey eating banana or a caterpillar eating the apple. But what about the banana smell? Technical textiles could be used, adding smell via microcapsules of scent. Fabrics' textures could also add softness and cold or warm sensations to the surface of the fruits, such as velvet for a banana, canvas for an apple and organza for a grape. In other words, other sensorial elements would sum up to the visual elements, like smell and touch.



Fig. 5. *Miss Fruits Go to School* pre-project, presented to Buzico! Produções Artísticas e Agenciamento Lda. Costume design by Alexandra Cabral.

Mechanic features could be considered, such as magnets as seeds in a grape, to help close both halves when cut in two or to get the grapes connected back to the stem. Separating parts of the costume, peeling and unpeeling the fruits by means of velcro or zippers, moving around gracefully in costumes that could change the gravity center of the performer's body, all those facets could represent challenges in the performers' acting. On the other hand, giving the children's the chance to hold separate pieces from a costume would place them as performers telling a story backwards, while looking around for the original pieces of fruit.

Sharing a costume with the spectator implies reviewing the staging process because it becomes a staging under construction. In this case, this would be particularly possible to be put into practice because the storytelling fruits summed up symbolic characteristics to their explanatory features, bordering somehow the possibilities of the narrative

to a few predictable topics, allowing the actors to expect, in advance, some reactions from the audience and be ready to deal with them on set.

2.4 Glove Functional Prototype, E-Textiles Art Workshop at Contextile 2014

A simple functional prototype was developed during the E-Textiles Art Workshop held at the contemporary textile art biennale Contextile 2014 (Guimarães, Portugal), based on a few electronic tools: conductive thread, Lilypad Arduino, 5 LEDs, coin cell battery holder and lithium battery. The goal was to accomplish something functional in a very limited time, having to be inevitably small scaled. The challenge represented an introduction to designing with smart materials, hence it sounded appropriate to make an interface someone else could activate, generating an active behavior between sender and receiver. The solution should embody the emotion in a handshake, relating it to lighting up the LEDs in a glove. The limited resources led to a rational choice of where to place them: LEDs along the thumb; switch near it, where the other person's thumb touches; remaining electronic components hidden in the palm (Fig. 6).

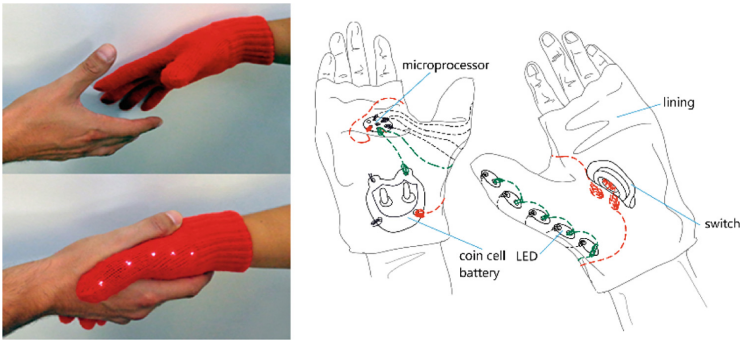


Fig. 6. Glove functional prototype: switching the LEDs on with a handshake. Developed during the E-Textiles Art workshop at Contextile 2014 by Alexandra Cabral.

The prototype surprisingly provoked the urge in the opposite person to keep repeating the gesture of lighting up the glove. Into what extent lighting up the glove meant an immersive feeling into a handshake? The limited functions of the LED circuit proposed other possibilities, such as how to create more correspondence with the intensity of the gesture (harder, with more lights; softer with less), relating the prototype's expressiveness to human emotions in greetings. Colored LEDs could be added, and the electronic circuit could be spread to other parts of the body, accordingly to the desired symbolism.

The ergonomics in this prototype became both functional and cognitive, for being allied to a communicative gesture. What if both users had a glove with lights? What narratives could one compose with such wearables? Into what extend would acting and

improvising contribute to open up new possibilities? Chance and intentionality would bring new narratives to a handshake discourse, showing that technological wearables can drive us to explore storytelling.

3 Conclusion

A few performative contexts within the costume design process were analyzed, from including the actors' collaborations from the beginning to counting on the director's inputs only. Anyhow, costumes were used as tools of the staging creative process and proved to perform a significant role in conveying meanings to the audience through their direct relationship with the plot. Accordingly, they helped actors develop both a performative narrative and the characters themselves.

Consequently, questions were posed regarding the acting process about how costumes, by their nature, could either become the core of a narrative or bring possibilities for other stories to be told. The creative process was based on the potentials of the costumes' materiality and their ergonomic relationships with the body itself, considering also the new dimensions added by technological components. Those promoted a transformation of the dynamics of interaction among performers and between performers and spectators, capable of bringing new insights in a semiotic point of view.

Dynamic properties in costumes, such as detachable parts, moving parts, changing colors or lights, promote levels of interaction between the characters that inspire storytelling and lead to the rewriting of the stories themselves. Plus, costumes can become props perceived as new entities, either apart from the body or gaining meaning from it. They can have new «smart» characteristics and promote interactivity. Unpredictability is then a variable to consider, having the spectator the chance to switch roles with the performer.

Visually, costumes can convey certain aspects of the narrative by their plastic expression and provide some traces of personality to the characters they intend to dress. Acting adds soul to the characters, and costumes then contribute to the plot thread, guiding the spectator. Additionally, costumes also influence coordination and interaction among actors and establish their degree of embodiment into the scenic space. Textile materials are relevant for compelling, by their structure, certain body movements, formerly promoted by the costumes' shapes and textures; those features, together with their colors, transparencies or opacities, are prone to either allow them contrast or blend into the scenery, thus creating different meanings.

Designing costumes meets then the staging process. They merge in the intricate ergonomic task, both physical and cognitive, linked to drafting a narrative, narrowing down the results, providing the audience with a convincible recreated fictional world. It's a process obviously framed by an appropriate stage and light design that emphasizes storytelling, promoting the immersion of the spectators in the plot. All cases considered, a user-centered methodology becomes particularly important, not only in the costume design process but also in the process of assuring which aspects should be present and which should be disposable in the construction of a certain narrative, so that the story can be conveyed to the audience in a specific conceptual framework.

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Reliability of Anthropometric Reference Data for Children's Product Design

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Abstract. In the United States, children's body dimensions are significantly different from what they have been in the past. Dissatisfaction with current children's clothing sizes and mismatched furniture are often reported in the industry. Children often show improper sitting posture in class due to mismatched sets of desks and chairs. A reliable reference for children's anthropometric data is needed to improve children's products' safety, comfort, and fit in the environment. The aim of this study was to provide the most up-to-date children's anthropometric data for 6 to 11 year-olds in the United States and examine the reliability of anthropometric reference data for children's products. This study was conducted at Texas Tech University, one of the scan sites for a national sizing survey, Size NorthAmerica (Size NA led by Human Solutions Inc.). A total of 21 girls between the ages of 6 and 11 participated in the study with IRB approval. A set of 52 body dimensions in each child was scanned with a laser-based 3D body scanner. The measuring procedure was compatible with ASTM standard measurement definitions in accordance with ISO 8559 (garment construction and anthropometric survey) and ISO 7250 (basic human body measurements for technological design). Current children's body dimensions were significantly different from the anthropometric reference size charts for children's product design. Results in this study would provide insight into the need for developing reliable anthropometric reference data for children's product design.

Keywords: Children's clothing · Furniture design · Anthropometric · Size · 3D

1 Introduction

The International Ergonomics Association (IEA) defines human factors (ergonomics) as the science which focuses on the interactions among humans and other elements of a system. It also describes anthropometry as a branch of ergonomics that encompasses measuring various dimensions of the human body in relation to products in order to optimize human and system performance. In the United States, apparel and furniture companies utilize anthropometric reference charts to develop their merchandise. In the apparel industry, three major anthropometric references are available, provided by the American Society for Testing and Materials (ASTM), the International Center for

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Health Statistics (ISO), and the National Center for Health Statistics (NCHS) [1]. However, some of this reference data are outdated for product development [2].

Several national sizing studies have been conducted to update anthropometric references. For example, national sizing studies, CAESAR, SizeUK, and SizeUSA provide accurate anthropometrics using 3D body scanners and reported a significant change in human body dimensions over past decades [3]. However, these surveys excluded children due to the difficult sampling procedures for this age group [4]. Dissatisfactions with the children's furniture sizes have been reported frequently [5–13]. Hwang and Kim [14], for instance, found children's body dimensions are significantly different now than from when anthropometric data reference size charts were collected. Also, based on the National Health and Nutrition Examination Surveys, children are heavier at present. Further, children often show improper sitting posture in classes due to mismatched desks and chairs. Van Wely [15] identified strong relationships between various musculoskeletal disorders and exposure to highly repetitive awkward postures, postures that hardly improve in adulthood [16]. There is a critical need to study children's anthropometrics and to update the references that can help with improving children's products' safety, comfort, and fit. Thus, the objective of this study was to provide the most updated anthropometric data for children aged 6 to 11 in the United States. For children's product development, it also aimed to investigate the reliability of anthropometric reference size charts, including the ASTM D6192-11 (Standard Tables of Body Measurements for Girls, Sizes 2 to 20) [17], and the standard size chart for children's furniture products provided by Panero and Zelnik [18].

2 Methods

In this study, 21 female children aged 6 to 11 were scanned from August to October 2018 using a laser-based 3D body scanner to collect updated data on children's anthropometrics. The measurement was conducted at Texas Tech University, one of the scan sites for a national sizing survey, Size NorthAmerica (Size NA led by Human Solutions Inc.). A set of 52 body dimensions in each child was scanned in four postures: three in standing positions and one while seated. The scanner provided fast and accurate measurements through an optical triangulation process using eight sensors. The measuring procedure was compatible with ASTM standard measurement definitions in accordance with ISO 8559 (garment construction and anthropometric survey) and ISO 7250 (basic human body measurements for technological design [19]. The Institutional Review Board (IRB) at Texas Tech University approved the data collection.

Next, two reference size charts, ASTM D6192-11 for apparel products (Standard Tables of Body Measurements for Girls, Sizes 2 to 20) [17], and the standard size chart provided by Panero and Zelnik [18] for children's furniture were compared. These standards are summarized in Tables 1 and 2. Accordingly, the sets of survey data were

compared with the references to investigate their potential differences. The analysis was implemented using SPSS version 25.

Table 1. Summary of ASTM D6119-11 clothing standard size chart [17]

Age	6	7	8	9	10	11
Body measurements (in)						
Body height	46.50	48.50	50.50	52.50	55.00	58.00
Waist girth	23.00	23.50	23.50	24.25	25.00	26.00
Hip/seat height	22.75	24.38	25.63	27.00	28.63	30.13
Waist height	28.00	29.63	31.13	32.88	34.75	36.88
Hip/seat girth	25.00	25.75	27.50	28.50	30.00	32.00
Crotch height	20.25	21.88	23.13	24.38	26.00	27.63
Crotch length	19.13	19.25	20.00	20.88	21.88	23.00
Knee height	12.00	12.50	13.38	14.00	15.13	16.38

Table 2. Summary of Panero and Zelnik furniture standard size chart [18]

Age	6	7	8	9	10	11
Body measurements (in)						
Body height	46.33	48.57	51.00	53.43	55.55	58.22
Knee height	14.14	15.00	15.80	16.88	17.47	18.34
Popliteal length	11.40	12.00	12.75	13.50	14.00	13.00

3 Results

3.1 Current Children's Body Dimensions

Table 3 shows the statistics of the participants' dimensions for body height, waist girth, hip height, waist height, hip/seat girth, hip, crotch height, crotch length, and knee height. These data were subsequently employed for comparison of current anthropometrics with the two reference size charts. Accordingly, Table 4 presents a summary of the participants' characteristics in terms of age, race, and Body Mass Index (BMI). The participants' BMIs were calculated using the BMI percentile calculator for children and teens provided by the Centers for Disease Control and Prevention at the U.S. Department of Health and Human Services [20]. Overall, the sample's average BMI was 19, placing it at the 71st percentile of BMI for girls in the healthy weight category [20].

Table 3. Descriptive statistics of current children's anthropometrics (N = 21, Unit Inch)

Age		6	7	8	9	10	11
Number of participants		5	2	2	1	6	5
Body height	Average	43.75	49.53	51.09	57.35	56.38	58.06
	SD	1.69	0.81	1.81	-	2.98	3.21
Waist girth	Average	23.69	21.58	25.73	39.51	30.31	26.28
	SD	3.24	1.68	-	-	4.35	2.01
Hip height	Average	17.91	21.13	22.54	27.55	26.68	27.42
	SD	1.92	1.62	0.18	-	2.18	1.70
Waist height	Average	25.75	29.44	31.27	34.37	34.53	36.44
	SD	1.36	0.28	0.19	-	1.96	2.60
Hip/seat girth	Average	27.21	27.18	28.93	40.21	35.64	32.81
	SD	1.61	1.29	0.33	-	5.50	2.33
Hip/hip girth	Average	24.68	22.99	26.16	41.33	32.585	28.676
	SD	3.27	1.64	0.89	-	5.16	2.04
Crotch height	Average	18.01	21.24	22.52	23.02	24.70	26.12
	SD	0.79	1.10	0.10	-	1.24	1.86
Crotch length	Average	20.37	22.21	22.51	31.23	26.33	26.23
	SD	2.18	2.23	0.48	-	3.33	1.51
Knee height	Average	11.09	12.63	13.59	14.79	15.15	15.77
	SD	0.56	0.42	0.06	-	0.89	1.07

Table 4. Participants' characteristics

	Count	Average BMI	Percentile BMI	Weight status
Race				
White	10%	18	60	Healthy
Hispanic	71%	20	76	Overweight
African American	5%	32	99	Obese
Asian	14%	16	45	Healthy
Age				
6	23.8%	16	58	Healthy
7	9.5%	15	42	Healthy
8	9.5%	17	71	Healthy
9	4.8%	30	99	Obese
10	28.6%	23	90	Overweight
11	23.8%	19	68	Healthy
Total	**100%**	**19**	**71**	**Healthy**

3.2 Inconsistent Anthropometric References for the Children's Size Charts

One sample t-test was applied to investigate the differences between ASTM D6119-11 clothing standard size chart for apparel [17] and the Panero and Zelnik standard size chart for furniture [18]. Table 5 summarizes the results for body height, popliteal length, seat height, and knee height of children aged 6–11. The results showed no significant difference in body height between the two reference charts. However, popliteal length among all ages (6–11) was found to be significantly shorter in the apparel reference when compared with the furniture reference (MD = −2.28 in, −2.00 in, −2.43 in, −1.50 in, −2.83 in, and −3.48 in, respectively). Similarly, seat height at age 6–9 was significantly shorter in the apparel reference than the furniture reference (MD = −2.40 in, −1.71 in, −1.32 in, −0.94 in, respectively). In addition, knee height was found to be significantly greater in the apparel reference than the furniture reference at ages 6 and 8 (MD = 0.60 in, 0.62 in, respectively) and significantly shorter for ages 10 and 11 (MD = −.57 and −1.02 in, respectively). These differences imply that the body dimensions recommended by the reference size charts for apparel and furniture do not conform in most parameters.

Table 5. Comparison of ASTM D6192 [17] and Panero and Zelnik furniture standard size chart [18]

Age	6		7		8		9		10		11	
Sig./mean difference	Sig.	MD	Sig.	Sig.	Sig.	MD	Sig.	MD	Sig.	MD	Sig.	MD
Body height	0.92	0.16	0.63	−0.11	0.47	−0.41	0.32	−0.93	0.66	−0.56	0.82	−0.23
Popliteal length	0.00*	−2.28	0.00*	−2.00	0.00*	−2.43	0.00*	−1.50	0.00*	−2.83	0.00*	−3.48
Seat height	0.00*	−2.40	0.00*	−1.71	0.00*	−1.32	0.00*	−0.94	0.72	−0.16	0.61	0.05
Knee height	0.04*	0.60	0.23	0.43	0.00*	0.62	0.12	−0.50	0.00*	−0.57	0.00*	−1.02

*Level of significance: $p < 0.05$

3.3 Anthropometric Reference Data for the Children's Clothing Size Chart

Table 6 shows the differences between ASTM D6192-11 [17] and the children's body dimensions measured through the data collection process. Since there was only one participant of age 9, this age category was excluded from the analysis. Comparison of body height showed that the sample at age 6 was significantly shorter than the reference chart (MD = −2.75 in). Also, the sample crotch heights at ages 6 and 10 were significantly shorter than the reference (MD = −2.24 in, and −1.30 in, respectively). In contrast, the sample crotch lengths at ages 10 and 11 were significantly greater than the reference (MD = 4.46 in, and 3.23 in, respectively). However, the sample hip height at age 6 was significantly shorter than the reference chart (MD = −4.84 in). Similarly, the sample knee height at age 6 was significantly shorter than the reference (MD = −0.91 in). Conversely, the sample waist girth at age 10 was significantly greater than the

reference (MD = 5.31 in). Finally, the sample waist height at age 6 was significantly shorter than the reference (MD = −2.24 in). The differences of the other values were insignificant.

In summary, children at age 6 showed more significant differences from ASTM D6192. This age group had a significantly shorter body height, crotch height, hip height, knee height, and waist height in comparison with the reference chart ASTM D6192 [17]. In addition, these participants had greater crotch length, hip/seat girth, and waist girth than the reference; however, these differences were not significant.

Table 6. Comparison of participants' anthropometrics with ASTM D6192 [17]

Age	6		7		8		10		11	
Sig./mean difference	Sig.	MD	Sig.	MD	Sig.	MD	Sig.	MD	Sig.	MD
Body height	0.02*	−2.75	0.32	1.03	0.35	0.59	0.31	1.37	0.97	0.06
Crotch height	0.00*	−2.24	0.57	−0.62	0.13	−0.43	0.04*	−1.30	0.15	−1.5
Crotch length	0.26	1.25	0.31	2.95	0.20	2.51	0.02*	4.46	0.00*	3.23
Hip height	0.01*	−4.84	0.22	−3.24	0.49	−1.41	0.81	−1.95	0.24	−2.71
Hip/seat girth	0.07	2.21	0.36	1.42	0.20	1.43	0.54	5.63	0.42	0.80
Knee height	0.02*	−0.91	0.74	0.12	0.26	0.21	0.95	0.02	0.28	−0.65
Waist girth	0.66	0.69	0.35	−1.92	0.41	2.23	0.03*	5.31	0.77	0.28
Waist height	0.02*	−2.24	0.52	−0.18	0.37	0.27	0.80	−0.21	0.73	−0.45

*Level of significance: $p < 0.05$

3.4 Anthropometric Reference Data for the Children's Furniture

The children's body height and knee height were compared to the Panero and Zelnik furniture standard size chart [18]. Table 7 shows the comparison results that the sample at age 6 was significantly shorter than the reference size chart (MD = −2.58 in). This is in accordance with the previous finding where the sample at age 6 was significantly shorter than the apparel reference chart. Further, it was found that the participants at ages 8, 10, and 11 had a significantly longer knee height than did the furniture reference chart (MD = 0.83 in, 1.07 in, and 1.00 in, respectively). The other values did not have significant differences.

Table 7. Comparison of participants' anthropometrics with Panero and Zelnik furniture standard size chart [18]

Age	6		7		8		10		11	
Sig./mean difference	Sig.	MD	Sig.	MD	Sig.	MD	Sig.	MD	Sig.	MD
Body height	0.02*	−2.58	0.44	0.92	0.98	0.18	0.45	0.81	0.86	−0.17
Knee height	0.27	−0.32	0.31	0.55	0.03*	0.83	0.03*	1.07	0.04*	1.00

*Level of significance: $p < 0.05$

4 Conclusions

Children's products help improve body development if designed appropriately. Clothing and furniture are the most commonly-used products and have a great influence on children's bodies by providing comfort and body protection. Manufacturers utilize anthropometric reference data for size charts to develop the children's products. It is necessary for the industry to reconsider the anthropometric references in accordance to changes in children's body dimensions, considering fit and size issues.

This study has revealed a potential problem with the anthropometric reference that would not be applicable for developing children's products. Children's current body dimensions were significantly different from the anthropometric reference size charts. The reference size charts, ASTM D6192-11 for apparel product [17] and the standard size chart by Panero and Zelnik [18] for children's furniture had a significant difference between the children's body dimensions at age 6–11 years and the references with respect to body height, crotch height, crotch length, hip height, knee height, waist girth, and waist height. These finding are in accordance with reports on dissatisfaction with apparel fit and musculoskeletal symptoms due to furniture mismatch.

Importantly, the problem is not only related to children's body changes. The main concern is the use of outdated sizing systems in the industry. Although some manufacturers have attempted to improve their products by considering additional sizes for apparel or producing adjustable furniture, more effort is necessary to better understand children's body proportions and shapes within different ages and stages of development. Also, this study provided evidence for differences among current children's body dimensions both from the past and from reference size charts. However, it had limitations associated with the collected data. For example, most participants (71%) were Hispanic, while this share in the United States' population is about 18% [21]. Due to the sample characteristics, further research is necessary to generalize the findings to the population of children in the United States. A larger sample population may provide a better representation of current children's anthropometric data. The anthropometric data collected on the participants' body heights and weights can be applied to clinical and health studies.

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Dynamic Wardrobe from a User's Perspective – A Previous Survey Study for Female Students

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Abstract. Evaluating all phases of Fashion Products, it is realized that the linear make-disposal model of Fashion has no longer future. This wasteful and polluting system has been replaced more and more by strategies based on a circular economy which aims to keep the highest clothing value, textiles and fibers during the use and re-enter the economy afterwards, never ending up as waste. The sustainable concepts of the new textile economy can provide new products and new services models that would enhance the benefit experienced by customers. With the aim to know the opportunity of people having a dynamic wardrobe (based on second-hand clothes, rental or personalized clothes) the present study shows a survey results on academic female population in order to investigate which items they most like and would never leave their closets. We realized that in 25 female students there is an interest for the same types of clothes and colors, even finding that the way the Fashion System is currently based is completely out of step with consumer behavior.

Keywords: Female wardrobe · Fashion waste · Wasteful consumption · Sustainable

1 Introduction

The reasons why it makes sense to know what goes on within female wardrobe are important to the future of fashion practice that we hope will become increasingly sustainable. Knowing people and understanding their clothing behavior provides a better development in garments matter [1]. So that is important to ask and evaluate the items they use because the wardrobe is a collection of items accumulated from previous occasions. It can have different orders which may be based upon social roles (work-wear), functionality (activewear, swimwear, leisurewear), type of clothing (such as coats, trousers or shirts), colours, textures or even other type of individual categories such as fun clothing. Taking into account the multiplicity of actions that can occur daily, these orders may help women to organize their outfits and make the act of choosing what to wear easier [2].

Many pieces of garment can be dressed on different occasions, changing the purpose for which they were originally purchased. Woman manage the items and recombined them to construct their appearance through the consideration of social and

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cultural contexts [3]: a formal black trousers jumper can appear funky when worn with sporty sneakers, for example. And woman can buy a new top to go with something from her wardrobe and yet arrives at the frequent conclusion that she has nothing to wear, a fact which may subsequently encourage her to buy clothing all the time. This attitude is ingrained and linked to all aspects of living in a modern society but the more it is done the more damage goes to the environment. Fashion waste does not directly go to landfill, rather it stays and keep inactive and unused inside people's wardrobes. A garment usually becomes waste when it is superseded by a superior version in style, cut, fit or textile, without describing the high levels of pollution and chemical that all the upstream supply chain has. People do not have the perception of that and who have it probably would express reluctance to sacrifice the habits with which have grown up.

In order to effectively reduce wasteful consumption new strategies, need to be planned so that sustainable development would not be based on the depravation of what people currently value but derived from what is easily accept. Not pushing people that are personally responsible by their consumption pattern, it is needed to create options for consumer having more sustainable opportunities [4].

This research aims to understand what type of clothes people wear more and to know, by user's perspective, what is wasteful consumption or not.

2 Female Wardrobe

2.1 Fashion Consumption

The purchase of clothing has witnessed a historical evolution, since it was made by need until it become a fast and quick impulse. Cultural anthropologists help us to understand its process, describing that people cover or decorate their bodies due to a variety of reasons, such as protection, modesty, and the desire to be sexually attractive [5]. Before and during Middle Ages, clothing characterization, in addition to be cultural and having religious connotations, was also representative showing the power of social classes through conspicuous consumption [6]. When the sumptuary laws were abolished, social discrimination declined, and the use of clothing starts getting broader.

Nowadays, Fashion consumption is a practice of purchasing connected to everyday life in a modern society and a medium to anybody adorn oneself. There are those who described it as an attempt to construct a wearer visual identity to be interpreted by the public [7]. Clothes we use can express our identity telling others something about our gender, class, status and so on, but once they not speak directly they can therefore be open to misinterpretations [8].

Veblen's theory is no longer able to explain the behavior of consumers in a modern and dynamic capitalist society, where the middle class became majority and tastes spread out [9]. The fashion system is no longer characterized by homogenous styles such as those that were represented up to the 50's but rather by fragmentation and uncertainty. At any one time there are multiple definitions appearing no rules, only choices [10]. Images of the fashionable ideal are so universal that women step outside the domain of fashion to go inside in television shows, films, etc. They have balanced so many different concerns, ranging from personal preferences and body shape that a

quest for fashionable wear is primarily motivated by their social desires. As identities are socially acquired in relate to socially constructed positions within a society [11] it is much safer aesthetically and less expensive financially to buy social and formal clothing solutions.

A study made by Hamilton [12] revealed that are youngest people (18–35 years) who are affluent or the highest waste-generating consumers. They can buy a lot of clothes and never use them, hence, making many purchasing errors and increasing waste consumption. They are more actively consuming and experimenting more to settle for their identity, once they are going through a transition into adulthood.

Therefore, fashion consumption display characteristics of users' personality, their taste and also their lifestyle but products materiality does not always respect their intentions because others may saw aspects they would have never wanted revealed at that time [2]. Only strong people and self-confident can have more successful impact changes upon others and reduce their environmental footprint because this time we see fashion as offering cheaper and endless possibilities for individual expression.

To examine female fashion consumers buying criteria a study made in 2011 for an active working people showed that they had the habit of buying at least 1 or 2 pieces of clothing from the latest trend. Their most important requirements to buy clothing were "personal taste" and "necessity", and most of them had concerns over reducing garments they do not need effectively. These results fit to the target segmentation theory with personality variables and lifestyles preferences, instead of demographics values [13]. Another issue is that people wear what they like but preferring comfort, an opposite tendency to the Tigert & Ring theory that have characterized the individuals with greater involvement with Fashion who had less relation to the "comfort" [14].

2.2 Wardrobe

A wardrobe can be organized by functionality, by colors, occasions, seasons, etc. There are many collective options to put clothing inside, as long as women know how to negotiate their sense of self, their individuality and their autonomy when choosing what to wear.

Women faced with many possibilities, since being chic or funky until to please family members and loved ones, or even with their position in life, such as being middle-aged, grandmother and not having the body she used to have [2]. These thoughts and concerns are many times restraints that they have to manage on a daily basis. The wide context is so big that sometimes the wardrobe fills up with new items to go with older ones. In turn these items remain inactive, keeping itself as memories from the past, waiting to be dressed on again and acquire a new identity.

Wardrobes can really be clothing collectors and chronological biographies of each owner and as people get older the wardrobe will accumulate clothes.

Analyzing all pieces of garment, and considering that Fashion is a system of signs [15], with greater significance for some people than for others, it has been observed over the years that there are numerous items with different typologies. A study carried out in 2015 in order to find out that basic wardrobe reveals about 20 types of pieces, including black dress, the polo shirt, the t-shirt, the twin-set, the "blazer", the "jeans", the "trench-coat", "black pants", "white shirt", the "skirt", the "day dress", the "training

suit", and others like a "sweater", "top", the "cardigan", the "jacket", "shorts", "leggings", "cape", and a "pullover" [16].

Nevertheless, analyzing the typology of each one, since for example in the jeans can exist several models, like skinny, straight leg, jeggings, boot cut, flared, Low rise, boyfriend and *cigarrete*, it begins the need to refine which more common among different users' type.

2.3 Fashion Waste

Garment can become fashion waste when the owner changes in shape it does not fits anymore. Fashion clothes are made in standard sizes and not all facilitate size variation. The users may keep their garment and thinking that will wear it again when they return to their original size, but it is likely that it remains in the wardrobe forever.

The same happens when clothes stops being attractive in Design and another superior version takes its place. The wearer may be attached to its clothes because they were used in very special occasions but as soon as they stop fitting, they start getting inactive and become fashion waste. The wearer may not be conscious of that because their focus is on the new pieces [4]. There are also who store such items of clothing as a significant extension of who they were used to be because they were worn habitually during entire working life [2].

However, saving items that are not used is not as much problematic as those which are bought and never used, such as young generations have done.

This research aims to know if female Portuguese students do the same as Australian young consumers that spend money on clothing they do not wear at all [12] and what happens to the clothes after they through them away.

The fact of having clothes at low prices with good design means a great increase in purchases, getting customers retain a large quantity of clothes in their homes, some stored in wardrobes, drawers, garages, etc. When this storage is exhausted the consumers have the options of selling to second-hand stores. give them as donations to charities or send to clothing banques [17]. In Portugal there are who put next to the waste conventional bin for someone can catch them up.

3 Sustainable Alternatives

3.1 Sustainable Consumption

Environmental concerns around fashion products have provided studies, incentives and partnerships between companies in order to make improvements in processes of production, services and means of communication to change the perception of clothing as a disposable product and reduce environmental impacts during its maintenance and after the first cycle of use [18].

Line of thought, sustainable consumption is an issue to be addressed in terms of resource conservation, waste reduction and reduction of toxic pollutants.

While people are focusing on wealth-creation and consuming commodities satisfaction there are also emerging social groups adopting alternative lifestyles and

choosing non-materials behaviors even in the field of fashion. Many of them buy as few clothes as possible and prefers second-hand clothing consumption. There are who called them the minimalist shopper [19], down-shifter 12 or even neo-consumers (Teutsch 2004 in Pears [4]) but all of them have already made a decision to reduce their work, incomes and consumption, having more leisure time for their kids and living in balance with their own values.

3.2 Sustainable Wardrobe

As soon as environment has become a differentiation source and a concern requirement for designers and green companies that they have recognized and promote new tackles for their consumers, adopting an holistic approach «from cradle to cradle» [20].

Design for sustainability focus on the systems that must be worked on several lines of though simultaneously and making a product lifecycle approach, ranging from design to end-of-life stage. There are several methodologies at all stages of the clothing product to reduce the environmental impact. The use stage is the one to which «wardrobe» is connected, thus it is firstly important understand the dynamics of that, which depends on user to user, to verify the best practices of use, care or even reuse. The idea of renting garment instead of buying seems unattractive for many consumers, however, for certain clothing styles (such as social clothing, maternity clothes, school uniforms, etc.) is a fairly common practice [21].

Nowadays our wardrobe can have places of dynamic equilibrium, if there are reworked clothes, shared and reused, without constantly requiring a flow of new goods and resources [22]. The clothing exchange may be a practice as a response to the problem of fashion waste by seeking to reactivate it [23]. However, the potential for exchange, as fashion waste activation, only may be realized if that become a regular event and generate an enthusiastic audience for people who consider it as a reliable method of fashion consumption and a genuine alternative to consumption of new fashion garments [4].

The aim of sharing goods is to increase the intensity of their use while reducing the material intensity and the need to buy new clothing.

3.3 Dinamic Wardrobe

A dynamic wardrobe can be like a house with good maintenance and care that changes when are out of time. It can have rental, shared and bought products, but all are actively used. To know the opportunity of people having one and with the purpose of verifying which pieces of clothing that nobody discards and that all use them, interviews were conducted to women students of higher education.

3.4 Survey Methodology

The interviews were given in the form of an open questionnaire and the students had two months to answer the questions and to illustratively assemble their wardrobe pieces.

The issues were made according to characteristics that have not been studied in the literary review such as:

1. What clothes are on your current wardrobe and what you really wear (coats, skirts, trousers, shirts…)?
2. What style of clothing do you wear more often (style, colors, textures, inspiration)?
3. What kind of store do you usually buy clothing (street store, shopping store, online, etc.)?
4. How many garments do you buy per season?
5. What reasons make you to buy garments (necessity, emotional feeling, to be attractive, etc.)?
6. How many garments do you put away per season and why?
7. Among all existing garments in your wardrobe which do you like most and why?

3.5 Survey Results

Among 25 inquiries, we realize that when we ask people about the wardrobe only a very small minority (8%) included accessories and anybody included bathing suits, gym suits and intimate attire.

Just under half (40%) of people have between 50 and 100 pieces of clothing into their wardrobe while only 8% have less than 30 because they are not living in their country.

64% of people buy their clothes in shopping centers or street shops and only a small minority buy online from foreign brands. About half the people that discard clothes keep them at home and other half give them to friends or send to charity.

Everyone says buying items by necessity, fashion and comfort, although a very small fraction confirms buying pieces of clothes to match what they already have.

In general, there are typologies of pieces and colors the vast majority preferred most, the coats and oversized pieces; the coats for the possibility of composing a personal look and the oversized pieces (especially wool sweaters, large and loose dresses or jumpers) for the ease of handling and comfort, all of them usually in dry, neutral or black colours.

4 Conclusion

All women have a clear sense of which items can be match simultaneously and which clothes go together, involving not only questions of colours and style, but also whether the garment fits on their own body. They know clothes are a medium they use to express their selves and despite the preference for neutral colours and basic styles on complete outfits, the patterns, accessories and specific items (more geometric for some and more floral for others) are aspects of their self-identity that may be externalized in the wider social and cultural context. Women can manage and construct their appearances based on social networks, lifestyle and personal taste as well often going in the opposite direction to what happens in fashion trends. These issues lead us to think that there is great amount of fashion products, more than people need. We have

found that although most students have more than 50 pieces of garment, some enjoy wearing items purchased in unconventional stores or inherited by family members. However, this concern is based on differentiation of consumers who are dissatisfied with the same figures of new fashion for mass market rather than environmental matter.

We think that in a more sustainable future the fashion design process will certainly be less massive and more personalized or rotating, where the wardrobes can be dynamic, with exchanges and rental clothes.

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Parametric Design for the Construction of a Corset Surface Based on Historical Female Bodies

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Abstract. This work shows the results of a research project which goal was to make a geo-historical study on clothes used by four civilizations: Rome, Greece, Egypt and India. A bibliography search was done, online museum image databases and other sources were accessed in order to have a photographic record of statues and female tridimensional figures corresponding to the selected historical periods and parts of the world. The method included a partial reconstruction of the body, referencing the sculptural representation of female beauty in those ancient civilizations. After the reconstruction an indirect extraction of anthropometric measurements was made over 2D images, and those data were fed into a generative design software to model a tridimensional torso. The outcome is a 'historical-customizable' 3D model that can be applied to the production of clothing and historical costumes.

Keywords: Parametric design · CAD · History research · Image analysis

1 Introduction

Based on the results of the first stage of a project named 'Geo-historical reading of garment' done with a team of undergraduate students from the School of Architecture and Design of a Colombian higher education institution, a set of morphological characteristics of women from four ancient civilizations were categorized. Based on those key morphological characteristics, a parametrization was possible on a second stage of the project.

To obtain both characteristics and parameters, a novel method was applied to collect data from secondary sources, in this case photographs taken by different individuals in different parts of the world. The interpretation of the anthropometrical measurements is key to include the historical force of the concept of beauty, divinity and perfection on each civilization, and their semiotic reading on the selected images that could include reproductions or photographs of sculptures and drawings. Semiotic readings in this context often include cultural, religious and social elements permeating

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the artistic representation of beauty, and such elements could insert distortions in such representation.

Historical clothes reproduction demands inference tools and indirect extraction of structured body measurements based on aesthetic canons linked to beauty and divinity, because it is not possible to measure subjects. All artistic or crafted representations are the best source possible and that reflects on both dressed and nude bodies what surrounded the maker, with a certain degree of objectivity defined by the cultural agreements on what was correct and divine.

For any of the four civilizations selected, the most long-lasting object to record the shape of bodies, excluding those of deities and mythological figures, are statues and figurines, regardless the scale. These objects can be found in both public and private collections around the world, and there are photographic archives of a large number of these tridimensional objects. An ideal scenario supported by new technologies like CAD and CAM applied to clothing design, could be having access to the physical object and make the measurements directly on it, however, that compromises the integrity of each piece and requires access to many facilities around the world, which may be restrictive for a research project. On a more practical perspective, overcoming these research challenges might help to have accurate historic anthropometrical models to be used in the construction of clothes, covering in a more precise manner the base body cylinder and the layout for cutting patterns and pieces to be sewn.

The main contribution of this work is the creation of algorithms fed with historical data extracted from bi-dimensional images, that can be used in the tridimensional modeling of a body-fitting surface. Although precise, most technical solutions to apply anthropometrical measurements in technical solutions in the clothing design process are rigid, and don't include ethnic nor body morphology factors.

2 State of the Art

Different instruments have been developed in the last two decades to make anthropometrical measurements to diverse groups, regardless they are segmented by region, ethnicity, gender and other characteristics, that help to draw conclusions about their body typology to be included in the identification process of sizing models used in the technical development of clothing. Body scanning technology complements all traditional instruments like rulers, tapes and calipers. Measurements obtained by these methods are called 'naked measurements' in which the subject uses underwear or a tightly-fitted bodysuit to avoid any error in data collection.

Nonetheless, the extraction of anthropometrical data of already deceased individuals is challenging. Some extrapolation can be made from forensic anthropology methods using bones, genotypes and comparative anatomy, however is not an exact measurement. Also, these methods lack the cultural and historical factor analysis that may explain the way clothes were used or why a certain body feature was admired. However some attempts to link body changes and economic cycles have been made [1].

Anthropometrics in clothing design have a direct influence in how the clothes are created and manufactured and any technology that supports data extraction and application can streamline this process. New technological opportunities and other

industrial applications have opened new fields of research related to the parametrization of the body, whether is for analyzing body shape variability for product design [2], or creating avatars with accurate body proportions [3], designing products [4, 5], or benchmarking measurement methods [6].

3 Methods

This research project is based on an inductive empirical method, in which early stage results of the project were used to refine the software solution on a later stage. First stage of the project, the geo-historical reading of clothing, included identification of dressing patterns for Rome, Greece, India, Egypt, Sumer, Persia, China and Japan. This was key to identify the body segments that were considered components of 'beautiful' proportions, and this concept is related to three concepts in clothing elements: access, cover and support. Body typology was a selection criterion to refine the search for digital images from which measurements could be made, as the interaction of clothing is relevant to the perception of beauty according to the time and place. The original list of eight civilizations was narrowed down to for, to continue with data extraction, as they had a higher number of tridimensional representations of the body (statues and figurines) compared to the number of paintings and drawings. For each one of the four civilizations eight online-available photographs of statues or figurines were selected, prioritizing those in which the posture was natural, legs were extended, and it was a frontal view. Over those images, a set of main axes were marked digitally as seen on Fig. 1.

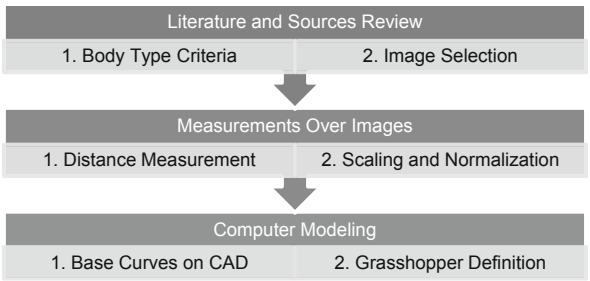


Fig. 1. Methodological process of the project

All images were placed horizontally in a row, and horizontal guidelines were added marking the top of the head and the end of the spine, using the distance between them to normalize and make the images comparable. A vertical guideline was added coaxial with the line that passes through where the spine is estimated to be, when possible and according to the posture to define the rest of dimensions. Finally, the rest of the key vertical levels were marked: chin, waist, hips and heels. These additional markings allowed a comparison between proportions of the beauty canons for each civilization as seen on Fig. 2.

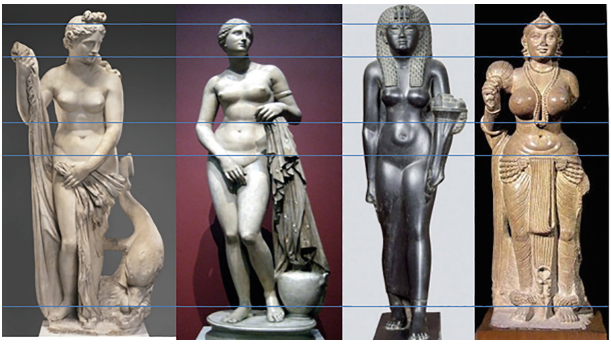


Fig. 2. Statues from five civilizations: Greece (Aphrodite, Getty Museum, USA), Rome (Aphrodite -Venus- of Knidos, National Roman Museum, Italy), Egypt (Cleopatra, Hermitage Museum - Saint Petersburg, Russia) and India (Didarganj Yakshi, Indian Government). Guidelines were added to mark heights of interest: top of the head, chin, waist, hips and Heels.

Next step after marking relevant height levels, was measuring distances defining body proportions. Bust level was included, and for the purpose of this study any spherical lens distortion was considered minimal, also, all distances considered linear. After measuring all distances of interest over letter-size printed versions of the photographs, values were recorded in millimeters for further processing. One of the limitations of the method is to estimate or extrapolate measurements that cannot be made directly due to the existence of 'obstacles' like the garment of the statue representation or a body part hiding key points of reference as seen on Fig. 3.

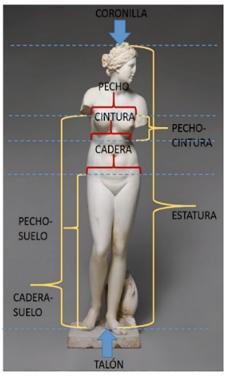


Fig. 3. Original training image handed to students to collect dimensional data. The five points of reference are marked with horizontal dashed lines (top of the head, bust, waist, hips and heels).

A second limitation for the method was handling images from diverse sources, with different printed resolutions and different qualities. To work with the best available printed image, each photograph was printed on a single sheet of paper and measurements done over it, therefore a scale standard was to be implemented. Used on

anthropometry, the height (or vertical dimension) of the figure from top of the head to the heels was selected as the dimensional standard.

4 Results

Even though there were limitations, the method allowed to obtain proportion parameters based on body type, and indirect anthropometry of body representations, from different eras and parts of the world. Those historical-based parameters were applied to a customizable algorithm and modeling result generated a large number of versions of the surface modeled. To support the parametric modeling process, measurements on paper must be translated into the unit system used by any digital modeling software, however, those parameters must be useful to the design process.

Measurement data from the five body points of reference (top of the head, bust, waist, hips and heels) of the bodies was processed and derived dimensions were calculated: total body height, distance between bust and waist, bust point height referenced to the heels, and hips height referenced to heels. Normalization and dimension-to-height ratios main advantage is that such data is independent of the measuring method, whether is millimeters on a piece of paper obtained with a ruler, or pixels on a digital image obtained with an image editing software.

Same normalization method was used to establish the ratios for standardized widths or horizontal extension measurements for bust, waist and hips. A sample of data based on the average of the eight sets of measurements for each civilization is shown in Table 1 below.

Table 1. Average height for each civilization and dimension-to-height ratios

	Width ratios				Height ratios			
	Height	Bust	Waist	Hips	Bust	Bust-Waist	Waist-Hips	Hips Height
Rome	168.1	0.189	0.173	0.223	0.754	0.132	0.250	0.508
Greece	172.4	0.169	0.174	0.221	0.750	0.128	0.250	0.497
India	169.0	0.175	0.132	0.233	0.743	0.129	0.257	0.487

After calculating averages for all four civilizations, dimension-to-height ratios were calculated, and this data were used in Rhinoceros 3D (by McNeel and Associates) and its generative design plugin Grasshopper (by McNeel and Associates). As a proof of concept, only height offsetting was modeled, although, contour scaling follows the same logic although that would require an expansion to the Grasshopper definition. To simplify the model a free-form curve resembling the contour of the waist was scaled and used for the bust and the hips contours as the main goal is to obtain a surface that might be used as the base of a corset cutting pattern.

This visual algorithmic definition has four parameters that can be changed: Height on a floating-point slider and three ratios that can be selected from a dropdown list. Not

only this allows to change in real time the proportions of the surface, but also, select in out of the different permutations a mix of the proportions from different civilizations, expanding the possibilities for design and clothing adaptation to historical shapes.

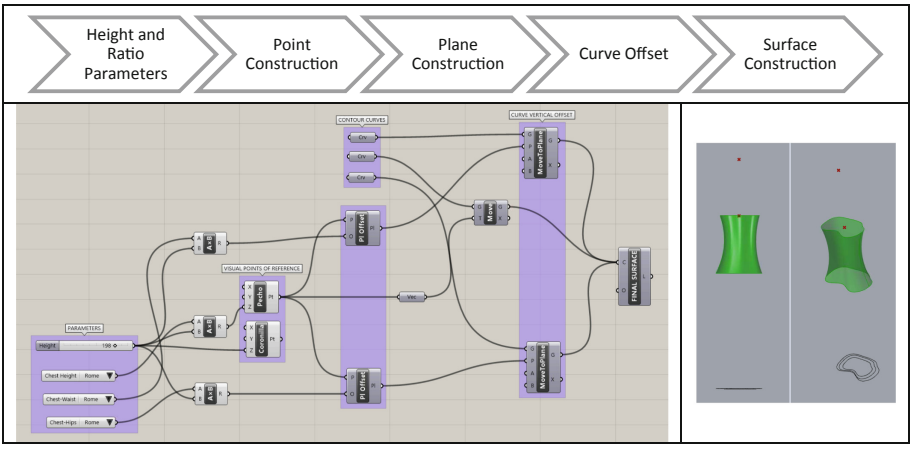


Fig. 4. Algorithmic process and Grasshopper definition

An interesting finding can be seen on Fig. 4 for a coaxial comparison of the three models. There are small variances between the Roman and the Greek beauty canons for the same height, although results suggest exact same waistline with slightly longer legs and upper back. Indian beauty canon for the same height suggests shorter legs, lower waistline and lower shoulders. Geo-historical interpretations of such difference may include religious reasons or deity shape emulation for India, to bone structure for Greece and Rome as seen on Fig. 5.

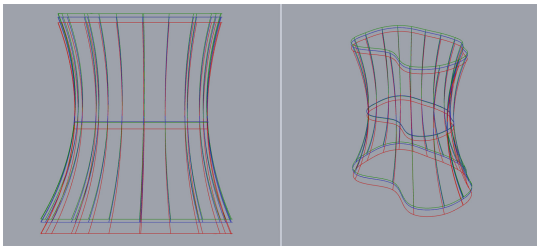


Fig. 5. Comparison of the surface obtained for three civilizations: India (red), Greece (blue) and Rome (green).

5 Conclusions

The use of parametric modeling brings technological opportunities for clothing and costume designers. With a subset of ancient civilizations and a small sample of images of body representations, cultural, genetic and religious aspects of sacred or divine proportions were included in parametric CAD models as a novel method. The results of this work can be expanded integrating other measurements of the body that can be normalized with a dimension-to-height ratio.

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Exploring Fashion Design Methods: Understanding Human Factors in New Society Contexts

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Abstract. In the last decades the progressive technological advances have been changing dramatically the way we experience life, shaping the relationships that we establish with what surrounds us in new unprecedented ways. By changing who we are and what we perceive to be, this phenomenon gradually created an individual that is self-aware and self-sustainable.

Technological advances change communication forever and the individual sees its existence split between two different worlds: the actual and the virtual. In this new era of existence new necessities arise from a body that finds new ways of experiencing its limitations (and enhancements).

In a time of growing individuality and with much more technological power at finger disposal, all users and especially new designers and design students, are allowed to play the "individuality game" even if dominated by rules of big corporations and globalized interests. It's a quest for self-identity and affirmation that we seek on the things we do, the things we buy and the people we connect, in order to make a statement on our person and nature.

Fashion design as a privileged means of communication is a great way for creativity and self-expression of the individual, playing and acknowledging his individual role.

This paper is part of a PhD research on the influence of the digital tools and digital environments in human creativity and concept development, in the specific case of fashion design products. With this paper we intend to comprehend how human beings have evolved culturally and socially so we can identify the most reliable paths to an efficient generative experience, regarding human factors and the users necessities and expectations. It's an attempt to map the actual human positioning on how we connect with each other and with the environment.

The digital environments induce a drastic change in the way research, concept development and project communication are made, changing forever the practice of design. The full understanding of the creative potential of digital languages is a real necessity to those who want to be prepared to the uncertain future of fashion design. Regarding this, the results of this study will help to understand how the fashion designer of the future will need to be, how he will act and how he will think.

Keywords: Fashion · Contemporaneity · Human factors · Society · Culture

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1 Introduction

Design is an ever-changing concept that seeks to respond and adapt to the new social and technical circumstances dictated by the contemporary world. It is a form of culture, of expression and can never be dissociated from the social context. As such, in an increasingly digital world, it will be normal to see design requiring different media and processes [1].

McLuhan and Fiore [2] in their book "The Medium is the Massage" speak about the deep sociocultural changes that contemporary society is suffering, reflecting on the way everything around us is reconfiguring, and how, the human being adaptively evolves. According to McLuhan [3] we are currently in a state of dormancy - which he calls the *Narcissus Narcosis* syndrome - that makes us to be unaware of the social and psychological effects that new technologies have on us. The human sensory balance is altered and the individual changes gradually without realizing it. Because of this unconscious evolution, the need to identify and reflect on the changes infused in the individual becomes urgent.

2 Modernity

The modernity, also called heavy modernity or early modernity, is a social phenomenon that starts in Europe from the XVII century, that changes the local social-cultural panorama and gradually the global landscape [4]. It's a phenomenon that changes radically the way the individual connects with the world.

This period, which Bauman calls "heavy modernity", was characterized with a great solidity in the strategies of growth carried out by countries and enterprises, that privileged a physical and territorial approach. Material assets were directly connected with the growth of financial capital so, the maintenance of work relationships emerges as an economical strategy [5].

In the Twentieth century, modernity becomes a global phenomenon characterized by the following dimensions and consequences:

2.1 Technological Advances

There is a generalized use of machines in the production processes and in war. This industrialization process leads to the emergence of production processes increasingly cheaper and more efficient. As a result, the human impact expands and most of the landscapes (urban or not) become controlled by man [5].

The industrialization and consequential technological advances of the world leads to an exponential acceleration and dynamism of society, resulting in:

The Split Between Time and Space

Human action ceases to be limited by space and information is able to travel freely and increasingly fast, between distant parts of the globe. The local and global realities overlap and the concept of "*globalization*" emerges. Social activity can now be established at a global scale, through big time-space distances [4, 5].

The Reflexive Appropriation of Knowledge
Traditional practices are gradually replaced by more effective ones, as the outcome of a review process whose focus is the knowledge that is constantly produced. This reflexive process of constant enhancement is also appropriated by individuals, generating a state of mental uncertainty that tends to lead to the construction of a trust system as a way to deal with instability [6, 7].

The Growth of Communication Technologies
First the printed text and then the electronic signal, lead society to an exponential growth in terms of the information available. This avalanche of information from all over the globe is gradually incorporated in the everyday consciousness, leading to the juxtaposition of stories and items that have nothing in common except being opportune. Narratives disappear and single elements are separated from their initial referents, turning into sterile signs. These signs go beyond the transmission of information, forming their own reality, disconnected from the actual world [4, 6].

2.2 Market

Capital and property is privatized. The commodification of the work force allows the individual to accumulate capital, boosting the competitiveness of the market. This phenomenon marks the emergence of capitalism as the new class system regulated by individual possessions.

The possession of things as a way of class distinctions is rooted in the exclusiveness of the objects. This exclusiveness is no longer strictly connected to materiality but also to the authenticity that comes from the gesture of who made it. Artistry becomes marketable [8].

2.3 Society

Administrative power is centralized in *nation-states*, in order to become more efficient, being able to mobilize larger amounts of economic and social resources than premodern institutions. The access to population data allows these nation-states to control and supervise population, directly or indirectly. Territorial and military power, allow them to control the multi-national companies that expand in economic and social power during this era [4].

2.4 The Individual

The division of work in the modern societies results in the emergence of people as individual entities, fully recognized and valued.

With the ability to make his own choices, the individual sees the future as full of possibilities and no indication on which path to take. This uncertainty exposes them to high levels of psychological insecurity. The individual is judged socially by his choices, and appearance becomes the central element of the construction of the identity of the self. Emergent questions of good taste label the produced goods and their users, positioning them accordingly to the capitalist class system.

Apart from individuality, another phenomenon that emerges in modernity is the emerge of the "lifestyle". More than the objects possessed, it is the practices that an individual embraces that give shape to a particular narrative of self-identity.

Lifestyle ceases to be adopted as a product of tradition or habit and starts to be embraced as a life's project where style is assumed to be synonymous of individuality. The adoption of a lifestyle is influenced by group pressures, by socioeconomic models and by circumstances. It is the lifestyle and not the physical items that are going to establish the class structure and the mechanisms of differentiation in society [4–7, 9].

3 After the Modernism

After the 1950's, the numerous crisis and wars give rise to a growing discredit in the universal and timeless principles of modernism. Particular visions gained a new importance and social regimes become anti-totalitarian. Democracy loses its idealistic grandiosity and accepts heterogeneous, marginal and quotidian discourses.

This period acquires several nomenclatures, depending on the specific focus of different authors. Jean-François Lyotard speaks of this era as a "post-modernity", as a way to mark the change from an industrial to a post-industrialization era. He acknowledges a change in society that goes beyond the values and practices of modernism. To Ulrich Beck, this period arises as a "second modernity" or "reflexive modernity", highlighting the way as society becomes aware of the processes carried out during the early modernity and start to think its conduct in a reflexive, rational way. The anti-totalitarian aspect of modernity leads to the concept of "alter-modernity" proposed by Nicolas Bourriaud. This view states that the same modern phenomena happens but, we have new, alternative views over them, deeply rooted in multiculturalism. To Zygmunt Bauman the uncertainty and instability of the end of the twentieth century gives place to the "liquid modernity" or "light modernity" where solidity of views and relationships become more fluid. Anthony Giddens takes a different stance, calling this era of "high modernity", "radicalized modernity" or "late modernity", since, according to the author, there was no break towards the paradigms of modernity but, instead, we see its consequences being greatly radicalized and globalized. Gilles Lipovetsky, takes a similar approach (with emphasis in the digitalization of society), stating that we now live in an highly radicalized and accelerated modernity called "hyper-modernity" [4, 5, 7–10].

None of these visions are antagonistic and, together, they are able to characterize this period of social history where modernist dimensions still apply, but with different, more amplified consequences:

3.1 Technological Advances

Modernism based its growing production of objects and signs in the thrust of infinite energy and in the projection of present into the future. But with the energy crisis that starts to be felt by the late twentieth century, a discredit in progress arises and ecological concerns emerge. The posture towards technology becomes reflexive, and

humanity starts to comprehend the consequences of the rapid technicalization of society.

Digitalization spreads through all the sectors of society, promoting deep socio-cultural changes that raise questions about man's dominion over technology. This highly digitalization of society causes a nostalgic search for physicality (real values and real people) [1, 4, 6, 8, 10].

The Transformation of Reality in Images and the Acceleration of Life

The gradual digitalization of the world since the 1980's leads to an exponential generation and transmission of images. This phenomena stimulate mechanisms of obsolescence where images are constantly consumed and replaced.

The concept of "*tabula rasa*" becomes impossible to conceive because every personal concept or creation is sustained by this chaos of products, media and comments experienced by the individual in his everyday life.

For Zygmunt Bauman, it's this acceleration of the daily life that differentiates "liquid modernity" from the early modernity of the twentieth century. Acceleration achieves its natural limit giving place to the instantaneity (of time and space) characteristic of our era. The surrounding ambient is constantly updated and reformulated, and what was "lasting" in our lives becomes "temporary". The concept of "possession" loses meaning because of the volatility of things and is substituted by the concept of the "access" to the experience.

Life becomes a never-ending race in which the individual tries to stay by all means. The precariousness that comes from this condition leads to everything being perceived as ephemeral and disposable after fulfilling its purpose. This principle encompasses not only objects but also other human beings that also become replaceable.

Progress ceases to be a collective goal and is now centered in the individual that is now responsible to his own upgrowth in life. The excessive amount of choices available generates anxiety in the individual who constantly questions themselves whether he has made the right choices. Therefore, he chooses to live of the immediate pleasure of the present because future is uncertain, and setting long-term goals seems a bad strategy. And since today's commitments can interfere with tomorrow's opportunities, the tendency is to keep commitments open, light and superficial.

If on the one hand this accountability leads the individual to isolate themselves and focus on his path (taking an exasperated stance towards everything that might obstruct his goals), on the other hand it leads to an unquestioned submission to social norms and institutions, in search for mental stability [4–6, 8, 11].

3.2 Market

At the end of the twentieth century, economy evolves towards a "light capitalism", characterized by the growth of technological innovation and by the disconnection from the physicality of the geographical place through a digitalization of the economy.

The economic system based on the manufacture of material goods shifts its focus to the commercialization of information and ideas.

The market is increasingly globalized and is ruled by the values of competition that create relentless policies of capitalist profitability. The automation of the functions of

regulation and reproduction, which are no longer made by human administrators, accelerates the production process and increases the accessibility of products [5, 8, 9].

According to Lipovetsky and Serroy,

> "Social relegation of large sections of the population grows, wages are degraded, old labour solidarities disappear and, trapped in the jungle of total capitalism, the individual is left to the uncertainty of the future, to a process of atomization that leaves they alone before himself and towards an unprotected existence, without class culture, without a collective framework, without a political project of world transformation." [10]

The Expansion of Production Capacity

The constant renewal of goods gives the consumer the illusion of complete substitutability of goods and unrestricted access to them. This illusion generates enormous pressures of obsolescence where the consumer gradually detaches himself emotionally from what he possesses, focusing on the immediate and superficial pleasure of consumption, rooted in novelty and not in affectivity.

Science becomes a tool of capitalism, making room for improvements in the performance of production and its products. Knowledge becomes commodified as a way of competitiveness in the world's capitalist scenery [7, 9].

Sign-Goods

The perception of the status or hierarchical position of the individual becomes a complex problem because of the existence of the constant renewal and increasing accessibility of products. Trends are brief, transitory and coexist simultaneously making the distinction process even more difficult to perform.

With this accelerated process of renovation, goods lose their real use value. Through advertising, mundane consumer goods turn into images (of romance, exoticism, achievement, etc.) becoming "sign-goods". The acquisition of things becomes primarily the consumption of signs and not only the purchase of material utilities.

Product rarity and uniqueness resurfaces as an effective way of breaking down the barrier of standardization and to transmit an aura of (marketable) individuality [7, 8].

The Emotional Pleasures of Consumption

Capitalism stimulates the celebration of individual dreams and desires in specific places of consumption. These constructed scenarios are designed to produce various types of physical excitement in the shape of an "aesthetic hallucination of the real" in which image and reality merge. Everything becomes performative, emotional and imaginary in order to constantly reactivate the desires of the consumer.

With the spread of these practices, everything gains a superficiality and instantaneity and the pleasure that comes from its consumption has to be immediate and intense. The "pure" taste of high-aesthetic, related to a cognitive and controlled appreciation is replaced by a "fast-aesthetic" controlled by immediate, direct, emotional and physical pleasure, widespread in and by the masses. Pleasure becomes the purpose of all human action itself [7].

3.3 Society

There is a constant affirmation of singularity, in a world where the right to be different has become a fundamental value. This concept overcomes pre-existing models and stereotypes, giving space to a multiplicity of new lifestyles.

Society moves beyond the concept of the universal (characteristic of the modernism) to embrace the idea of a fluid plurality built by systems (cultural groups, subgroups or single individuals) with relationships between them [9, 10].

The Plural Globalization

In contemporary society, cultural diversity is identified as a patrimony to be preserved, in response to the standardization of imaginations felt during modernism. The process of globalization becomes plural and starts to support several images of what the world is (or should be).

Global culture tends to follow in the opposite direction of homogeneity and of a common culture. In this plural cultural scenery, no discourse assumes itself as "\the true" or "the dominant one" and conflicting trends coexist in harmony.

Globalizing pressures strengthens social feelings of regional cultural identity and local empowerment. This fact results in the recognition of local, regional and subcultural differences, by the *nation-states,* through the process of decentralization.

Society begins to see narrative knowledge (originating from popular cultures) in a more dignified way, accepting it as a method of legitimation in the form of social consensus [4, 7–9].

The Abolition of the Border Between Art and Everyday Life

Art ceases to be seen as a superior form of experience, derived from the creative genius or special qualities of the artist. Artistic and intellectual goods become capitalizable, becoming popular and accessible to larger audiences. Art migrates to industrial design, advertising and the industries associated with the production of symbols and images. This migration makes the separation between "art" and "non-art" doubtful, so that any object of everyday use can be aesthetized.

The mass-produced culture that results from this democratization of art ends up being reduced to the lowest common denominator so it is accessible to a greater public, in the form of extremely limited discourses. Eclecticism and the mixing of codes in the form of parody, pastiche, irony, amusement and the celebration of the "lack of depth" are favored. The volatility of public memory leads to the emergence of "new" information and "new" elements that in fact are recycled or plagiarized from pre-existing ones [7, 12].

3.4 The Individual

A focus on the individual arises after modernism. According to Lipovetsky and Serroy, this new individualism, also known as the "second individualist revolution," is characterized by some fundamental traits: "body worship, psychological and relational worship, consumerist-hedonistic worship and autonomy worship (as a consequence of the disappearance of faith in the great historicist ideologies: Nation, Revolution, Progress)" [10]. Constant concerns with self-development develops in the individual a

growing narcissistic, hedonistic and egocentric posture. Compared to early modernity individualism, the contemporary approach is less frivolous, less playful and more reflexive.

The rediscovery of physicality emerges as a counterbalance to a dematerialized and disembodied culture. Contemporary life is divided between these two realities, equally important to the individual. New opportunities for social relations arise through new contexts (such as the internet), which prevents the modern world to become highly impersonal. We do not live in a "world of strangers," we have just changed the ways we relate [4].

Aestheticization of Everyday Life

We tend to see other people's lives as a work of art and thus aestheticize our own lives. To the practice of aestheticization Bauman calls "identity" [5]. We tend to have the illusion of confidence and solidity of these "identities," believing that they are constant in time, covered by the cloak of authenticity. Only with the use of fantasy mechanisms (dreamlike strategies that consumer brands have learned to capitalize) can these "identities" be cohesive. These "identities" are now purchased on commercial surfaces in the form of mass objects that point the way to a costumed self. This is a "false self" that becomes an object manipulated by the "true self". This dissociation generates an anxiety that leads the individual to question his true authenticity and existence, and to increasingly confuse the two types of "self".

Another form of fantasy arises through the proliferation of the image, with special focus on the screens that have spread throughout society. The fantasy presented through images sets standards for the reality world that is now expected to be more intense and pleasurable. The image becomes the only possible reality and our bodies accompany this mentally constructed ideal. But this surrender to image supremacy is not without its consequences. After experiencing the overwhelming intensity of images, the bigger is the sense of poverty felt towards reality and, the more we feel disappointed with our daily lives.

According to Bourriaud, the contemporary individual becomes a "radicant," an entity that only through constant movement manages to form an identity [8]. These "radicants" refuse to settle in a certain space, time or aesthetics and borrow elements, quotes and proximities to construct their identity. If during modernism the individual is transformed into an industrial machine, contemporaneity aims to equate the individual with the dominant technology: the computer and its reticulated networks. The individual becomes a network, establishing several bidirectional connections (influencing and being influenced), both in the personal and professional spheres [5, 6, 8].

4 Conclusions

The contemporary individual carries within themselves the result of more than a century of intense technological advances and deep social-cultural changes. The concepts introduced by modernism evolved over the past decades in an exponential way, resulting in an amplified version of its social impact, as identified by the multiple authors (previously identified in this paper) through their particular perspectives.

At the center of these social changes, like McLuhan [3] notes, is the individual that reflexively evolves and adapts to this new environment.

The levels of stress, chaos and uncertainty of the social environment are absorbed by human beings that incorporate them and generate internal mechanisms of defence. As a result, identities are no longer stable and the individual defines himself through a constant movement that can only capture loose fragments of reality. It's with these fragments of hollow cultural signs that they construct their fragile identities.

The obsolescence introduced by capitalism becomes the normality and the concept of ephemerality is accepted in life. Nothing is stable or lasting so options are kept open and commitments are avoided. Everything is perceived as disposable so the individual lacks connectivity with things in their life.

Even identity is an open concept and individuals change them at ease, in order to reflect their present mood and context. The boundaries between the "outer identities" and the inner selves are blurred and authenticity gradually fades away. Individuals become the images of a self-created world. These images are signs with no reference, just like all the images proliferating in the world. These hollow images create alternative, pleasurable realities, easier to control, and where the individual can escape from the cruelty of actual reality.

In an unstable, unreliable world, the only concern of the individual is with themselves because everything else can fail or collapse. Everything else becomes irrelevant, even their action as citizens. This egocentric approach is intentional, reflexive and acts as a protection towards the adversities of facing the world at their own risk.

This focus on the self leads the individual to pursue immediate pleasure in the form of easy consumable objects, relationships or situations. As a result, everything in life becomes measured by the pleasure it provides. Novelty is the drive of this pleasure, which, in the contemporary social world, can only be obtained by a constant movement and self-reinvention. Like Lewis Carrol said:

> "it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!"

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Impact of a New Designed Automation Process in Textile Natural Fibers and Yarns Dying

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Abstract. The fierce competition in the textile sector, especially due to the producers in Turkey, China, India, etc., implies the development of new competitiveness strategies based on cost reduction in the dying process at the same time as ensuring the quality of the products to the required standards.

The solution developed by a team of researchers within the National Research and Development Institute for Textiles and Leather and successfully implemented in the economic environment consists in the design and realization of an electronic and automation system that ensures the process of textile fiber dyeing under conditions efficiency and increased productivity that responds to the technical and quality performance requirements imposed on end-user products and by consumers.

The proposed technological solution is based principally on generating the turbulence stream of the solution in the dyeing bath by driving the main pump motor and maintaining the flow rate in the dye vessel constantly by actuating the float pump motor.

Using the theories of fluid mechanics, optimization of the recirculation pump speed regime in under pressure textile fiber dyeing processes has demonstrated that the implementation of the technological solution leads to a turbulent regime that ensures the uniformity of the solution in the dying bath, while reducing energy consumption and energy costs, increased productivity through better process control, increased equipment lifespan, and decreased maintenance time.

Keywords: On-line management · Natural fibers · Fluid mechanics

1 Introduction

In the context of continued concern for maintaining high quality standards, attention is paid to the textile fiber and yarns dyeing process, which is one of the most important phases of the technological process and which, unfortunately, is currently being achieved with high consumption of materials and utilities.

The technical and economic efficiency of the textile yarn dyeing process is conditioned by ensuring the proper homogeneity of the dying bath (by generating turbulent motion) while maintaining a constant flow rate in the dying vessel [1].

The improvement of the natural fiber and yarns dyeing parameters is based on the intrinsic connection between the process controller, speed variator and pump-adding system.

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2 Materials and Methods

The novelty in this dying process is to maintain the bath flow at constant pressure and variable temperature depending on the dying diagram.

Based on the information received from the temperature and pressure sensors, the process controller controls the pumping system by means of the speed variators, so that the dying diagram to ensure a constant pressure throughout the technological process.

The electrical signals from the sensors that monitored the functional blocks are transmitted to an automation module that signals the occurring events [2].

At constant pressure in the dyeing vessel, it is ensured a uniform color absorption in the bath, having as result a uniform dyeing process of the material (Fig. 1).

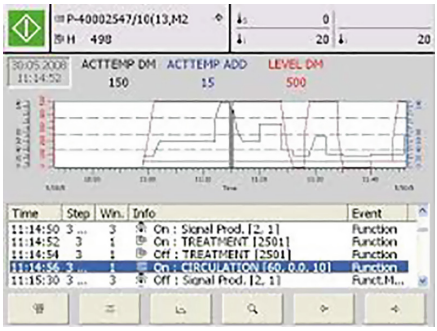


Fig. 1. Management of the dying diagrame through the process controller

The control of functional parameters is based on a sensor system that monitors temperature, pressure, flow as well as the proper functioning of the other functional modules.

Information from these sensors is transmitted to the process controller.

The flow and quantity of the bath are monitored via an analog output flow sensor so that the ratio between the amount of dye and afferent bath being according to the recipe (dying diagram).

Using the theories of fluid mechanics, for the optimization of the recirculation pump speed regime in textile fiber pressure dyeing processes, it has been demonstrated that the implementation of the technological solution leads to a turbulent regime that ensures the uniformity of the solution in the dying bath, while reducing energy consumption and energy costs, increasing the productivity through better process control, increasing the equipment runtime and decreasing the maintenance duration (Fig. 2).

The phenomenon analyzed using the hydrodynamics equations revealed the tendency of the response of the random variables to the turbulent movement (mean and turbulent fluctuation) [3].

To predict the phenomenon, a specialized software was used, starting from the following hypotheses:



Fig. 2. Automation of the dying equipment

$\ddot{Y}$ – predicted value of the variable: power of the pump of addition;
X_1 – independent variable: diameter;
X_2 – independent variable: fluid density;
X_3 – independent variable: pumping height;
X_4 – independent variable: fluid pressure;
X_5 – independent variable: fluid viscosity.

Using a dedicated software, the coefficient values of the regression equation were determined as follows:

$$\ddot{Y} = A_0 + A_1X_1 + A_2X_2 + A_3X_3 + A_4X_4 + A_5X_5 \quad (1)$$

The distribution form was verified through non-parametric Kolmogorov-Smirnov test (initialized sequential commands).

The values of the Kolmogorov - Smirnov test demonstrate that the data complies with the normality criterion for the population of which they belong [4].

From the analysis of the values (Table 1) it follows:

(i) for a significance threshold p = 0.05 - the values obtained show that there is a relationship between the studied variables, namely "fluid pressure" and "diameter of the feeding device" - Pearson Correlation: −0.762; "Pumping height" and "fluid density" - Pearson Correlation: −0.684; "Pearson Correlation: 0.712"; "Pump power" and "fluid flow" - Pearson Correlation: −0.635;
(ii) for a significance threshold p = 0.01 - there is a relationship between the studied variables, namely: "feed device diameter" and "fluid density" - Pearson Correlation: −0.837; "Fluid density" and "fluid pressure" - Pearson Correlation: 0.848; "Pump power" and "fluid density" - Pearson Correlation: 0.834

Table 1. Experimental values

Nr. crt.	d feed device	h pumping height	P fluid pressure	ρ fluid density	P power of the add. pump
1	60,00	4,70	,140	,1000	1,8542
2	55,00	4,20	,150	,0800	1,8697
3	55,00	4,58	,158	,0790	1,8622
4	50,00	4,56	,159	,0780	1,8797
5	50,00	4,55	,150	,0790	1,8799
6	60,00	4,68	,140	,1000	1,8509
7	45,00	4,33	,160	,0700	1,8834
8	45,00	4,38	,161	,0710	1,8833
9	50,00	4,55	,148	,0782	1,8388
10	60,00	4,66	,150	,0900	1,8552
Total	10	10	10	10	10

(iii) for the "fluid pressure" and "feed device diameter", "pumping height" and "fluid density" variables, "additional pomp power" and "fluid flow", the correlation sign is negative, 95% can be said that the link between variables is inversely proportional

(iv) for the "feed device diameter" and "fluid density" variables the correlation sign is negative, so with 99% probability it can be stated that the link between the variables is inversely proportional

(v) for the variables "power pump additive power" and "fluid pressure" the positive sign for correlation was obtained, so with a probability of 95% it can be stated that the link between the variables is directly proportional.

(vi) For the "fluid density" and "fluid pressure" variables, respectively "additional pump power" and "fluid density", the positive sign for correlation was obtained, thus, with 99% probability, is directly proportional.

(vii) The absolute magnitude of the coefficient (which describes the strength of the link between the variables) shows that there is a strong link between all the variables subjected to the correlation analysis ($r > 0.50$).

3 Results and Discussion

The regression equation is: Power of the addition pump = 1.86 − .002 * Diameter + .001 * Pumping height –247 * Pressure − .049 * Flow rate

This highlights the followings:

- The value of the multi-patch correlation coefficient R^2 reveals that 97.0% of the variance of the dependent (predicted) variable power additive pump is explained by the model, the prediction power being 93.1%;
- The standard error of the predicted dependent variable (addition pump power) demonstrates that the standard power output deviation is 0.041 kW, if the value of the independent variables in the model is known: the feed device diameter, the pumping height, the fluid pressure and its flow.

- The value of 0.970 demonstrates that R^2 does not change when variables are added to the model.
- The variant analysis highlights, with a probability of error of 5%, that the model significantly explains the variance of the dependent variable. The values of the F mark demonstrate that the variance explained by the model is significantly higher than the residual, so the created model is effective in prediction.

The differences between the predicted value of the model and those determined experimentally are: for experiment I: with .002 kW higher, for experiment II: with .002 kW lower and for experiment III: with .003 kW higher but all values are falls within the standard deviation of the .0413 kW dependent variable.

4 Conclusions

The proposed technological solution is based principally on the generation of unsteady vortices (vortex stretching) of the bath into the dye vessel by driving the main pump motor and maintaining the constant value of the pressure in the dyeing bath by driving the addition pump motor that assure the circulation of the bath.

Using the theories of fluid mechanics, for the optimization of the recirculation pump speed regime in textile fiber pressure dyeing processes, it has been demonstrated that the implementation of the technological solution leads to a turbulent regime that ensures the uniformity of the solution in the dying bath, while reducing energy consumption and energy costs, increasing the productivity through better process control, increasing the equipment runtime and decreasing the maintenance duration.

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Lean Manufacturing Model for the Reduction of Production Times and Reduction of the Returns of Defective Items in Textile Industry

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Abstract. Textile garment industries must be readily aware of the system's current situation, respond quickly to changes in style to process orders on time, and manage an appropriate method of work to avoid production delays. In addition, the textile sector plays an important role because it presents a significant weight in the world economy. Likewise, this sector is considered influential when defining an international business agreement. Therefore, adequate management is required in the sector. Otherwise, it will generate a competitive disadvantage because the Peruvian industry is approaching an export recession. This paper proposes using the lean manufacturing methodology to reduce production times. The project is validated through a simulation of the current and proposed processes with the application of lean thinking tools to reduce waste (manufacturing process times).

Keywords: Lean manufacturing · Textile · Production time · Kanban · 5S

1 Introduction

Currently, the textile sector reports production delays due to inefficient and lengthy manufacturing processes. According to Grimaldo, Silva, and Molina [1], in a textile company, manufacturing process times delay production since different parts of the product are assembled in this activity.

According to Güner and Ünal [2], "Garment industries, especially those which rely on small batches and orders, must respond quickly to changes in style. It is essential to be aware of the current situation of a system to process orders on time." Therefore, the critical issue is the high times in the manufacturing area, as they evidence a slow and inefficient delivery service. Likewise, exports have decreased by 16.5%, from 2015 to

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2016, for the Peruvian textile market. This decrease is due to the preference of foreign buyers for Central American products.

The environment of the research project is manufacturing and its sector is textiles. According to the National Peruvian Institute of Statistics, the manufacturing environment represents 13.30% of all economic activities, and in recent years, its gross domestic product has been decreasing, since there is a percentage variation of −0.6%, for 2015 and 2016. Then, in light of these problems affecting textile companies, new techniques that may help reduce high manufacturing times are required. For this reason, the diagnostics VSM tool was used to identify waste in each production process. Likewise, the Kanban and 5S techniques were used, obtaining a favorable impact on the returns of defective products and penalties for late deliveries, generating higher revenue and increased sales for companies. In addition, the Deming Cycle will be applied to secure continuous implementation and future improvements.

2 State of the Art

2.1 Lean Thinking

According to Kovács [3], the contribution of lean thinking is that it helps improve productivity and quality to achieve long-term success to maximize the competitive advantage in the organization. The following results were obtained in different case studies:

For offset printing, cycle times were improved, obtaining 65% of added value. This translates in less inventory and waste [3].

In a chemotherapy health process, average patient waiting times were reduced by 42% [4].

In a manufacturing company, the application of the methodology helped to reduce polishing process times to 4.15 s. Likewise, the activities without added value and cost of overtime hours were reduced by 66.53% and USD $1,764, respectively [5].

The problem of the manufacturing company is that operators take a long time to find information. The main results were the reduction of lead time by 78%, the cycle time by 3.3%, and in-process inventories by 77% [6].

In a health company, the lean manufacturing methodology was used to increase admissions and consultations by 33% and 23%, respectively [7].

In conclusion, according to the aforementioned studies, the implementation of lean thinking is significant for all types of companies, since it focuses on reducing or eliminating factors that do not add value to processes; the latter is executed with the ultimate objective of achieving an efficient productive chain.

2.2 Lean Manufacturing Philosophies

According to Sundar and Kumar [8], using lean manufacturing philosophies may contribute in the improvement of several types of companies. To illustrate this point further, the results obtained in different case studies are mentioned below.

For example, in one case, lean manufacturing was used to reduce workspace by 22.3% and average times by 61.5%. Likewise, in another case, workspace was reduced by 53% and profits of USD $21,350 were obtained [9, 10].

A manufacturing company managed to reduce in-process inventory levels by 71.43% through the Kanban tool. In addition, this company increased its daily production to 105 products [11].

In a textile company, through the application of total productive maintenance, machine downtime was reduced by 25%, increasing machine performance (OEE) by 15% [12].

In a company, by means of the Standard Work tool, cycle times and configuration times were reduced to 350 s and 1,500 s, respectively [13].

In a production process, through the SMED tool, all activities that do not add value were eliminated, reducing average changeover times by 61.29% [14]. In a metallurgical company, the Kaizen technique reduced in-process inventories by 77% and generated savings of USD $37,600 [15].

In conclusion, according to the aforementioned studies, the implementation of lean manufacturing philosophies helps reduce unwanted activities in the production process. In addition, they seek to reduce internal activities within the company.

2.3 Time Studies

According to Jaramillo [16], time studies are an important technique for measuring work. The results obtained in the different case studies are described below.

In a flat weaving plant in Mexico, manufacturing times were reduced by 5%, with an average time of 233.50 min [1].

In a manufacturing company, idle times in the preparation process were reduced by 85%, with an average time of 3981.50 min. In this way, the company was able to save $1,983,682.84 per month [17].

In another example, in a company that produces printed shirts, production bottlenecks were reduced to 21.29 min. In addition, the standard shirt production was reduced to 74.68 min, which equals 1.24 h per unit produced [18].

In a sewing production line, it was observed that productivity increases significantly if order preparation time is reduced. Here cycle times and lead times were reduced by 3.3% and 78%, respectively [19].

In another company, an average reduction of 136 s in production times was reported. In addition, at the end of the day, the company was able to produce 455 more sweatshirts [20].

In conclusion, from the set of time study articles reviewed, reducing production times is a critical factor for the garment assembly (manufacturing) process, since it allows companies to correct errors and assess the cost of bottlenecks.

2.4 Simulation

According to Segovia and Pozo [21], simulations help visualize the possible behavior of the solution to be implemented. Below are the results obtained in different case studies.

In a service company, a Bizagi simulation was used to reflect the average production times, obtaining 30 days for the current scenario, against a proposed ideal time of 12 days [2].

In a manufacturing company, its current diagnosis with respect to production is 432 units per week and the proposed solution scenario, using the Arena simulation tool, is 480 units per week, thus improving productivity by 11.1% [22].

In conclusion, from the set of simulation-related articles reviewed, it is clear that Bizagi is oriented to business processes and Arena to manufacturing processes. In addition, Arena seems to generate results that are more accurate.

3 Collaborations

3.1 Rationale

Once the information and the selected articles were reviewed, five models were selected. Each set had different dimensions, with each one directly contributing to the objectives set forth (Table 1).

Table 1. Comparison matrix

Models	Dimensions				
	Labor	Machine	Method	Communication & planning	Environment
Paper 1: Zakarial and Nik Mohamed et al. [6]		x	x		
Paper 2: Cheng and Cheng [19]			x		x
Paper 3: Randhawa and Ahuja [9]	x	x			
Paper 4: Millstein and Martinich [11]	x	x			
Paper 5: Nallusamy and Saravanan [13]					
Proposal	**x**	**x**	**x**	**x**	**x**

Through the comparative analysis, it is evident that each selected model shows a different approach, depending on the type and sector of the organization under study. This evidences how valuable our proposal is, since the background information greatly contributes to validate our model. This model consists of integrating the Kanban and 5S techniques to find an adequate level of work for operators and maintain efficiencies when performing tasks in the organization. Likewise, this model is applicable to SMEs, and at the same time, it is attractive for future research with broader analysis due to its simplicity and flexibility for the simulation of management models.

3.2 General Model

Based on the research study, opportunities for improvement have been identified. The general production model (Fig. 1) seeks to integrate the dimensions from the comparison matrix. Furthermore, the Deming Cycle will be used to integrate dimensions, thus guaranteeing constant improvement after applying the different lean manufacturing methodology tools.

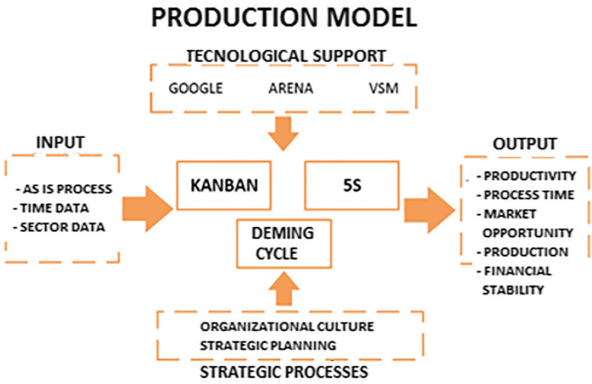


Fig. 1. General proposal model

This proposal then integrates lean manufacturing techniques (i.e., 5S, Kanban) to provide an adequate flow of information, planning, work method, and reduce production times. In addition, this model involves the Deming Cycle to secure proper production model operations through the continuous improvement of its processes. Therefore, the contribution of the Deming Cycle to the proposal is unique and will have a great impact for the project.

3.3 5S Technique

For the 5S technique, several steps were performed. Below, a detailed description of each step has been provided (Fig. 2).

– Step 1: A training schedule for the 5S technique was developed, which focuses on educating the operators on the benefits of applying the tool and providing success stories that support the information. Next, the 5S training schedule is presented.

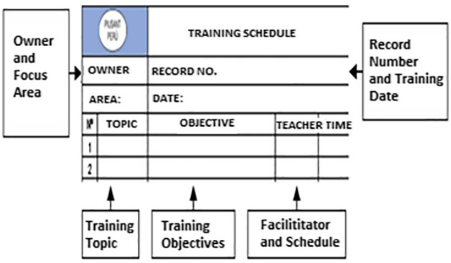


Fig. 2. Training schedule - 5S

– Step 2: This step represents the first stage—classification. In this stage, anything that is not needed should be discarded, and only the required tools should remain in the work area. For these purposes, the following guidelines are followed:
  - *Recognize the area:* Its objective is to identify the area and the number of tools required in terms of their corresponding usefulness.
  - *Identify unnecessary objects:* It lists all process elements to identify any unnecessary items. For these purposes, the red card shown in Fig. 3 is used.

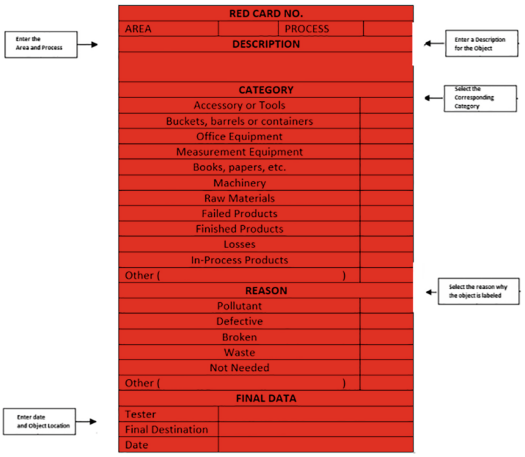


Fig. 3. Red card

  - *List of selected objects:* Once the red cards are made, the list of objects deemed unnecessary for the production process is prepared.
  - *Evaluate the selected objects:* Finally, a diagram is developed for the selected objects, where objects that are still useful for production are separated and sorted for future use. Unnecessary objects are also separated for evaluation.
– Step 3: This step represents the second stage—order. Here, the purpose is to facilitate work for the operators. In this stage, all objects and tools must be in order and in the appropriate position. For this, the following steps must be followed:

- *Tools and quantity to be used:* If production tools are located in strategic places, they can be found and returned quickly. For this reason, keeping a daily tool usage control record is recommended, using tool inventory forms.
- *Specify work area*: It seeks to identify the most important areas within the process. For these purposes, work area forms will be used to describe area specifications and tools required.

– Step 4: Represents the third stage—cleaning—that strives to keep equipment, tools, and work areas clean and tidy. For this, the following steps must be followed:
  - *Determine cleaning responsibilities:* The company under study uses a cleaning service; however, it does not have a specific daily cleaning schedule. Therefore, a cleaning schedule is proposed. See Fig. 4.

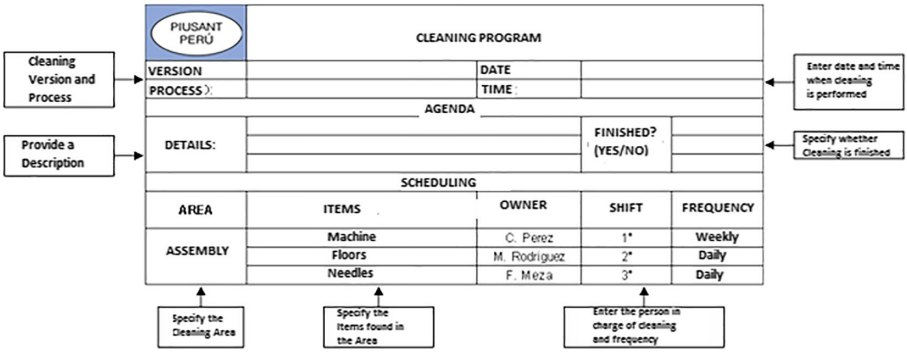


Fig. 4. Cleaning schedule

  - *Record schedule compliance:* A form is developed to guarantee compliance with the proposed cleaning schedule. This form is similar to the previous form, with the addition of one box, where the status on which the area is found before cleaning is recorded.
  - *Evaluate work area:* Finally, work areas were evaluated to identify whether materials may be donated, sold, or transferred. If they can still be used, they are returned to the corresponding area.

– Step 5: The work area is standardized. This process aims at normalizing and maintaining order and cleanliness in work areas through visual controls. In addition, it guarantees compliance with the first 3S. For this reason, this step is also assigned to the same person in charge of enforcing compliance with cleaning schedules and other instructions.
– Step 6: The last step of 5S implementation is discipline. This stage comprises motivating operators. For this reason, management should implement incentives within the organization.

3.4 Kanban

Once the implementation of the 5S technique has started, the Kanban technique will also be implemented. The implementation steps for this technique are:

- *Operator training:* First, training must be provided to operators to disseminate the changes that will be implemented in their work methodologies.
  According to Leonard and Sereno [23], this training should focus on the importance of the Kanban technique for operators and thus foster their commitment of improving the company. Next, Fig. 5 shows the training schedule for the Kanban technique.

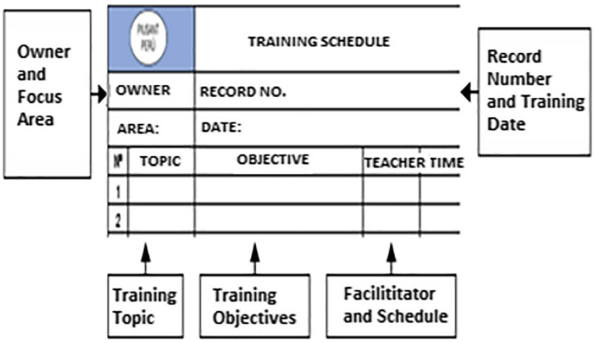


Fig. 5. Kanban training schedule

- *Develop the card:* The second Kanban implementation step is to develop the card, which will prevent workers from making production mistakes. This card promotes better understanding and greater organization, and for this reason, it includes a section for instructions from customers. Next, the Kanban cards are presented (Fig. 6).

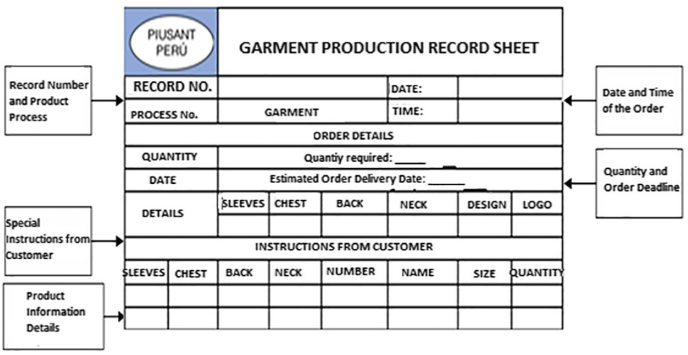


Fig. 6. Improved record sheet

- *Kanban system review:* The last implementation step is review. This stage consists of monitoring the implementation of the technique to see what can be improved and to adopt new prevention measures.

3.5 Deming Cycle

The contribution of this project will be the interaction of lean manufacturing techniques with the application of the Deming Cycle. This Cycle comprises four stages.

– *PLAN:* Determines the objectives and processes necessary to reduce production times. Here the development of Kanban and 5S techniques is described in detail.
– *DO:* Implements the processes proposed in the previous item. Each step and the proposed flows are applied for an adequate management of the techniques.
– *CHECK:* Reviews processes, policies, or objectives, provides information on the results achieved, provides focus, and identifies possible improvements to the process.
– *ACT:* Uses methods to improve the processes conducted, for example, the continuous application of the Kanban and 5S techniques in the company's processes.

The proposal includes linking the techniques to a complete Deming Cycle. This way, implementation may be continuous and may be repeatedly improved (Fig. 7).

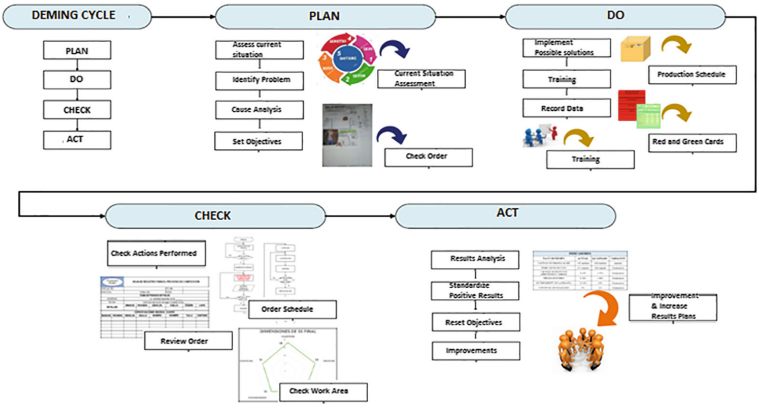


Fig. 7. Proposed model details

3.6 Implementation Process

One of the problems that generate the greatest economic impact for companies in the textile industry is returns due to product defects. The causes for this problem are different for each company, since each company uses a different management style and different processes. For this reason, the following flow is proposed. This flow allows for a complete analysis of the company, from the collection of information to solution simulation. Likewise, follow up and control will be performed with the help of the Deming Cycle (Fig. 8).

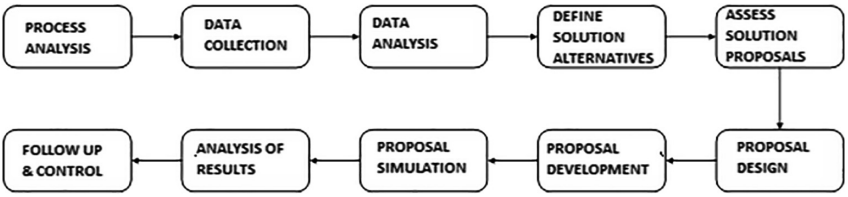


Fig. 8. Model implementation phases

3.7 General Indicators

Primarily, organizations need to improve three indicators: return of defective products, high manufacturing times, and penalties. These indicators are characterized as they hinder companies from meeting their organizational objectives.

- Demand: It has to be fulfilled by the established deadline. Hours are used to complete tasks that were not performed in the established period.
- Percentage of defective and late products: Percentage of defective products and products delivered late due to process inefficiencies per month.
- Percentage of income losses: Reduce income losses per month.

4 Validation

4.1 Case Study—Simulation

The case of a textile company is presented. This company markets and manufactures various sports garments, such as polo shirts, shorts, Bermuda shorts, and gloves. Their most popular product is polo shirts, representing 91% of their sales, which is the reason why we focused on their flagship product and its main problems.

4.2 Current Assessment

Through all the assessments performed, it was determined that the main problem afflicting the organization is shirt production times, most notably in the manufacturing process, since manufacturing times exceed the Takt Time.

MANUFACTURING = 487 sec. > TAKT TIME = 320 sec.

In the current scenario, 58 polo shirts are produced per day.

4.3 Proposed Model Application

After the proposed scenario was implemented, daily production increased to 81 polo shirts, that is, polo shirt production increased by 40% (Fig. 9).

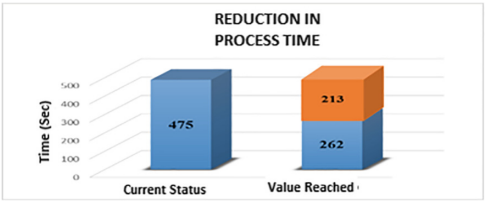


Fig. 9. Decrease of manufacturing time

4.4 Results

The results from the proposed model are as follows (Table 2):

Table 2. Current and achieved indicators

Indicators			
Factor/time	Actual	Reached	Reached
Production per month	1392 units/mo	1968 units/mo	Increased
Production time	671 sec/unit	380 sec/unit	Decreased
Defective/late products	8.14%	2.75%	Decreased
Income losses	6.32%	1.96%	Decreased
Non-fulfilled orders	35.5%	10%	Decreased
Percentage of penalties	9%	2%	Decreased

5 Conclusions

- In the case study, the integration of the Deming Cycle, 5S, and Kanban techniques increased the company's income by 84%.
- By integrating the Deming Cycle, 5S, and Kanban techniques, the proposed model may be adapted for any other company area or even another company.
- Polo shirt production was increased by 41%.
- The number of defective products and non-fulfilled orders was reduced by 25% and 26%, respectively.
- In addition, polo shirt production times and penalties were reduced by 77% and 35%, respectively.

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Ancient Handcraft Improved by New Material

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Abstract. The bobbin lace is considered an ancient handcraft. It already exists for more than 500 years as we can see it at the city of Peniche in the country of Portugal. Of course, it hasn't a linear story to write about the bobbin lace. It was weave as the same manner, using the same technique over the years, and the same material was been used, the cotton wire.

Following the new tendency of the world and using the skill that the technology brings to us, we are improving this ancient technique. With an interventionist methodology we introduce a new material. Replacing the cotton thread, we proposed to weave with the ceramic wire. Maintaining the same technique of weaving we got different results what bring to us the conception of new other objects.

Keywords: Design · Bobbin lace · New materials · Innovation

1 Introduction

In this paper we focus on an important handcraft, the bobbin lace, that we can see normally in the seaside. In Portugal we have an important focus localized in the little peninsula named Peniche, located in the Midwest of the country. The bobbin lace is considered a part of culture and identity for the people who live there. They refer to it like an ex-libris from the city.

Even tough, we found it in a difficult situation. Less people searching it, lack of demand is nowadays the status of this handcraft. The same way of weaving it and using the same materials that they used a hundred years ago can bring this result.

Worried about it we think to propose change the materials that the lace makers use to employ. That can open new possibilities of products.

2 The Bobbin Laces

The technique of bobbin lace holds up long time. It's necessary having specifically materials for practice it. Because of this it's so called. For to do this are been used both hands that moving at the same time for twisting the wire [1]. It's indispensable use a cylindrical cushion that stay over a stool, we need also the pike, the thread, the pins and the bobbin that is the instrument that gives name to the technique. The numbers of bobbins depend of the type of the lace that we want to do. The bobbins support the

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thread and always work in pairs [2]. The thread used it's normally one hundred cotton in the white color [3]. "Bobbins are made of bone, wood or plastic; some are highly decorated, others are plain and inexpensive. It is essential that the slim North Bucks bobbins are weighted with rings of beads" [4] (Fig. 1).



Fig. 1. Producing the traditional bobbin lace. Photograph taken on 13 April 2017. Source: Isabel Bieger

"A piece of lace is an artistic composition expressed in twisted thread, just as a piece of wood-carving is the expression of the artist's idea in chiseled wood. Lace is not, like embroidery, an ornamental fabric; it is itself ornament. It is not the application of art to a craft; the whole pattern is the fabric, and the fabric is the pattern. It is this peculiarity that distinguishes lace from needlework and woven work" [5].

The bobbin lace survived through many years, we believe it's because her exceptional characteristics. Many women do it because believe in a tradition handcraft like a true cultural heritage, for increase the family yield or do it like a hobby. Women who produced bobbin lace, the lace makers, were usually the wives of fishermen. To be a lace maker reveals itself in the way of life of the women of the fishermen. These women developed the activity very early. Some before they went to traditional school already knew how to produce the bobbin lace. Activity that demarcates the natural life flow of many Peniche's women [2].

The lace makers of Peniche, mostly had the first contacts with the bobbin lace in their childhood, normally through family. Many of them learned from their mother, from someone they were producing, or from relatives. Others have had the opportunity to learn at schools, such as the Industrial school for example, and learn the bobbin lace in a professional way. In Peniche the bobbin lace, in the early 1900s, was considered the second largest industry in the city [6].

The traditional yarns used in the confection of bobbin lace are cotton, linen and silk. The most important feature is that the yarns used have low elasticity. Preferably thin thickness and in colors of white or beige. For to achieve the mastery of the technique they suggest using the cotton yarn.

The entire fabric process of bobbin lace is made manually "… a craft object must be made substantially by hand, utilizing the hand itself, hand tools, and to some degree, power tools" [7]. The lace makers and the learnings are taking care for maintaining the bobbin lace as a real handcraft. And so, they are producing it with the same ancestral technique.

3 Changing Stereotips Through Design

The handcraft must follow the trends of the world and for not to be forgotten. Especially such an ancient craft. The author Ethel Leon [8] warns of the neglect of artisanal culture. Craftsmanship is not just an archaic knowledge "devoid of great utilities, reserved for the market of futilities or tourism". Craft and manual making encompasses most of the creation of a product. The author also refers to the manufacture of automated objects where the stages of creation are produced with artisanal procedures. Moreover, the author conveys the notion that artisanal culture is an integral part of the industrial culture, validated by the Bauhaus.

For the bobbin lace not be only a reminder of previous generations, strategies are necessary, in the sense of their use, in another profile and at the same time a re-signification of their use.

"This is not to say craft is somehow equivalent to materiality in itself (that is, the extension of matter in space). It would be better to say that craft always entails an encounter with the properties of a specific material (…) craft involves direct engagement with specific material properties. The normative idea of modern art, by contrast, involves the transcendence (which, as in the case of autonomy, is also a repression) of just this encounter" [9].

For changing the way and be able to show other side, we convoke a designer. A designer brings a different vision of the craftsman, has technical knowledge about materials and productive techniques, serves as a facilitator between the product and the maker, building tangible and improving local identity products. According to Lima, the relationship and the work carried out jointly between the designer and the designer are important because "the artisan must be seen as a protagonist and not an auxiliary, that is, labor without creative autonomy, which would lead to the proletarianization of the craftsman" [10]. In this relationship with the bobbin lace of Peniche and the introduction of new materials, it is necessary to consult a specialist in the production of bobbin lace. However, the material to be chosen for its execution needs to be sorted by

the lace makers. Considering that not all materials are possible to be produced, and others, we try not to change the identification of the bobbin lace of Peniche.

Changing the material that they usually use for producing the bobbin lace, may be a possibilities for to give another perspective and creating new products. And so, expecting that the practive of doing bobbin lace don't fall into oblivion, like are happening nowadays with this ancestral activity. Handcraft and design have a dichotomy of values as innovation and handmade. Though design the things can be reinvented, specially using new technology to put them to use the language of post-modernism [11].

Innovation requires constant work in search of solutions, of research, of search. The products cease to be innovative very quickly, this is due to the constant competition of the market, where everyone struggles to take their space and captivate customers. To innovate, one projects the thought for the future, for a change of life or for a better quality of life. Continuous innovation is a way of rationalizing creativity in the projection of design into the future of the new. Carrying creativity into material object is to launch the scientific platform, in the strict and precise demand of the new for the future project [12].

"Innovation is about knowledge – creating new possibilities through combining different knowledge sets. These can be in the form of knowledge about what is technically possible or what configuration of this would meet an articulated or latent need. Such knowledge may already exist in our experience, based on something we have seen or done before. Or it could result from a process of search – research into technologies, markets, competitor actions, etc." [13].

For the author Lalkaka [14] the change can cause a great rupture or, to increase, modernize, boost or refine a certain product. Innovation is the dynamic and integrated chain of activities, from the identification and creation of a new concept to meet a market opportunity, followed by its search for commercial achievement. The challenge is to identify a market opportunity followed by the development and implementation of a new concept.

According to Papaneck, the main function of the designer is to solve problems. However, the lack of demand of the bobbin lace makes the designer more sensitive to understand what problems exist. Easily a designer will discover the existence of a problem that no one suspected before. It will define it as a problem and try to solve it. This can be read as a definition of the creative process [15].

4 Introducing New Materials

A product should arouse emotional and deep interest in the user/consumer. Regarding the bobbin lace and Peniche is not difficult to think about. Bobbin lace is imbedded in the culture of the local population. To extend this interest about bobbin lace is necessary that some emotional meaning could be developed for the populations that do not know it. "The engineered product can sustain in the external world only when the meaning and measure of the utility of this product is derived from those contexts that belong to the subjective world of the customer" [16].

Giving a new context to certain materials and objects are marks of this time. Innovation ambitions the search for new forms for products and at the same time gets new solutions to existing problems. The author Blaine Brownell points out that no traditional product is saved from this system, so the materials are in permanent study to improve their function or replacement of existing ones. In this way, the reuse of materials and the new way of using them, accompany the evolution of other technologies, developing a positive attitude towards this development [17].

The path to the choice of new materials and their specification is rarely linear. "As always, it is devious, assembling bits of information by one method, other bits by others, and combining them into a solution that - although based on existing information - can be entirely new" [18]. It is in research and construction, between advances and retreats that innovation arises.

"In this context, the "new materials" are not only the new polymers, new alloys, new ceramics, or new advanced composites, that is, the cutting-edge materials that are emerging from the most advanced research centers. We may define as "new" even materials that are the result of creative combination of familiar materials. This combination, thanks to more sophisticated management of matter and energy, leads to greater information content and higher density of performances" [19] (Figs. 2 and 3).



Fig. 2. Ceramic wire. Photograph taken on 28 March 2017. Source: Isabel Bieger

A yarn to produce bobbin lace need to be flexible enough for to do the knots. So, we thought at the ceramic fiber. The ceramic fiber is frequently employed in the textile industry mainly in the weaving. "These yarns have opened up new possibilities for lacemakers, taking the craft into their rightful place in the twenty-first century" [20]. The ceramic fiber yarn, with a cross section around 2 mm, has like benefits:

- Good mechanical resistance
- Extremely lightweight

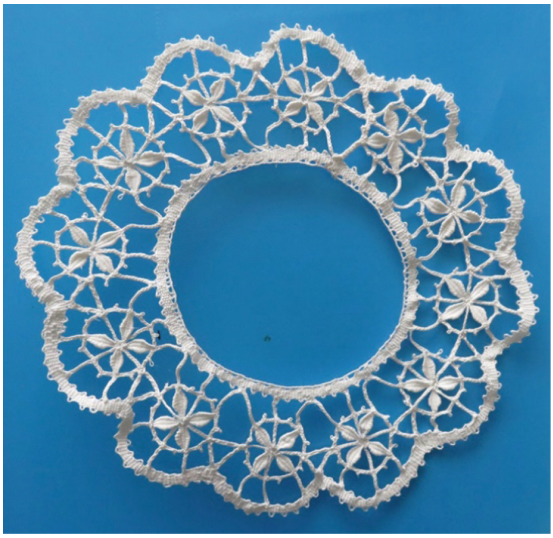


Fig. 3. Ceramic wire test. Test performed with ceramic thread. Photograph taken on 28 March 2017. Source: Isabel Bieger

- Very flexible and moldable
- Supports up to 1.260 °C (around 2.300 Fahrenheit)
- Composed of silica and calcium

5 Conclusion

Research and applications of materials in other possibilities compared to those usually applied have led to the abandonment and transposition of barriers between material, technique and specialties. More and more the division between the professional, the material and the product is becoming more tenuous.

As a result, new products as well as new and potential markets could be identified. Therefore, highlights the need for a series of tests that will give increase to the experimental results, being these able to alter the processes of use of materials and consequently change of the variables of the systems.

Trough the test we can confirm that is possible change material for weaving the bobbin lace and so producing new objects. The new objects can be made with pieces of bobbin lace inlaid. The material of outside can be plastic/polymer or even glass. We thought on them because it's materials that support high temperatures like the ceramic fiber. Joining these different materials, we can create decoration pieces with innovation.

We can observe and withdraw this conclusion according to the delicacy of the result of the bobbin income obtained. The lace is quite flexible which can acquire the shape of a mold for example. The joining of the parts was practically perfect, resulting in an integrated and unique piece.

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Solutions in Designing of the Composite Textile Structure Destined to Block, Intake and Storage of the Petroleum Residues Due to Natural Disasters

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Abstract. To floating dams for limiting the expansion of the hydrocarbon film to the sea surface, different physicochemical processes are used which consist in the gelation of the marginal portion of the oil film by polymerization or by the dispersal of various products that prevent the expansion of the oil pan by altering superficial tension contact oil.

For the design of the composite structure destined to the blocking, capture and storage of the oil fractions, several structural analyses has been performed by considering the initial conditions differentiated as a function of wind force measured on Beaufort Scale.

In this respect, a specialized software that allows the setting of calculation parameters, performing actual calculations, processing, visualization and export of numerical data was used.

The structural analysis was based on the theories of continuous medium mechanics.

The values resulting from the structural analysis for: structural deformation, Von Mises stress values, displacement vectors, as well as those resulting from the use of membrane theory, allowed the determination of the structural parameters necessary for the design of the textile structure.

Keywords: Disasters · CAD/CAM · FEM

1 Introduction

Water pollution with petroleum residues is an extremely important and difficult problem to be prevented and fix it that affects both surface and underground waters.

The pollution of the marine environment with petroleum residues is a worrying phenomenon that has taken an unprecedented scale since the 1960s. Sources and causes of pollution have multiplied year by year proportionally with the occurrence and proliferation of some risk factors.

Incidents in drilling, extraction, transport, transfer operations, loading - unloading, refining, storage, etc. have generated imminent risks due to the hazardous properties of oil and petroleum products.

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Marine pollution with petroleum residues may be the cause, also, because of the acts of war targeted at shore-side oil installations [1].

The limitation of the oil fractions pellicle extension can be achieved by the use of dams. The most used dams are pneumatic and rigid ones.

Special firefighting, filtering or recovery dams are rarely used due to their high cost.

In addition, the special dams involve difficult exploitation technologies.

Supplementary, to floating dams for limiting the expansion of the hydrocarbon film to the sea surface, different physicochemical processes are used which consist in the gelation of the marginal portion of the oil film by polymerization or by the dispersal of various products that prevent the expansion of the oil pan by altering superficial tension contact oil.

Antifire dams are intended to protect the pellicle of petroleum fractions that have been incinerated under controlled conditions and in well-defined situations.

Filtering or absorbent dams are those dams that have a semipermeable structure that retains the hydrocarbon film. These dams are used in cases of low-carbon hydrocarbon pollution, situations where classic dams and high-capacity recovery systems would be uneven.

Recovery dams combine the functionality of classic floating dams with those of film-collecting devices.

The design and implementation of petroleum residues blocking, intake and storage systems must take into account several factors, such as: the type and amount of pollutant recovered, the flow rate of the recovery units, the area of use, the hydrometeorological conditions in the field, transport, way of positioning.

2 Materials and Methods

In order to describe the phenomena that arise when the fluid is delimited by a floating structure that blocks the expansion of a mixture of water and petroleum residues in open space, and in order to clearly predict the efficiency of the blocking, capture, storage of oil fractions, it is necessary, from a mathematical point of view, to properly consider the theories of the type of the wave, the shape of the sea bottom and the dimensions of the floating superstructure.

For the design of the composite structure destined to the blocking, capture and storage of the oil fractions, several structural analyses has been performed by considering the initial conditions differentiated as a function of wind force measured on Beaufort Scale.

In this respect, a specialized software that allows the setting of calculation parameters, performing actual calculations, processing, visualization and export of numerical data was used.

In the preprocessing stage the following structural parameters were defined: the unit system; the reference system; geometry of the structure; the material from which the structure is to be made; element type for mesh structure; the type of analysis to be performed; contour conditions.

Through the included solver, during the post processing process the phenomena that occur on the textile structure, which allowed the determination of the variation intervals of the structural parameters, were evidenced [2].

The structural analysis was based on the theories of continuous medium mechanics. It was considered that the textile composite structure is a continuous, waterproof filling environment that fills a certain area of space, so that at every geometric point there is an environmental material point.

In these conditions, the geometry of the structure was discretized in a series of finite elements, with the elemental mass Δm, in which the continuity property imposed the existence of mass density.

It has to be emphasized from the beginning that the actual exploitation conditions have been taken into account. Thus, the elasticity of the structure was considered and included in the analyses.

The calculation and simulation were performed using FEM, and by setting the values of the constituent elements of the mesh network, namely:

- for discretisation (mesh):
  finite element dimension: 20 mm;
  maximum tolerance between the real model and the discretised model: 9 mm;
  minimum size of the finite element: 0.1 mm;
  tolerance: 0.01 mm;
  element type: linear (4 nodes, 1 Gauss point, 3 degrees of freedom).
- constraints: - for each face of the geometry (Fig. 1). For the horizontal face was used the surface constraint.

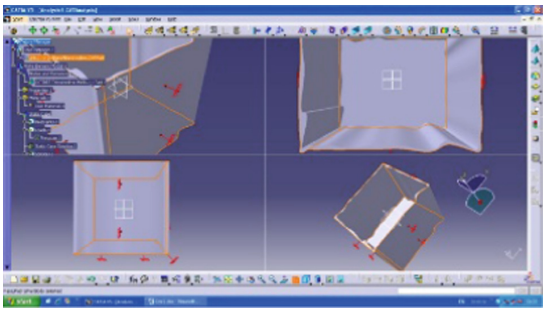


Fig. 1. Constrains of the composite system

Since the textile structure is under the action of an arbitrary medium of mechanical loading, the physical bonds between the material particles are subjected to mechanical stresses that depend on the type and level of the existing demands in the environment in which this system is defined, but also on the position and the direction of the point where the analysis is to be performed.

Thus, the phenomena must be interpreted by its components (normal stress and tangential stress), bearing in mind that the stress values will be different when they are calculated on different directions (the state of the stresses - Fluid Mechanics) [3].

Under these conditions, the description of the composite structure during the movement is accomplished through tensors (mathematical entities).

The software used allowed the visualization of the vector distributions displacement (Fig. 2) as well as of the deformation of the structures as a result of the demands from the real environment of use.

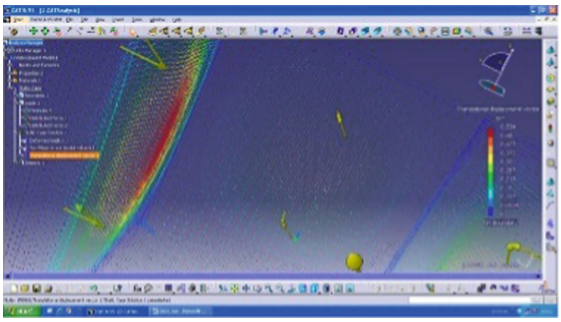


Fig. 2. Vector distributions displacement: wave direction: to the seashore, wind direction: South East

3 Results and Discussion

In order to determine the values of the design parameters of the textile structure, the following specific conditions were considered:

- linearisation of the solution for low amplitude waves (B = 4) which implicitly neglects the slope of the free surface;
- hydrodynamic equilibrium equations (for trochoidal waves);
- free surface degeneration (sinusoidal wave Fourier series); constant temperature and intensity of solar radiation;
- system homogeneity at the trophic level (for closed systems);
- membrane vibration (boundary conditions): the thickness of the membrane that can be neglected compared to the other two dimensions of the fluid interaction surface - the structure (length and width).

In addition, was considered the following conditions:

- the impermeability of the wall to the external surface interface; the equilibrium of the membrane (wall);
- the internal elastic forces determined by the fluid produce an equal mechanical effect of contrary sign with the one determined by the external forces produced by the wall;
- Work of an external force for a membrane sector appearance is proportional to the deformation;
- the proportionality coefficient T is positive and independent of the shape and position of the sector.

4 Conclusions

The theoretical fundamentation of the design of the studied systems was based on the theories of Fluid Mechanics, which allowed the determination of the equations of potential for small amplitude waves, as well as of the equilibrium equations for the case of the trochoidal waves (with solutions for the Stokes waves).

For the design of the composite structure destined to the blocking, capture and storage of the oil fractions, several structural analyses has been performed by considering the initial conditions differentiated as a function of wind force measured on Beaufort Scale.

The values resulting from the structural analysis for: structural deformation, Von Mises stress values, displacement vectors, as well as those resulting from the use of membrane theory, allowed the determination of the structural parameters necessary for the design of the textile structure.

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Changes in Physical and Technical Characteristics of Raw Materials in the Process of Making a Bra

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Abstract. The amount of raw materials possible to be found in the construction of a bra is huge. Such diversity in this single product makes its execution very complex. This study focuses on the relationship that exists between the processes that the materials experience and their result in the fitting moment. When the bra samples are developed in the development office, the tolerances allowed and the repression that the materials experience are different from the results obtained when the same product is run in a mass production. It is important then to understand the discrepancies that exist during both processes and how they can be taken care of. For that, it is necessary to identify and handle those several factors to minimize the suffering of raw materials.

Keywords: Bra design · Raw materials · Bra process · Importance of fitting

1 Introduction

In the construction of a bra, how the elements are taken care of is paramount for the success of its execution and for it's great purpose, the support of the woman's breast.

When it comes to building a supportive brassiere, the materials still acquire a superior exponent of importance so that more naturally their function is achieved. Controlling rigorously such diverse materials is a work that begins from the development of the design of the model. However, it is through the pattern maker that all the perspectives are fine-tuned so that the production of the bra reaches the determined requirements.

In the diversity of materials we can find metallic wire, ribbons, elastic of various sizes, microfibers, powernet, silicone tapes, foam, laces, embroideries, powernet knits and some fabrics, elastic bands, elastic straps, hook and eye, lining that can be of cotton, charmeuse, marquisate or meshes, etc.

This results in a rather complex equation in the sew execution, both in the control of all the machines involved, and in the stability of the materials throughout the process, while safeguarding their characteristics.

The process of building a brassiere will always have to start point with the design office, which defines the development according to the needs of the target. In the case of this type of product, the fitting in the process is of extreme importance, since it will

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allow faster detection of error in time before the next steps are taken. It is also a product that lives a lot of the subjectivity of women who do the fitting of the bra. Some of the factors are due to the direct relation of the level of comfort with the changes in the patterns; to the type of breast of the woman, since several breast sizes can wear the same bra size.

Consequently, the control of the bras fitting goes well beyond dressing just to make sure everything fits and sits in place. It is through dressing and using the bra that it will prove that has achieved the function for which it was developed. However, the fitting bra may have differences in the process of before and after washing, as well as the user's perception of the level of comfort, and the communication of this information to the designer and/or pattern maker, and finally in the sewing process of that bra.

Without declared center stage, the materials end up by playing much of the problem vs. solution to the understanding and success of the fitting of a bra. If the samples taken during the brassiere study are not with the materials of mass production or if they do not guarantee the same results, there will certainly be significant discrepancies between the sample of the design office and the mass production of the model in question.

Each brand is governed by measures that it considers to be the most appropriate to its target, for that purpose, when subcontracting to the sewing process, they deliver a whole set of rules and parameters that they consider essential to guarantee the viability of the production. The sample made by the design office will have to correspond to all the items in this brand order book, but in addition it must predict the scenarios in which in series production it is more complex to meet all the requirements determined by the brand. Is it correct, then, to affirm that follow-up of the design office during series production allows full control of success?

The tech pack is very unique and personalized according to the characteristics implemented by each brand, however authors such as Jonsson [1], transcend this secrecy and demonstrate the requirements, specifications and standards that can be more common on some brands to standardize the universe of this kind of product.

Understanding how to ensure maximum reliability according to the approved sample is an arduous task, which is often forced to go back to previous steps so that the next steps are not compromised. Testing with real examples of samples (from the office sample and from the production area) and confronting with the tolerance charts (ordered by clients), of the same bra, will reveal the consistency achieved throughout the process.

The patterns of the bra are the starting point when each of the materials takes shape and coordinate with each other; the cutting period is a time of use of several techniques that depend very much on the type of material that is being used. The precision achieved is of extreme importance, whether in manual or automatic cutting. The confection is a fundamental part for the pattern maker to succeed and when it is verified if the cut of the diverse materials was well executed; the allowed tolerances behave as controllers of the whole process. In quality control, the measures are all reviewed but it is undoubtedly in the fitting moment that everything is proven. With the fitting it can be understood whether the tolerances are (not) excessively high or not, and if the different materials have also reacted within the tolerances provided.

The way that all the processes worked out at each stage, through which the bra goes, will provide success according to the tech pack.

All the process reveals that many materials are more vulnerable of being changed in their physical and technical characteristics as result of the effort that they are submitted throughout the process. Such may culminate in the substitution of materials, when the style bra goes into production, to minimize the problems that have occurred.

2 Review of the Bra Process

2.1 Main Discrepancies Between the Creation of a Final Sample by the Design Office and the Mass Production

The Sewing. One of the first differences is the team. Who produces the samples from the design office, is not who will make the mass production. Hence the importance of the specifications that will define all sewing parameters, from stitches per centimeter, types of seams, colors of coating lines, outer lines, tolerances in measurements, changes of materials by grading, etc. However, we will always have to contemplate that even though they are always the same person performing these samples, they will have derivations that may be associated with concentration, stress, speeding of the worker, among other factors. The machines where the samples are made may have oscillations. Would simplify the process if the machines in which the samples are sew, were exclusively for making the samples of the design office. Ideally, don't change the working parameters of the machines until the sample is completely tuned and revised to go into production. As the sew of new samples and new developments are constant, the adjustments to making a style are changed to make another and that can make some information of the entire sewing process losted.

In mass production, there are various ways of organizing such as in-line or by cells, but in any one of them, different workers will do the style. This factor is very important for the chart of tolerances, in order to provide a greater precision and working parameter. So that at each sewing operation it is confirmed that it is within the tolerance gap. To achieve those goal it is necessary that the sewing machines are tuned in perfect harmony with those used for the sew of the samples of the design office.

The Materials. Other of the discrepancies that can affect more deeply what was done as final sample, and what will be the production of this style, are the materials used.

In the development stage of a new bra sample, it's made with the materials chosen from suppliers that come in small quantity, as they will serve only to sew some style, in the design office. In this stage, work is done with materials that do not have industrial finishing. This affects many characteristics such as elasticity, hardness, touch, color, opacity, which may be of extreme relevance for the whole process of creating a new style and it's mass production. Without the guarantee of the materials having an industrial finish, the final sample of the design office will not be correct nor valid to serve as a production sample. Even if it was approved in terms of fitting, the sample should be repeated with the arrival of the purchased industrial quantities of all materials. This will allow adjustments in design, patterns, cutting, molding, sewing and fitting, on the style made, with the correct materials that will enter on the mass production. However, this procedure is not always possible, those with tight deadlines and

with high fines if the orders do not leave in the correct time. They risk producing that style by looking at a sample design office made from materials without industrial finishing.

For better understand the problem the research team brought some examples of their experience in the industrial activity in this sector.

If a color requested from suppliers through a *Pantone Textile*, this color will have to be worked in the laboratory and the design office will have to receive a several color shade options ordered on the material in which it will be produced. Designated by *lap dips*, they are small samples (about 20 cm if it is an elastic, about 10 × 10 cm if it is a mesh) representative of what will be the color in the production. The design team will select one of them. It will be the swatch color for to control the bulk (industrial sample representative of the industrial item). After the *bulk* validation allows the suppliers can send the industrial quantity purchased for the beginning of the mass production of the style bra. In the middle while, it is necessary to make the final sample of design office, make the graduation of the style and approve the size range according to the intended fitting. It turns out that, if in the design office, the materials available to sew the final sample and the graduation of the style, are the standard colors available from the suppliers.

Dyeing is probably the method most used by suppliers, since having the yarn in the exact Pantone color required is not economically regular. The industrial quantity purchased of an elastic is always with their technical sheet, which includes tolerances of elasticity percent. Because of the dyeing process, the material can expose a lower elasticity. It will be sewn with others like a mesh or lace or even to several different materials together, that can result in a more rigid behavior, different from what would have been expected and different from the sample of the. Therefore, it is extremely important to make a fully made sample of industrial production materials.

The Patterns. Is a walking that can last for a long time but that allows the viability and the correct fitting to create a successful product. The importance of a discipline such as Patterns is present throughout this creative and productive process. According to the National Geographic documentary - Secret history of the bra, there are six months separating the initial creation until its conclusion and entry into mass production. According to the company Helix - Indústria de Confecções SA, this time can be reduced thanks to the know-how that the team has, since it does not always need to go to the first steps and the others styles already created and validated can be adapted according to the materials and fitting. Nothing can ever enter into production that is not dressed, commented, corrected, and dressed again until the bras conforms to the intended fitting [2].

Just with the accuracy of patterns the bras can be successful. The more we specify the functions we want in a bra, the more important is the patterns of them. When we make the patterns of a D+ cup, the demands of its construction are greater. It is often the job of the patterns maker to change the visual aspect of the bras in favor of a better fitting. This may even result in changes in the visual appearance of the brassiere. This study is done in detail, from size to size, from cup to cup, to understand where it will be necessary to add a lining, to remove the cutlets cup, to reinforce the wings, to increase the strap elastics or even their quality, etc. The limitations found in some materials may

require major changes in the patterns, such as the width of a lace. This material may even work in terms of cutting up to a certain size, but when developing graduation to larger sizes, certainly it will need extra cuts that are only made because of the lace width. After approval and validation of the graduation style, the specificities of the style are gathered in its technical sheet. In this way, any pattern maker can pick up and work according to the specifications that the brand requires for their style bras.

From the very beginning, the creation of a style bra just achieves success with the presence of the patterns process. It is the stage to materialize an idea, the design and the function through the patterns that interpret what the woman's breast needs in order to have the support and adequate level of comfort. Often, the patterns are identify as the most responsible in the entire process of creating and developing a new style.

The Cutting. The cut consists of several specialties. Cutting elastic is not the same as cutting lace, therefore it's necessary need to understand the characteristics of different materials to produce the bra. There are machines for the automatic cutting of elastics, which facilitates the quickening of the process, the same goes for the elastics of the loops, in which also the necessary components (ring and slide) are placed for the adjustment of the loops when sewn in the bra. As a rule, all materials are layered and cut into the automatic cutting table, with either saw or laser. The lace and embroidery cannot be extended to be cut automatically, without the presence and support of a worker. They require much more attention to position the molds in the right way so that the seams are correctly sewn and to be positioned in a way that saves as much material as possible, from size to size. The study, the machines and the solutions for cutting lace and embroidery are very particular. It can always be done manually; precision is also possible by cutting machines. However, they require a time-consuming and meticulous process of schematizing all patterns, drawing cuttings to be placed on a tray. It's necessary the constant presence of a worker, to place the lace or embroidery, on the reference points for the board and its cutters, to execute the cutting of the pattern. The great advantage of this method is the precision achieved (which can be better than achieved when cutting manually) and the speed in the cutting stage, which recoup for the entire preparation stage.

When cutting samples for the design office, due to the needs in terms of time and the low amount of raw material available at this stage, it is certain that manual cutting becomes the most appropriate. The extreme precision of cut has to be achieved as early as this first stage because all detour can dictate the measurements out of tolerance.

It is sometimes necessary to unseam to understand whether the cutting of the material it's correct to the patter draw.

Another great focus is the study of the selvage fabric for cutting in the correct position. Something that must already be provided by the pattern maker, but it's always has to be confirmed by the cutting worker, by the position in which the material is intended to have elasticity.

The Molding. The complexity of molding is extreme. The research's team has already saw the difficulty of many molding machine's workers in understanding what to do without having the parameters of the molding machines completely defined by the technical team. The biggest problem of molding is always work with the transformation of the raw material. Something that had 2D characteristics and that by the intervention

of the machines originate patterns in 3D. With the creation of volumes, it will allow to increase the versatility of using the same material in different ways in the same in the bra. In addition to the great advantage of removing any seam in the cup which is makes the bras more invisible over the outer garment. It is also the bra molded it's the preferred and bestselling style worldwide [3].

In the opinion of the researcher's team, when it is necessary to mold a new material, a new fabric, it will have to take two steps. One it's to confirm by the technical sheet of this material that it can be molded; other it's make tests not only for the size in which the final sample is made, but also in all the size range that is intended to produce.

The researcher's team perceive that different batches or colors of the same material may have different behaviors in the molding. Which forces adjustments. Whenever there is a change of batch of material, it is necessary to test if the molding parameters need some adjustments to according to the range defined by the tolerance. To confirm it should be necessary to line the canopy with the molded fabric and sew it in the size range.

The Fitting. "Just because a prototype looks good in the bust form, don't mean it can stand up to the demands of a real woman." [1].

Dressing a rigid mannequin will be only a guide to identify easily some structural problems, and serves as a support to attest that the visual image is being achieved. However, it is necessary to understand if the fitting is correct with the requirements and the goals defined by the design office.

The standard industrial size is the 34B. A woman that wear it must to control all the time if her body size change it, like weight, menstrual cycle or others, that can influence the dressing correctly.

In the fitting session with the first prototype there are many conclusions that can be drawn. One of the first is whether the materials, that were used, are most suitable for the intended visual image. Like the lining and the position of the selvage, in which way the fabric has been cut. Have to be reviewed to improve a better fitting. Checked the first measurement charts, for example the distances between the straps, both front and back, distance between cups, etc. At this time the user will indicate how she feels wearing the bra style. The user must have some knowledge about this kind of product. Normally are employees of the company or models that have some training. Some of the parameters that the user will have to evaluate is the cradle and the cup adjustment, in the breast volume, the tightening and comfort level of the bust contour, the stability of the straps, etc. Often neglected, the basic movements and their relationship to the stability of the bra, makes it possible to understand changes in the patterns that will have to be done.

It is very common to repeat two, three time the sewing process of a bra style, to guarantee all the desired settings. During this process its necessary that more than one user woman wear it and check it (in the same size), to refute or add the necessary changes. According to the *Maidform* brand, the prototype goes through five real models to be validated. This practice is very personal, according to the organization of each production company and each brand. With this method, the design and technical office are only validating a single size and it being necessary to understand the graduation that the bra will suffer and its reaction in the fitting test. For this reason, many brands produce all sizes that will move on the mass production and, in the same way, will have

users to wear and comment the fitting. Through all the tests in different users and in different sizes of the size range, it will be possible to find most of the problems and resolve them after the mass production.

However, the fitting process does not end in the prototyping stage. In a pre-production stage it is advisable to confirm that everything is like expected. Repeating the process and understanding if there are significant changes to what was defined in the prototype stage. Being considered one of the parameters of the Control and Quality of the product.

2.2 The Importance of a Technical Pack for Raw Materials Control Throughout the Sample Bra Process

In a production working, all the procedures, rules and specifications are according with the Design and Technical Office. This information must be transmitted in a very clearly way to mass production.

A technical or specifications pack is not only for the production stage, but also for the prototyping stage, to follow the rules so that always styles are regulate by the same parameters defined by the brand. Will provide a noise-free information for the creation stage of a new style and in the patterns stage. The guarantee that a technical pack offers will allow new styles to be developed or produced anywhere in the world, having a universal reading, so the results in different places should be the same. Almost like a cookbook, it is a DNA structure in the brand, which is shared only with those who have work partnerships, the technical pack are rich in documentation intended to achieve the intended target in an almost customized way.

It should indicate the wires used their graduation, thickness and dimensions. In what type of models and styles should have lateral bones and in what materials, the ring and slide dimension; their equivalences from cup-to-cup sizes and their singularities. It should indicate in all sizes of cups and waistbands/wings where you will take lining and how they will be reinforced, their formats, the type of material; these lining can be found for example in waistbands/wings, center gore, in the cup, etc. It should indicate when it's necessary to change the elastic widths on straps, waistbands/wings elastics, armhole, neckline… It should show the image about were to open the cup to place the cutlets, show the types of preformed cups, foam thicknesses for cups and cradles. It should show the image of different widths for hook & eye tape according with the size range; stitches for different width of elastics according with the size range; position of each elastic tape.

A more complete technical pack also controls the type of graduation of each pattern and the growing table for every patterns of the style. It is common to present changes of patterns because of the graduation. Things like transform a regular wing to a U-backwards, for example. Jonsson [4] considers that different companies can provide different measurements with which they want their models to be graduated.

Each brand has a technical pack structured according to the characteristics it considers indicated to reach and satisfy its target. Therefore, its uniqueness makes these pack unique and confidential information.

"The bigger the company, the more detailed a tech pack usually is, for the simple reason that it'll pass through many hands before it reaches production".

The production pack is different from a technical pack. The production pack is an archive and knowledge base of the decisions made for the design technical team of that unique style bra. It will have information about fabric tests, color approval, washing tests of the style made, fitting comments, etc. It is a pack that will become more complete as the style gets approved to go into production. Jonsson [4] organizes a list of the documents that should be part of the production pack:

1. Production Order sheet
2. Comment sheet
3. PP Meeting sheet
4. Approved Fabric Swatch sheet
5. Approved Strike Off sheet
6. Trim Card sheet
7. Label Approval sheet
8. FPT/GPT Report sheet
9. PP Size Set Sample sheet
10. Shipment Sample sheet.

The Technical Sheets for Bras. The technical sheets establish a relationship between the design team, the technical team and the production team. It may seem too pretension, says but we consider that there is a higher specificity in the technical sheets of lingerie.

Firstly, it is necessary to make a distinction. While the technical pack is the procedures, rules, tables, agreements to use during the creation of the styles. Serving as support for who will produce the style bra, knowing exactly all the following rules of the brand in a technical analysis. The technical sheets is relative to the details of the style according to the intended concept. It's about all the answer for the aesthetic points, all the specificities details for the style in that particular collection, especially to understanding the graduation. In the technical sheets it is necessary that there is information of size of the style. Yu [5] considers that there are two ways of elaborating the technical sheets:

– The Designer creates the sheet with the specifications of measurements and the pattern maker follows the directions to get to the design wanted.
– The Designer creates only a technical draw for the first sample and only after it first prototype sewed and measured, define the directions and measurements.

In both situations will result in the PP sample (pre-production sample) or sealer. It means that the measures may change from the initial directions due to the adjustments and changes necessary, to agree for the result that the designer wanted to achieve. After this development approved, proceed to the seal sample, which represents what will be the final sample. It is very common to be a label with an inviolable seal, usually a golden tag Jonsson [6].

The technical sheet is changed with the exact measurements according to the seal sample and sent with this physical sample to the factory where it will be produced. It should also be followed by the measures intended for the size range.

The walking of a technical sheet is the same as the sample. Since the creation stage, the technical draw or a simple sketch, with or without measurements, it is forwarded to the pattern maker. After the preparation of the final sample, it is necessary for the purchasing team to understand with the Designer team, if the prices are within the intended or it is necessary to rethink in some decisions taken.

The production team based on the technical sheet, to parameterize the measures for the sewing workers of the style bra to guarantee that the measurements will be inside of tolerances. Finally, the quality control also needs the measurement sheets to ensure that all the parts are in tolerance, for their success in the place of sale.

3 Conclusion and Discussion

Looking at the structure of a bras it's possible to understand the various processes, machines, materials, that are present for its execution. In a bras creation the raw materials are determinants for the success of that style.

According to some authors such as Van Jonsson [1] the bra is have a particularized structure that needs to be dissected so that each element reveals its individual importance and its collective function.

There must give an intelligent support, which certainly has to go through choosing more properly the materials to be used for the intended purpose of the bras.

The anatomy of the bra or the parts of the bra can vary, however some basic parts in the structure are constant. The structures vary depending on the support that intended for a breast that oscillate in size. Understanding the anatomy of the bras can help in their creation, to make it perfect in fitting and in design.

The materials used for the construction of a bra result in its perfect adaptation to the woman's body. The opening of the wires, the typologies and thicknesses of the cups are the fundamental elements, which used according to the needs of the breast that intended to support. With that, it will be possible to provide a very high level of comfort and a greater degree of satisfaction of the woman who uses it.

Often, patters identified as the most responsible in the entire process of creating and developing a new style. It's present in all the process to guarantee the design and function of the model, thanks to the satisfaction in the use, which should be a prime objective to achieve.

The raw materials that most relate to lingerie increasingly used in outerwear. Many of these materials were until recently used exclusively for the clothing used for underwear. However, fashion design began to become more and more interested in their delicacy, specificity, and their hidden side. We consider that the relevance since study is in the diffusion of the type of work that carried out for the construction of the bras, its procedures and specificities. It is a closed sector, where each brand works differently and for the target that considers most appropriate for its brand. However, it is possible to find a uniform and universal structure in the creation of the bra. We believe, therefore, that it is important to insert more knowledge within the professional training and even the academic universe. All of these factors: sewing, sample materials and production materials, fitting, molding, molding, cutting influence on the behavior of the raw materials, up to the visual result and your bras life (Fig. 1).

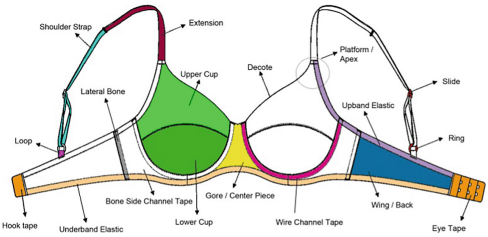


Fig. 1. The bra anatomy, Filipe (2014)

The loyalty of the user to a brand that really enjoy the style bra, want it in all future collections. That is also one of the consequences of a successful process.

Allow to the production pack and the technical pack, information on the entire process, materials, construction, labeling, packaging, can be easily controlled in an exemplary way, unambiguous information for the manufacturer, whether in Portugal, Turkey or other place at the world.

Through the classes Fashion Technology, include in the Master of Fashion Design, there was opportunity to input some issues related to lingerie and more specifically about the execution of a bra. Since it has been discovered what knowledge masters students have. From the fragmentation of the bra to understand its structure, to interaction of the most diverse materials present in this structure. Elastic behavior, molding, the type of cutting and how to do it in different materials, the students did not have the knowledge bases to enter the market and work and to design a style bra as they would easily do for a dress or a sweater. It is understandable that they do not have this knowledge. It is a niche market in production in Portugal, but it already represents a product that manages a world industry equivalent to that of outerwear, and thought to have a production that exceeds 16 billion dollars per year [7]. We can verify that one of the great positive aspects of having introduced some knowledge about the materials, the processes and the product, is the huge surprise and interest that the subject created. The interest was really growing and we had to witness the bras production in loco. Following the progress in each of the different stages, interacting to understand the methods in detail. Increasingly interested in the process of creating a bra, will allow the construction of products with more quality, that are suitable to the user and taking advantage of the maximum of the capabilities of all the raw materials that are bound to this product.

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Use of 3D Printing and Nano Materials in Fashion: From Revolution to Evolution

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Abstract. The purpose of 3D technology is to transform the most challenging concepts into reality. In Fashion, 3D printing is continually evolving with the designers' interest and professionals in technology. It opens new avenues of fascinating and endless possibilities for fashion designers. In this process the object is created layer by layer without any mould, based on its design which was developed through Computer Aided Design (CAD) and use powder particles materials, like plastics, metals, and resins etc. 3D printing offers different perspectives in almost every field of life. This innovation has impacting the new industrial revolution and creating vibes, in majorly all the industries. Including high fashion apparels and could change the future of both Haute Couture and Pret. Regarding three dimensional printing there are various ways and technologies have been developed by the professionals, but this outrageous technology is having an obstacle in fashion apparels, like materials, which are mainly synthetics and lacking the natural properties to produce desired silhouettes.

Keywords: 3D printing · Computer Aided Design · Sustainable · Nano materials · Environment-friendly · Fashion · Design

1 Introduction

3D is a familiar word. However, 3D movies are more familiar and easily understandable for the layman. However, 3D printing or Additive Manufacturing (AM) is entirely a unique term for most of the people who are not related to this domain. 3D printing refers to a computer-controlled fabrication process, which enables the creation of a three-dimensional object from the 3D model, designed using computer-aided-design software [1]. The ultimate success of the 3D printing process is making three-dimensional objects with extreme intricate, geometric and structured details. Currently, this is a unique technology related to producing anything. In other words, you name it, or you can have it, with the help of 3D printing or AM. 3D printing got the attention of designers because of its sustainability in the form of wastage and environmentally friendly, as no waste of water or any harm to the environment takes place. Technologies have already changed our routine life, like Artificial Intelligence, Robots, and World Wide Web etc. As per data by a specialist of 3D printing market research, it has

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recorded that financially it has grown amazingly from 3.07 billion dollars in 2014 to 21 billion dollars by 2020. It is approximately 32% growth annually [2].

In the beginning, designers used rigid and synthetic surfaces to create apparel collections. However, 3D printing was having challenges like stiffness, rigidness and non-flexibility. Practicality, comfort and feel of materials were also missing. Designers and professionals related to 3D printing overcome rigidness and stiffness issues by producing materials, which are flexible. They have successfully produced the body-hugging outfits, which move as the body move and helps to perform the routine task without any issue. Nevertheless, the use of NANO materials improves the properties making it durable, sustainable and with no colour constraints. Nanotechnology is itself is the industrial revolution. In which the properties of any material can be changed making it more towards performance-based in all aspects. By advancements of Nanomaterials, possibilities in terms of design and practicality are endless [3].

Using NANO materials through 3D printing technology in Fashion for mass production is the concept of discussed and explored in this paper. If we look into the history of 3D technology which is not very old, and it seems that this technology has already set the strong footsteps in the area of design and manufacturing not only in Fashion but almost all the aspects of life, rather Fashion comes quite after some time. Few of the fields where 3D technology has made its debut; are Medical and dentistry, Aerospace, Luxury Automotive, Jewelry and accessories, Art & Design, Architecture, Food etc. 3D Printing or AM technology has not only changed the apparel design and methodologies of manufacturing dramatically but has moved it forward to limitless boundaries. This unique way of manufacturing has given the new paradigm to conceptualize and materialize the creative design process in the Fashion, textiles and accessories, which ultimately lead to resolve many problems related to textile and fashion sector. It is a well-known fact that the textile industry is one of the most polluting industries in present times [3].

2 History of 3D Printing

The history of 3D Printing technology indicates that it first came in the picture in the 1980s. When the first patent application for rapid prototyping was filed in the 1980s, albeit the first patent was issued and registered in 1986 for "Stereo-Lithography Apparatus" (SLA) [1]. In 1987 SLA-1, appeared, it was the first commercial 3D printer produced and after strong critique on its operations and possibilities the first unit was sold in 1988. [4, 5]. In 1989, the Selective Laser Sintering (SLS) came into existence and was subsequently patented [4, 5]. In 1992 the patent was issued for another technology within 3D printing, it was Fused Deposition Modeling (FDM) [4, 5]. These were the initial developments and technologies of this unique mode of printing, and after mid-nineties, the race is still going on about to reduce the price of 3D printing apparatus and bring it down to be within the approach of individuals. The advancement of this technology has reached a certain level with the passage of time, as its main purpose is to develop this technology was to produce prototyping in almost all the aspects and areas of life. The objective of 3D printing is to create objects which can be conceptualized but difficult or next to impossible with the bare hands. The prototyping

or artworks which have been developed with the help of 3D printing technology through its design software's are very intricate and detailed [2, 4, 5].

Using a computer-aided design program (CAD), designers create and modulate a 3D model to generate by computer [6]. From this model, it is necessary to create a "build path" which specifies each movement to be made by the printer, when to start printing out the specific material and at what rate. To do so the designer must make use of a separate program. Through the later, the 3D model is transformed into a series of 2D slices thus informing the printer where to solidify the starting material for each slice [6]. Every layer printed out represents one of the digital slices generated through CAD. Making use of a binder, a laser or an electron beam, the 3D printer will solidify the material along the programmed build path [7]. Today, several different printing processes as described earlier exist such as stereolithography (SL), Polyjet, fused deposition modelling, laminated object manufacturing (LOM), Prometal or selective laser sintering (SLS) [8].

3 Literature Review

At the outset, it is important to lay the framework for the proposed study through a detailed review of the existing literature to identify key theories and concepts deemed relevant to the research topic.

Above mentioned materials, from liquid resins to Powder formulation in the shape of plastic, aluminium, titanium to PLA, ABS, TPU type of materials are being used in the process of prototyping or commercial purposes [1, 9, 10]. If we go in details all these materials are based on synthetic structures, which are somehow, rigid, rubber type flexible materials, and metal like strong. wIf we talk about textiles and in a more specific way wearable textiles, it requires comfort and practicality which are somehow lacking in the currently developed clothing using 3D Printing or AM. As per saying by famous Dutch designer Iris Van Harpen, that now you can wash and Iron the 3D printed garments [12, 13]. Her collections related to 3D printing are the next level of development in the domain of apparel design. She has merged the Design and technology in such a way where every creation is art itself. In other words, 3D printing is a correct and ultimate tool as the expression of designers.

Another company "Continuum" has developed Bikini Dress named N12, Nylon 12, which is entirely developed by the 3D Printing using SLS technology [14]. This outfit is purely for the swimming purpose and its uniqueness is that while getting wet, it is amazingly comfortable and waterproof because of the properties of Nylon. An interesting fact is that it is solid, flexible and strong as it is only 07 mm thick and not gets de-shaped. No hand or machine sewing is involved in its construction, as it is developed entirely with the process of 3D printing including closures and hooks [14].

In current development a graduate student, Lingxiao Luo, who is currently in process of her Masters in Women wear Design from the Royal College of Art(RCA), she has used this unique 3D printing technology and merged with her knitwear project called it AddiToy collection. She has mainly used knitwear fabric and applied 3D printing mesh patterns directly onto knitted fabrics in order to attach another knitted yarn piece. She also used the felting method to use 3D printed patterns directly onto

knitted fabric, and then wet and shrinks the knitted fabric to produce three-dimensional structures [15].

Fashion Designer Frances Murphy also studying in Royal College of Arts (RCA) is experiencing the Bioplastic and cellulose-based materials to examine the possibilities to use them for 3D printing. Her idea is to use traditional structures of textile, and experiments on materials like silk, which is cellulose, based [16].

4 Materials and Methods

4.1 Liquid Resins

Stereo-lithography (SLA) technology uses liquid resins, which converts the liquid Resin into solid materials using high strength of ultraviolet UV light. The process of high intensity of light is to harden the liquid layer drawn by the printer as per the design layer by layer [1, 9].

4.2 Powder Based Materials

Powder-based materials used in the Selective Laser Sintering (SLS) technology, which is a rapid prototyping technique. It is more like (SLA) technique but without the ultraviolet light. Powder materials like, Glass, Aluminum, Titanium, Nylon, and Polystyrenes replaced with Resins and spread on the base of machine evenly and the prototype is developed with the help of a laser, which fuses the plastic materials into layers. This process explains the objects developed with this technology, the process is mostly in the rigid forms, and they are fragile. If we use these materials in the form of apparel, yes it would be an enormous and creative achievement, but fragile. It shall be a perfect piece of art but in rigid form. Same materials also use in Selective Laser Melting (SLM) technology. In this process rather fusing the powder, it is melted with the high temperature [1, 6, 9].

4.3 Paper Materials

By using paper material and applying adhesive coating on at lower side of the object as layer-to-layer. The Laminated Object Manufacturing (LOM) is another type of additive manufacturing technique. In this process, the heated stainless-steel roller applies the pressure to place another layer on top of the already laid down layer. The excess material, which covers at the surrounding of the object, removes manually at the end of the process [1, 9].

4.4 Thermoplastic Materials

Thermoplastic materials like ABS, PLA, and HDPE, are types of materials, which are being used in Fused Deposition Modeling (FDM), which is another additive manufacturing technology. A temperature-controlled nozzle develops the object layer by layer. In this process, the material becomes solid form, semi-liquid form during the extrusion process to form an object. As these materials sound, they require high

temperature by melting them in the extruder just before printing. In one experiment in which they have designed the 3 different types of plain weave structures [1, 7, 9, 10]. To avoid any complexity basic geometrical shapes like straight line and circles uses for the fabric design. The printing material used in this project was ABS (Acrylonitrile Butadiene Styrene) which is a lightweight filament. It is high impact resistant and high creep resistant polymer.

The result of these samples is quite promising as this shows about the possibilities to develop the weave like structure, which is also wearable and functional through 3d printing or AM [1, 9, 10]. The same FDM technology also used by the Houston Based designer "Maria Alejandra Mora-Sanchez" who has developed the "LOOM" dress by using Push Plastic Flexible TPU material. She was inspired by the "Wayuu" tribe patterns and developed the flexible, stretchable material, which basically quite stretchable and moves along with the body [11].

4.5 Nano Materials

In parallel with 3D printing, Nanomaterials is another key area, which has revolutionized the Textile and Fashion sector. The concept of this unique technology is to treat materials related to textiles like cotton, silk, and other organic based with the coating of Nanomaterials, this procedure improves the properties and making them sustainable, durable, and enhances their performance and they become biodegradable. Nanotechnology has changed the entire perspectives in almost every field of life including, Agriculture, Medicine, Automotive Industry, Fashion and Textile. To examine the Nanoparticles with the naked eye is not possible, as one has to use the proper equipment to see them at the nanoscale level. At this stage, particles can even change their colour, which is great news for the fashion and textile designers as they can create wonders by using such properties, which are helpful for them to create their products [3, 17]. By using Nanomaterials can create wonders in the process of 3D printing technology. As described earlier, Nanomaterials coating apply to any type of material in particular organic and synthetic can change their properties. In addition, when we say organic, we need to look into Biotechnology, which is based on DNA technology heading enzymes synthesis to save natural resources, most importantly water [3, 18].

History of Biotechnology is based on centuries ago when people were not even aware of this word, but it actually came into existence in 1953 when American Biologist James Watson and English Physicist Frances Crick discovered the structure of DNA. Biotechnology is the performance-based technology, which has actually directed the manufacturing industry into a new paradigm. Through, Biotechnology a new range of hi-tech and eco-friendly materials have revolutionized the Textile and Fashion sector and ushering them into the future. These materials will lead the fashion into more sustainable way [19–21]. Few biodynamic materials like, 'Zelfo', which is cellulose, based organic material, like, Hemp, Flax and Paper. This substance uses renewable sources for production without using any inorganic form. The interesting thing is there is no wastage of material in the process of making it, as waste is reusable too [20–23]. Another substance is 'Sorona' polymers, which drive from plants. It is a high-performance fibre made it through plant-based ingredients. An interesting fact is

that this fibre is stretchable without any use of stretchable yarn or substance, and its outcome is marvellous after using and washing it numerous times [20, 24]. These materials are the combination of agriculture and biotech science capabilities to give bio-based solutions to the needs of humankind while protecting the environment. Another interesting fibre is 'Cocona', which is another performance-based fibre harvested from nature. These kinds of fibres can be used for woven and knitted fabrics, which promote evaporation of moisture, and protection from ultraviolet rays, giving comfort to the wearer in hot climate regions. An excellent fibre is also derived from coconut husk, which is waste from the water filtration industry. These sort of unusual materials, which are results of Biobased technology, are the great source of inspiration to the industry, which is at the verge of disaster for nature [25].

5 Limitations

Despite there being great, hope about the future of 3D printing, the existing body of literature agrees that 3D printing still faces many challenges. The marginal costs of production continue to remain higher with 3D printing than with conventional technology. This is linked to the cost of material used and the consumption of energy by the machines [26]. The lack of material also raises questions in terms of quality and can discourage designers and firms to opt for 3D technologies. However, researchers advance that once more suppliers enter the market for 3D printing such costs will begin to decrease.

In addition, 3D printing poses problems in terms of designers' abilities and capabilities [27]. If on one hand, the ability to design viable products and bringing them to manufacture is enhancing the demand for qualified designers, faster and simpler prototyping as well as easy to use 3D software's are opening up doors for automation and non-professionals [27]. Another issue linked to 3D printing technology relates to intellectual property.

Today, many blueprints are distributed freely online and can be replicated and printed out by all those having access to the file [28]. So, just as streaming enabled cheap counterfeiting for the music, publishing and movie industries, 3D printing enables decentralized piracy, meaning that consumers can obtain counterfeits cheaply without having to pass through commercial counterfeits [28]. Today, 3D printing is not submitted to IP laws. In the current digital age, copyright laws are under revision, with policymakers under pressure to reevaluate the role of copyright protection [29]. With innovations being rapid and unpredictable, it takes legal systems time to adapt to newly introduced technologies and the consequences they entail in diverse industries. What is more, because of the aforementioned unpredictability of new technologies, it is difficult for legislators to predict or anticipate the effects of given technologies [28].

6 Conclusion

Things are moving quickly. 3D printing will ultimately become supportable. Its beauty is its limitation is dependent upon materials. It is not so difficult to understand that the evolution of the human brain, who invented technology for the betterment of the human kind but ultimately disastrous for the natural world in which they lived. Now the advancement of technology has forced the human kind to develop the solutions to prevent further disaster and apply the reverse engineering method to resolve such problems. Through technologies like Biotechnology and Nano Technology, organic and performance-based materials can transform the 3D technology. Materials can be easily transformed into powder and liquid form to be used in the additive manufacturing capacity. A blend of different fibres like manmade and organic can further enhance the process of 3D printing. Using this unique technology, the mass production of apparel is not very far from existence. Rapid prototyping like its name can set the new horizons for the mass production of clothing by using bio, technological based hi-tech, materials for the sustainability of this advanced unique domain.

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Cognitive Behavior Difference Based on Sensory Analysis in Tactile Evaluation of Fabrics

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Abstract. The hand evaluation of fabric is the psychological cognition and experience when people interact with fabrics and clothing. In this study, the subjective evaluation method was used to evaluate the tactile properties of 11 fabrics to find out the cognitive behavior difference in tactile evaluation. 30 subjects were selected for tactile sensory evaluation. The results were collected by a 5-level scale sheet, and were analyzed by Excel and SPSS. Based on the evaluation results, in sensory evaluation, there was a short-term memory effect, which led to a difference in subsequent illusory memory (DIM), it affected the results of sensory evaluation. There was a cognitive behavior difference in tactile evaluation of fabrics. In a sensory evaluation sequence for thickness test, the evaluation value was influenced by the previous sample. Cognitive evaluation of thickness of fabric was also affected by its surface property.

Keywords: Fabric hand · Cognitive behavior · Sensory analysis · Tactile evaluation

1 Introduction

Skin of body is the soft outer tissue covering of human with three main functions of protection, regulation, and sensation. It is the largest organ of human body with a total area of 1.5–2 m^2 and a thickness of 0.5–4 mm [1]. The skin interfaces with the environment and is the first line of defense from external factors. Hands and fingers are very important organs of human beings, sensation is one of the significant functions of hand for temperature, pressure, roughness, hardness, friction and so on, because of the dense distribution of the sensory nerves at the hands, fingertips in particular.

Fabric hand or fabric handle is the "feel" of the fabric, the way the fabric feels when it is touched. The fabric hand is everything you can tell by touching a fabric with your hands: texture, drapability, stretch, wrinkle resistance, etc. it is the sum total of the sensations expressed when a textile fabric is handled by touching, flexing of the fingers and so on [2]. It is the comprehensive evaluation of the mechanical properties of fabrics. The hand evaluation of fabric is the psychological cognition and experience

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when people interact with fabrics and clothing. The tactile evaluation of fabrics is an indispensable part of fabric hand evaluation. There are two methods used for fabric hand evaluation: objective evaluation and subjective evaluation. The objective evaluation refers to a mechanical equipment measurement, professional instruments are applied to measure the physical properties of fabrics directly. The comprehensive hand value of fabrics is obtained from a data analysis. The measured value is objective and accurate relatively. However, the implementation is complicated, and requires special equipment and professional technicians, in specific occasions with great limitations. Sensory analysis experiment is used as a subjective evaluation method. Subjective cognitive behavior is evaluated in the interaction of subjects and experimental target. Psychological scale is used to reflect the subject's cognition of the experimental target. Subjective analysis is simple and feasible, it is also susceptible to external conditions, leading to inaccurate experimental results. Both methods have its advantages and disadvantages in different application.

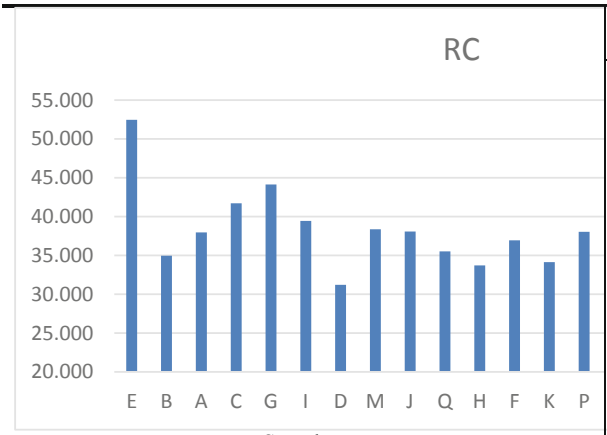
Objective evaluation is usually conducted using a special equipment with high accuracy of results. Kawabata Evaluation System (KES) and Fabric Assurance by Simple Testing (FAST) are the widely used devices for objective evaluation. Tokmak investigated the relationship between KES and FAST [3]. Some researchers developed some new method for the objective evaluation of textile hand, Strazdienė and Gutauskas proposed a new method for tensile property testing by pulling a disc-shaped specimen [4]. An artificial finger was developed to evaluate the tactile perception by Chen et al. for tactile evaluation [5]. Some researchers using the two methods for fabric hand evaluation, such as tactile properties of wool [6], wetness sensation [7], and thermal sensation of wet fabrics [8], to obtain the accuracy and reliability of fabric's hand subjective evaluation [9, 10].

New intelligent technologies were developed to predict fabric hand value based on objective or subjective evaluation. An intelligent method was proposed for fabric hand evaluation and prediction of fabric formability for men's suits [11], and a fuzzy neural network (FNN) prediction system is explored with a prediction accuracy over 80% in the past report [12]. Subjective evaluation method is easy for implementation without some special equipment, which is widely used for various evaluation. Kandzhikova developed a methodology to determine the weight coefficient of the factors involved in the evaluation for terry fabrics handle [13], subjective evaluation also can be used to assesses the comfort of functional fabrics for smart clothing [14] and fabrics for protective clothing [15].

Tactile sensation is a common method to evaluate textile products, such as stiffness, roughness, thickness and other properties of fabric. Friction of fingertip skin was measured to study the tactile perception [1] in previous report. Tactile sensation also was used to evaluate quality and aesthetic of woo fabrics [16]. Subjective cognitive behavior is evaluated in the interaction of subjects and experimental target, it is influenced by some test condition, subject situation and the experimental target. In the paper, we investigated the cognitive behavior difference in tactile evaluation of fabrics based on sensory analysis. It was found the surface property of fabric sample and different evaluation sequence would influence the sensory evaluation. And the Subsequent illusory memory (DIM) would cause a cognitive behavior difference.

Table 1. Characteristics of samples

(a) KES-FB3 Compression properties



Sample	LC	WC (gf/cm2)	RC %	Tm mm	To mm
A	0.	0.16	34.	0.	0.
B	0.	0.18	52.	0.	0.
C	0.	0.18	36.	0.	0.
D	0.	0.16	44.	0.	0.
E	0.	0.18	39.	0.	0.
F	0.	0.22	38.	0.	0.
G	0.	0.30	34.	0.	0.
H	0.	0.24	32.	0.	0.
I	0.	0.34	31.	0.	0.
J	0.	0.27	38.	0.	0.
K	0.	0.33	33.	0.	1.

(b) KES-FB4 Surface properties

Sample	Surface				Back			
	Warp		Weft		Warp		Weft	
	MIU -	SMD (μm)	MIU -	SMD (μm)	MIU -	SMD (μm)	MIU -	SMD (μm)
A	0.12	4.26	0.12	2.82	0.13	4.44	0.13	2.70
B	0.18	4.56	0.18	4.20	0.18	4.13	0.18	4.32
C	0.14	8.28	0.15	2.24	0.14	2.37	0.15	2.52
D	0.15	3.32	0.14	2.23	0.14	2.22	0.15	2.47
E	0.15	2.78	0.16	3.15	0.16	2.32	0.18	4.26
F	0.13	13.40	0.14	15.53	0.14	15.70	0.14	15.98
G	0.15	7.95	0.16	8.82	0.16	6.59	0.16	8.23
H	0.17	5.88	0.16	3.45	0.16	3.61	0.16	7.42
I	0.15	1.53	0.16	3.32	0.16	4.31	0.16	2.01
J	0.15	12.54	0.14	10.76	0.14	13.09	0.15	11.53
K	0.16	1.95	0.16	4.07	0.15	5.55	0.14	3.00

2 Experiments

To investigate the cognitive behavior difference in tactile evaluation of fabrics. In our experiment, it was focused on the relationship and interaction between the surface characteristics (roughness and friction) and the compressive properties (perceive thickness) of the fabrics, to find out the correlation and interaction between the two aspects.

In this study, the subjective evaluation method was used to evaluate the tactile properties of 11 different fabrics named A, B, …, J, K, including plane, twill and satin weaves. Samples were cut into a square with sides that were 20 cm in length. The basic properties of the samples were tested using Kawabata Evaluation System for Fabrics (KES-F) after placing into a thermostatic chamber for 24 h under condition of 21±1 °C, RH65±5%. Each sample was tested 3 times to get its average parameter, and the characteristics of the samples are shown in Table 1 (a) and (b). 30 subjects were selected for tactile sensory evaluation with the average age of 21.2 including 20 female and 10 male university students. Tactile sensory evaluation experiments were conducted in a room with controllable temperature and humidity set as 21±1 °C, RH65±5%.

The critical issue discussed in this paper is the perceive thickness of the same fabric sample was evaluated in different evaluation sequences to confirm whether there was a cognitive difference in different evaluation sequence. To investigate this issue, we randomly arranged the sensory evaluation sequence, and randomly repeated some fabric samples in the test sequence to verify the hypothesis of cognitive difference in tactile evaluation of fabrics. In this experiment, sample A, C, F, G, H, I, J, K were repletely evaluated 2 to 4 times randomly. The evaluation sequence is shown in Table 2. For example, the 2nd sample ^{K}I in the sequence means the I sample is tested after K sample.

The subjects are asked to use fingertips of one hand to pick up the sample and sliding with thumb and other fingers as shown in Fig. 1. Subjects "feel" the 11 fabric samples to understand the coverage of 5-level scale of the sample thickness with a patch over his eye, and then have a three-minute break. After that, they give an evaluation value of thickness in the assessment table whit a ten-second time interval between two samples.

The results were collected by a 5-level scale sheet, and were analyzed by Excel and SPSS.

Table 2. Tactile evaluation sequence

Sequence	1	2	3	4	5	6	7	8	9
Sample	K	^{K}I	^{I}G	B	^{B}A	^{A}H	D	^{D}C	^{C}K
Sequence	10	11	12	13	14	15	16	17	18
Sample	^{K}F	E	^{E}G	^{G}A	^{A1}C	^{C}I	^{I}F	^{F}J	^{J}K
Sequence	19	20	21	22	23	24	25		
Sample	^{K}H	^{H}G	^{G}J	^{J}I	^{I}K	^{K}A	^{A2}C		

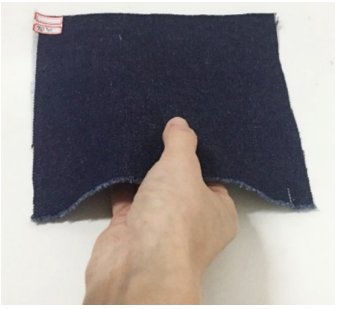


Fig. 1. Tactile evaluation of fabrics

3 Results and Discussion

We measured the surface property and compression property of the samples. Standardizing the collection of data helps to analyze and compare the date differences. Standardized data is shown in Table 3 and Fig. 2. The surface roughness of warp direction is marked as *SMD-swa*, measured thickness is marked as *To*, and evaluated thickness is marked as *Toe*, as shown in Table 4, the average value of thickness collected from 30 subjects.

Table 3. Standardized characteristics data of samples

Sample	Surface		Back		Thickness
	Warp	Weft	Warp	Weft	
	SMD-swa	SMD-swe	SMD-bwa	SMD-bwe	To
A	1.92	1.18	1.67	1.20	1.00
B	2.02	1.59	1.57	1.66	1.57
C	3.27	1.00	1.05	1.15	1.94
D	1.60	1.00	1.00	1.13	2.03
E	1.42	1.28	1.03	1.64	2.38
F	5.00	5.00	5.00	5.00	2.95
G	3.16	2.98	2.31	2.78	3.18
H	2.47	1.37	1.42	2.55	3.40
I	1.00	1.33	1.63	1.00	3.63
J	4.71	3.56	4.27	3.73	3.78
K	1.14	1.55	2.00	1.28	5.00

Table 5 shows the significant difference between *Toe* and *To*, except sample H and J, H and J repeated 2 times in the tactile evaluation, other samples repeated 3 or more times show significant difference at 0.05 level ($P < 0.05$). It indicates that the results of subjective sensation show deference to the objective measurements, and the same sample shows different value if it has a different position in the tactile evaluation sequence.

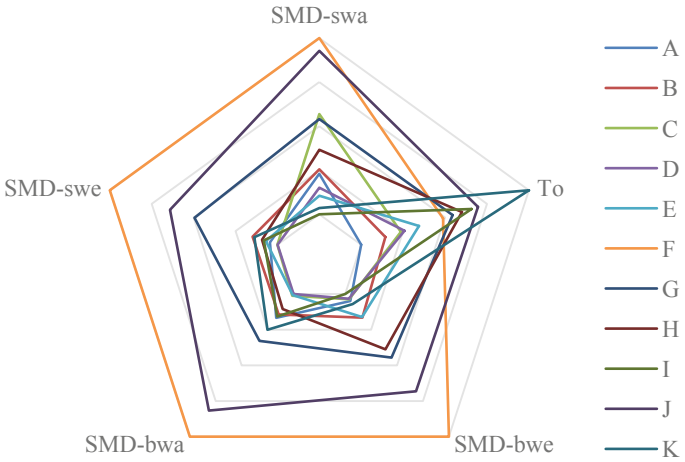


Fig. 2. Standardized roughness and thickness of samples

Table 4. Tactile evaluation of thickness of samples

Sequence	1	2	3	4	5	6	7	8	9
Sample	K	^{K}I	^{I}G	B	^{B}A	^{A}H	D	^{D}C	^{C}K
Toe	3.47	3.16	3.47	2.00	1.68	3.74	1.84	2.74	3.42
Sequence	10	11	12	13	14	15	16	17	18
Sample	^{K}F	E	^{E}G	^{G}A	^{A1}C	^{C}I	^{I}F	^{F}J	^{J}K
Toe	4.68	2.26	3.63	1.42	2.84	2.89	4.74	4.21	3.16
Sequence	19	20	21	22	23	24	25		
Sample	^{K}H	^{H}G	^{G}J	^{J}I	^{I}K	^{K}A	^{A2}C		
Toe	3.42	3.68	3.68	2.84	2.58	1.32	2.79		

Table 5. Significant difference between *Toe* and *To*

Sample	A	C	F	G	H	I	J	K
Sig.	.000	.050	.011	.023	.463	0.22	.645	.003

In a tactile evaluation sequence, the evaluation value is influenced by the previous sample. If the previous sample has a greater thickness, the evaluation value of the current sample will get a stronger influence and shows lover value, according to Tables 6 and 7. The surface property of fabric sample also affects the cognitive evaluation of fabric thickness. Sample has coarser surface, the evaluation value of thickness tends to be smaller than reality and vice versa, according to Tables 3 and 4.

Table 6. Tactile evaluation of thickness of samples A

Sample	^{B}A	^{G}A	^{K}A	A	B	G	K
SMD-swa		1.92		1.92	2.02	3.16	1.14
SMD-swe		1.18		1.18	1.59	2.98	1.55
SMD-bwa		1.67		1.67	1.57	2.31	2.00
SMD-bwe		1.20		1.20	1.66	2.78	1.28
To, Toe	1.68	1.42	1.32	1.00	1.57	3.18	5.00

Table 7. Tactile evaluation of thickness of samples C

Sample	^{D}C	^{A1}C	^{A2}C	A	C	D
SMD-swa		3.27		1.92	3.27	1.60
SMD-swe		1.00		1.18	1.00	1.00
SMD-bwa		1.05		1.67	1.05	1.00
SMD-bwe		1.15		1.20	1.15	1.13
To, Toe	2.74	2.84	2.79	1.00	1.94	2.03

From the perspective of cognitive psychology and medical neuroscience, in sensory evaluation, there was a short-term memory effect, which leads to a difference in subsequent illusory memory (DIM), it affects the results of sensory evaluation. This effect is more significant when the time interval of continuous experiment is shorter. The cognitive behavior difference of tactile evaluation caused by a DIM. The time interval is a key factor which is cannot be ignored in sensory evaluation.

4 Conclusions

In this study, we conducted a sensory evaluation of fabrics, 30 subjects were selected to evaluate the thickness of fabrics. To investigate the cognitive behavior difference in sensory evaluation, we setup a distinctive evaluation sequence with some fabric sample repeated to confirm the cognitive difference.

Based on the experiment and the results, it was found that the results of subjective sensation showed deference to the objective measurements. In a sensory evaluation sequence for thickness test, the evaluation value was influenced by the previous sample. Current evaluated sample showed lower value if the previous sample had a greater value. Cognitive evaluation of thickness of fabric was also affected by its surface property, the evaluation value trends to smaller if the sample had a coarser surface, and vice versa.

Subsequent illusory memory (DIM) caused cognitive behavior difference of sensory evaluation. In sensory evaluation, the time interval between two sample is an important factor affecting evaluation result. Appropriate time interval is essential to offset the short-term memory effect in sensory evaluation.

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Human Factor in Apparel and Fashion Exhibition Design

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Abstract. The need to preserve past cultures, textile and clothing creations, identities of a society in a certain time period, made the development of exhibition design area relevant. Exhibition spaces must give innovative answers to the aspirations of the society, which are the visitors, reason of being of its existence. In this framework, human factor is essential in the exhibition design field.

The present article intends to address essential points regarding human factor in its relation with the design of exhibitions of fashion and clothing products. Thus, we intend to equate and emphasize the role of the exhibition designer in solving issues related to human factors, both with regard to exhibition design projects and also with regard to the visitor/user experience of the exhibitions. In this sense, through the literature review and the presentation of examples it is our intention to clarify concepts and modes of action.

Keywords: Human factors · Exhibition design · Apparel and fashion design · Design · User/visitor

1 Introduction

The relationship between the disciplinary areas of design and museology is increasingly important, particularly in the museography area and in the problematic of exhibition and fashion activities and projects. The movement of the new museology opened dimensions and fields of work with multiple applications and senses. With the new concepts and purposes, new museographic practices are now necessary as a response to a society of cultural consumption. The need to preserve past cultures, in particular textile, fashion and clothing creations, the identity of a society of a certain period, made the development of the exhibition design area relevant.

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The museum ceased to be a hermetic and delimited space, became an open process in permanent interaction with the community and the territory of belonging. It is a condition of the museum to preserve and communicate. The communication takes place through various means, among which the exhibition gain special relevance. Everything can be musealized in terms of social, cultural, scientific and educational objectives. The museum is a space of knowledge and enjoyment, a place of citizenship, where design can intervene with its thinking, methodologies and instruments. Thus, the museums field find in design a fundamental support to make visible and understandable textile objects.

As a multidisciplinary area, design relates to the most varied disciplines, acting as a foundation and complement. The design of exhibitions emerges as a field of action, specific and directed to the display area. Thus, the exhibition spaces must give innovative answers to the society aspirations, which are the visitors, reason of being of its existence. In this field, human factors, in its relation with space and objects, are essential because without visitors the exhibition objects are lost. In order to work on these assumptions, by designing creative, coherent, functional, attractive spaces that maximize the visitor's experience, in view of the exhibition of fashion and clothing products, we highlight the discipline of exhibition design, which acts as an intermediary between the exhibition and the visitor. The importance of exhibition design as a means of communication between the object/art and the observer/visitor has come to play a fundamental role over the years.

2 Exhibition Design and Human Factor

Exhibition design is an activity that designates and plans in order to produce or install a communicative expository method through exhibits that use the fundamentals of interior design, equipment design and graphic design, as Fernández and Fernández [5] says.

The realization of exhibition spaces is increasingly recognized as an area of creative expression that uses a process of interaction between the most varied disciplines, such as architecture, design, museography and museology, stage design, lighting, audiovisual and multimedia. According to Dernie [4], in a global way, the term exhibition means *"(…) proposing, offering, displaying the result of the work"* (p.6). Belcher [1] says that an exhibition is like a show. In this sense, *"(…) everything in the world is an exhibition of one kind or another"* (p. 51). They can be commercial or cultural, from exhibition fairs, brand exhibitions, launch events or consumer pavilions, to museums and galleries of all kinds or artistic installations. What they have in common is the fact that they have at their base *"The idea of explaining a story in a three-dimensional space"* [7] (p. 10).

Analyzing the expositions according to their typology or exhibition mode, Fernández and Fernández [5] consider four types of functions: symbolic, commercial, documentary and aesthetic. The first is aimed at political or religious elevation or just

the show of objects. The commercials are oriented towards the value of the product to be exposed. The documentaries are directly linked to informative and scientific value of the exhibition products, in order to disseminate knowledge. Finally, the aesthetics are sedimented in the artistic value of the works. Regardless of type, the design of exhibitions is done with specific objectives in the sense of social and cultural inclusion. Design competencies in this area must be bi-dimensional and three-dimensional. For, what is exposed must be explained and well exposed, requiring good communication to be well seen and well interpreted by visitors. The exhibition projects are extremely important for promoting, showing, teaching and disseminating past cultures and knowledge of the present [3].

In the past, the most important was the object and its information. Nowadays, the visitor is attracted more and more by expositions whose expositive method belongs almost exclusively to the design world. The light, the color, the audiovisuals, the touch and the relation of the senses make the visitor himself part of the exhibition, never losing sight of the educational and cognitive. For better consolidation, exhibitions tend to be interactive and didactic. In this field, there is a strong intervention of the visitor with the exhibition contents and with the space [2].

The exhibition space configures in practice all the elements, including the objects. It is a determining factor of the exhibition visitor's experience, a determination that has had different interpretations over time, accompanied by the evolution of exhibition methods. Since the twentieth century, the public gained a place as a protagonist, as a catalyst for cultural consumption in museums. The growing number of audiences in museums led to a series of circulation studies by the architects of the modern movement. Le Corbusier, Mies van der Rohe and Frank Loyd Wright were pioneers, creating flexible, modular and extensible exhibition solutions in their architectural projects. There are several studies on the organization of space, graphically expressing different expository paths through diagrams, but the human dimension should be central to defining these aspects. Therefore, in an exhibition of fashionable objects it is necessary to take into account the minimum measures of the body width, front and side, as well as its height, this with respect to the static body. Then it is also necessary to consider the rotation angles of the head, trunk and eyes.

Inclusivity in terms of exhibition spaces is also one of the essential premises of design and museology. Thus, the exhibition contents must be placed within the limits of the visitors visual fields with special mobility needs, as well as the visitors that accompany them. The exhibition organization should allow the visualization of the displayed objects by the citizen with reduced mobility in two different ways: front and side. In order to be able to make a 90° rotation, the circulation space must have the necessary measures to allow this movement (Figs. 1, 2, 3 and 4).

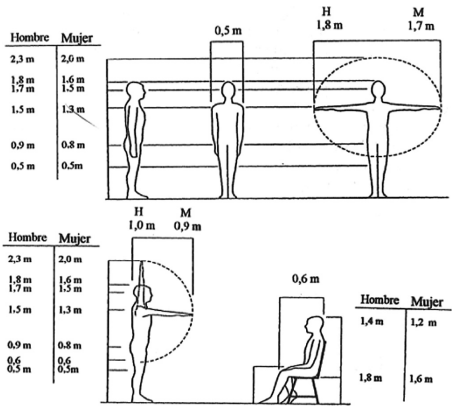
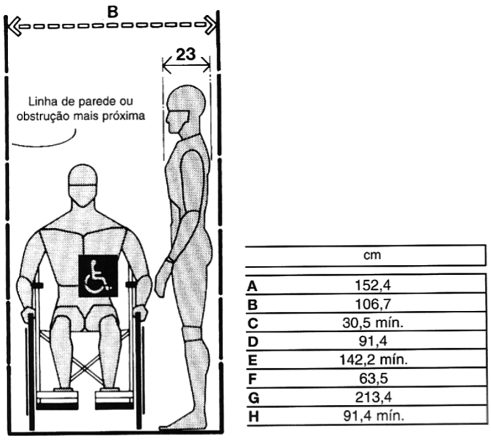


Fig. 1. Human dimensions [Dean, 1994 apud Fernández & Fernández, 2007:52].



	cm
A	152,4
B	106,7
C	30,5 mín.
D	91,4
E	142,2 mín.
F	63,5
G	213,4
H	91,4 mín.

Fig. 2. Partial circulation for two people [Panero & Zelnik, 2002:270].

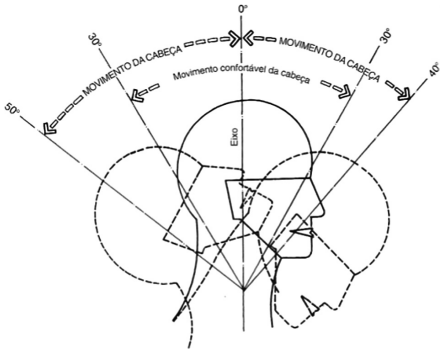


Fig. 3. Movement of the head in the vertical plane [Panero & Zelnik, 2002:286].

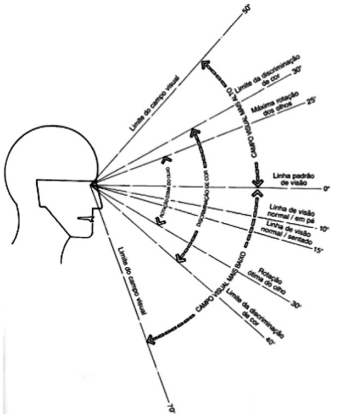


Fig. 4. Field of view in the vertical plane [Panero & Zelnik, 2002:287].

The studies of Herbert Bayer make a great contribution to the conceptual and technical foundation of the designers. The "Field of Vision" diagram demonstrates the principle that graphic support surfaces should be oriented towards the viewer, in view of an optimized effect [3]. The available exhibition space is delimited according to the angle obtained by the eyes, head and neck (Figs. 5 and 6).

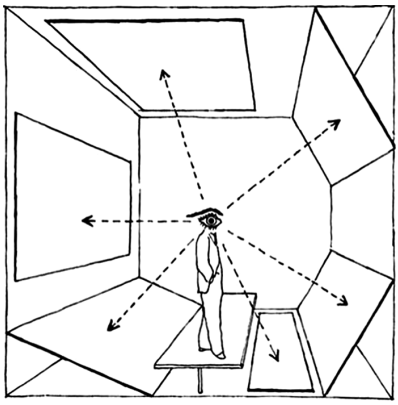


Fig. 5. Field of vision. Diagram of Herbert Bayer based on the idea of the human visual field [Fernández & Fernández, 2007:112].



Fig. 6. Deutscher Werkbund Exhibion, Paris, 1930 [Fernández & Fernández, 2007:113].

Not only space, but also the type of objects will condition human behaviour. The specifications when two-dimensional objects are exposed differ from three-dimensional objects, since the height component (Z in the cartesian coordinate system) will assign depth and volumetry to the pieces. We can consider painting, photography, textiles, drawings, posters as two-dimensional objects, as well as three-dimensional objects, such as sculpture, utilitarian objects, furniture, fashion and clothing, among others. Regardless of type, objects should be placed within the human visual field, where the average height of the eyes of a child, an adult and a person in a wheelchair should be considered. In the case of hand-held small objects, the exhibition equipment should allow the visitor's approach for better observation. The distance from the eyes to the object will directly interfere with your enjoyment, as well as with your perception.

In all the exhibitions there is a story to tell or a message to be transmitted that is not limited only to the exhibition of the objects. It is also necessary a whole process of creating texts, based on the interpretation of the object exposed. Hughes [6] stresses the importance of letter size and text, which may be perceptible at a distance and not at all. In many cases, designers develop a hierarchy of signals at different scales, according to the informative and communicational nature: large size for signage, medium size for thematic identification of zones and small size for text body and for object legends. The author also highlights the fact that the text is created based on the behaviour of the visitor and their perception of space.

The quality and type of lighting will also influence the way we perceive the exhibition space and objects. The way the space is illuminated can even indicate the exhibition route to follow by the visitors. The light is directly connected with the vision, so the light intensity should be sufficient to ensure good visibility. In exhibitions, "*The approach to lighting is very similar to that of theater, but there is a significant constraint: lighting equipment must be hidden so as not to destroy the*

illusion of actual experience" [8] (p. 161). However, the lighting imposes some care of the parts conservation. Some (organic) textile materials are damaged by exposure to light and, so that they do not degrade more rapidly, their exposure should be limited.

3 Human Factor in Fashion Design Exhibition

Fashion and textile design is designed with the user in mind. Like the design of exhibitions, fashion, clothing and textile products are designed based on anthropometric and ergonomic measures. It is increasingly permeable to the world around it, accompanying the evolution and needs of man and the context in which he was inserted. The technical reproducibility opened up the cultural and creative industries, where fashion and clothing design gained expression. In the fashion world, where the inspirations are diverse and the limits of creativity are infinite, textile productions have gained special relevance for museums, bringing to light exhibition, conservation and restoration needs. Several fashion, apparel, costume and design museums (with fashion and clothing collections) were created in an attempt to preserve the past, educate and stimulate, presenting the new. According to Valencia and Andújar [9], *"Today's society demands to seek new models of exposure, demand, in part, provoked by a new culture or new models of understanding culture"* (p. 21). The incessant search for differentiation sometimes leads to the search for concepts or recurrent practices in parallel creative areas.

The iconic temporary exhibit "China: Through the Looking Glass" by the Metropolitan Museum of Art (MET) in New York, in 2015, clearly portrays different levels of human factor intervention in exhibition design. Having been one of the MET's most visited exhibitions, the large number of visitors created some imponderables in the circulation, as well as in the minimum dimensions necessary for movement in the space, taking into account the high number of people. This aspect interfered both in the visual relation with the displayed object and the set, as well as in the questions of the proxemia. Of the distances defined by the anthropologist Edward T. Hall (intimate, personal, social and public), the one that prevailed more was the intimate distance, causing some discomfort between the visitors/users during the visit. Although the space is not small, the large number of people, in the same space, has made it limited. Considering that the intimate distance presupposes an approximation of up to 40 cm, which, therefore, easily allows the physical contact.

Fashion and clothing allow the use of exhibition techniques applied to two-dimensionality and three-dimensionality. However, the trend is to expose the most important pieces in three-dimensional mode since it allows their visualization to fullness. Mirrors can also be used to allow 360° viewing (Fig. 7).



Fig. 7. "China: Through the Looking Glass" Exhibion, MET, 2015 [Foto by Carreto & Carreto, 2015].

Concerning the rotation of the eyes, head and trunk, the exhibition *"China: Through the Looking Glass"* has several levels of observation. Smaller and more minutia objects were placed at eye level, while larger objects were placed at ground level, simulating, as in the figure below, the object in an original context. Video projections were also used as an expository complement. The projection occurs at a higher level, above the height of the visitor, in order to allow the image not to be obstructed and that all visitors can see. The size of the gallery allows the detachment required for an ergonomically comfortable viewing, not putting the neck into tension (Figs. 8 and 9).



Fig. 8. "China: Through the Looking Glass" Exhibion, MET, 2015 [Foto by Carreto & Carreto, 2015].



Fig. 9. "China: Through the Looking Glass" Exhibion, MET, 2015 [Foto by Carreto & Carreto, 2015].

Display cabinets control the environment of the piece, in terms of conservation and safety, and also allow the installation of lighting equipment. In this type of exhibitors it is necessary to take into account the glare reflected by the exterior lamps, whose incidence angles are not well calculated will interfere with human visual perception [8] (Fig. 10).

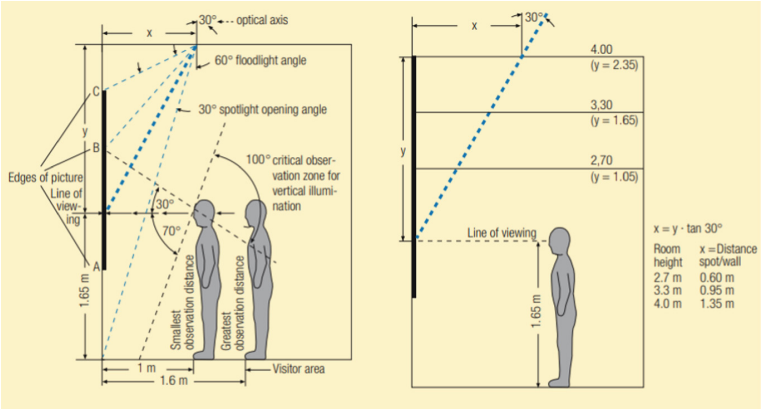


Fig. 10. Calculation of the optimal positioning of a luminaire for pictures on a wall [Retrived from: http://en.licht.de/fileadmin/Publications/licht-wissen/0703_lw18_E_light_museums_galleries_web.pdf, access date 2nd June, 2018].

In the figure below, the lighting intervention transports the visitor along the pieces. Here, in addition to lighting, sounds were used that contextualize the original environment of the piece. In this example, the Guo Pei dress is placed in the center of a base that not only lifts the piece, allowing for its full enjoyment, but also delimits access to visitors (Fig. 11).



Fig. 11. "China: Through the Looking Glass" Exhibion, MET, 2015 [Foto by Carreto & Carreto, 2015].

4 Conclusions

Exhibition design, such as fashion design and apparel, is a constantly updated creative area. The need for the preservation and dissemination of past cultures, in particular textile, fashion and clothing creations, the identity of a society of a certain time period, makes relevant the development of the area of exhibition design. The fashion, although it may be considered artistic creation, is to be worn/worn by people, where the various human factors must be guarded, in terms of dimensions, textures, colors and materials.

When designing an exhibition of fashion and clothing products, the human factor in its relationship with space and objects is essential, since visitors are the main elements and without them, the objective of the exhibitions is lost. In this area, it is essential to take into account the type of lighting and circulation in space, the colors used, the height and distance to which the exhibition object is placed, the minimum dimensions of the human body and the rotational movements of the trunk, head and eyes, as well as the size and legibility of the letters and texts that support the exhibition. With the change of the exhibition paradigm, visitors are increasingly looking for didactic and interactive exhibitions. Today they visit exhibitions not only for their fruitive character, but mainly for the educational and cultural.

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Distribution of Clothing Pressure in Support Knee-High Socks and Its Evaluation

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Abstract. The relationship between clothing pressure and the evaluation of tightness of the lower leg and foot was examined. Participants were nine young Japanese women in their twenties. Clothing pressures were measured adopting a hydrostatic-pressure balanced method as participants wore three SKSs while standing. The pressure feeling was evaluated employing a ratio scale. The order of the average clothing pressure was sample A > sample B > sample C. However, the feeling of pressure was not in the same order (B > A > C). Our results show that the feeling of tightness depends on the position on the body, and the distribution of clothing pressure is thus important in the development of SKSs. A preferred SKS provides higher pressure for the foot than for the calf/ankle.

Keywords: Clothing pressure · Support knee-high socks · Pressure feeling

1 Introduction

Compression wear for the lower half of the body is expected to reduce swelling and improve the leg shape but its effects on human health and stress remain controversial. Tamura [1] reported that the level of clothing pressure affected not only wearing comfort but also health. The relationship between swelling of the lower half of the body and the current purchasing trends of support knee-high socks (SKSs) was examined in an online questionnaire of 1425 female Japanese consumers aged 10 to 60 years. The questionnaire revealed an awareness that swelling is closely related to the total time spent walking and sitting, and respondents were particularly aware of swelling at evening and night. Among participants who were aware of swelling of their bodies, 79.3% reported swelling in the lower halves of their bodies, such as the calf, ankle, and instep [2]. We therefore expect that knee-high socks are a desirable product to develop. The situation of swelling of the lower leg and foot has been examined for people not wearing SKSs. Relative volumes have been measured for healthy young females sitting for 8 h. The volumes of the lower legs and feet increased slowly from morning to evening whereas the volume of the ankles rapidly increased around noon [3, 4]. The relative volumes of the lower leg and foot, the clothing pressure of SKSs, and the feeling of the tightness of SKSs have thus been measured for three conditions: condition A in which loosely fitting SKSs are worn, condition B in which tightly fitting SKSs are worn, and condition C in which loosely

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fitting SKSs (condition A) are worn with added support of the calf. The clothing pressures of the calf and foot under condition A and the clothing pressure of the foot under condition C were lower than 5 hPa, and a loose feeling was felt. Meanwhile, the clothing pressures of the calf and foot under condition B and the calf under condition C exceeded 20 hPa, and a tight feeling was felt. The calf relative volume increased 4% under condition A but did not increase for condition B or C. The foot volumes did not differ significantly among conditions A, B, and C. The relative volume of the tightened part of the calf significantly decreased for both partial and total tightening [5]. When the ankle is constricted and the clothing pressure increases, the volume of the ankle decreases whereas the volume of the foot increases. However, the foot volume does not increase when the ankle is constricted, resulting not in a tight-fit feeling but in a perfect-fit feeling. Our final goal is to make comfortable SKSs that prevent swelling. Using three types of SKS, comprising two commercial SKSs and SKSs that we made, the present paper investigates the relation between comfortable clothing pressure and the feeling of pressure.

2 Experiment

2.1 Participants and Samples

An experiment was conducted for nine Japanese female participants in their twenties, whose physical dimensions are given in Table 1. Participants were nonsmokers, had no history of systemic disease, and were not engaged in physical training or dietary programs. Their figures ranged from slender to slightly overweight. Clothing pressures on the abdomen depend on the menstrual cycle of the participant, with the pressures in the luteal phase being higher than those in the follicular phase [6]; the former phase was thus chosen in the present study. Experiments were carried out over four days from the luteal phase latter half to the menstrual phase former half. Clothing pressures were measured for the participants wearing three types of SKS, and the tightness feeling was evaluated as follows (See Sect. 2.4).

Table 1. Physical constitutions of participants

Age (Year)	Hight (cm)	Weight (kg)	Under knee girth (cm)	Calf girth (cm)	Ankle girth (cm)	Arch girth (cm)	BMI (kg/m^2)
22.1 ± 0.4	157.1 ± 5.8	53.5 ± 5.7	21.7 ± 2.0	35.0 ± 1.7	20.9 ± 1.6	22.3 ± 1.3	21.7 ± 2.0

The three types of SKS used in the present study are shown in Fig. 1. Samples A and B were commercial SKSs while sample C was our own product. Each sample came in two sizes; i.e., foot lengths of 23 and 25 cm (corresponding to sizes medium and large). All samples were made from nylon, cotton, and other materials. Each sample was stretched using an AUTOGRAFH (AGS-H, Shimadzu, Japan) at a pulling speed of 300 mm/min, maximum load of 3.5 kgf, holder width of 10 mm, and exposed core of 10 mm in a climate-controlled room (environmental temperature, 20 °C; relative humidity, 65%), and the relative stretching rate was calculated in six directions as shown in Fig. 2.

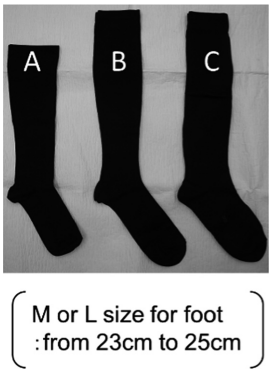


Fig. 1. SKS samples

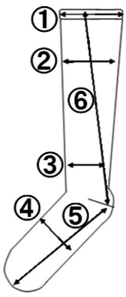


Fig. 2. Measuring positions for stretching

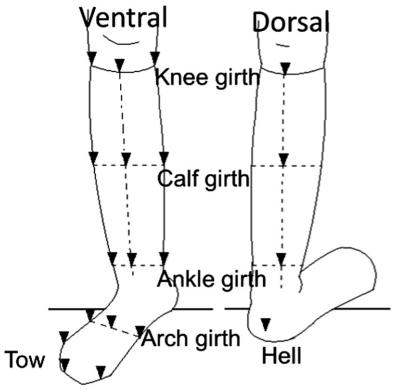


Fig. 3. Measuring points for clothing pressure

2.2 Experimental Schedule

Two experiments, Experiment I (control) and Experiment II (in which participants wore samples) were carried out following the schedule shown in Fig. 4. Participants awoke at 05:30 after 7 h of sleep and ate breakfast until 06:00. They then entered a climate-controlled room (environmental temperature, 24.5 ± 0.3 °C; relative humidity, 50.3 ± 2.5%; lumination, 827 ± 27 lx; air current, 8.0 ± 0.1 cm/s) at 07:00. Participants remained in a sitting posture from 8:00 to 12:00, and the skin temperature of their foot was measured using a thermotracer (TH-3102MRS, NEC, JPN) before and after the 4 h of sitting in Experiments I and II. In experiment II, the clothing pressure and its feeling of tightness were measured after participants wore SKSs.

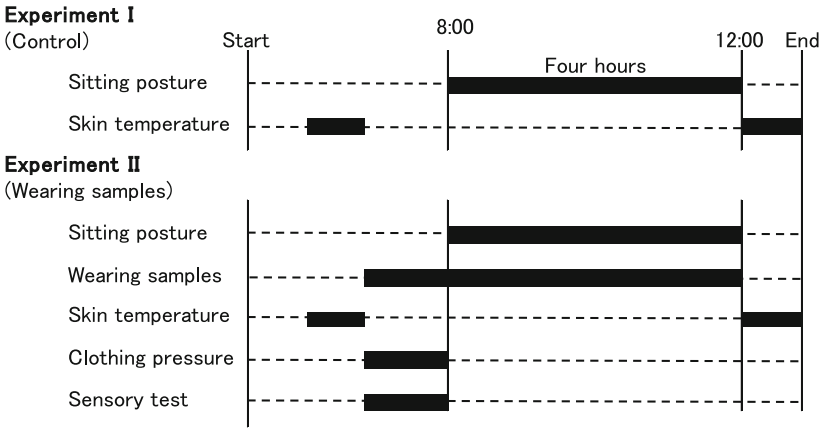


Fig. 4. Experimental schedule

2.3 Measuring System for Clothing Pressure and Measuring Points of the SKS

Clothing pressures were measured adopting a hydrostatic-pressure balanced method [7] for participants wearing SKSs while standing. There were 19 measuring points on the lower right leg corresponding to the intersections of four vertical lines (anterior/posterior midlines, inside/outside lines) and horizontal lines (under-knee girth, maximum/minimum girths, arch/tow girths), and heel as shown in Fig. 3. The average clothing pressures in the horizontal direction were calculated for all subjects.

2.4 Evaluation of the Feeling of Pressure

The pressure feeling was evaluated employing a ratio scale [8]. Participants evaluated the pressure they felt when wearing SKSs by completing a questionnaire (Fig. 5).

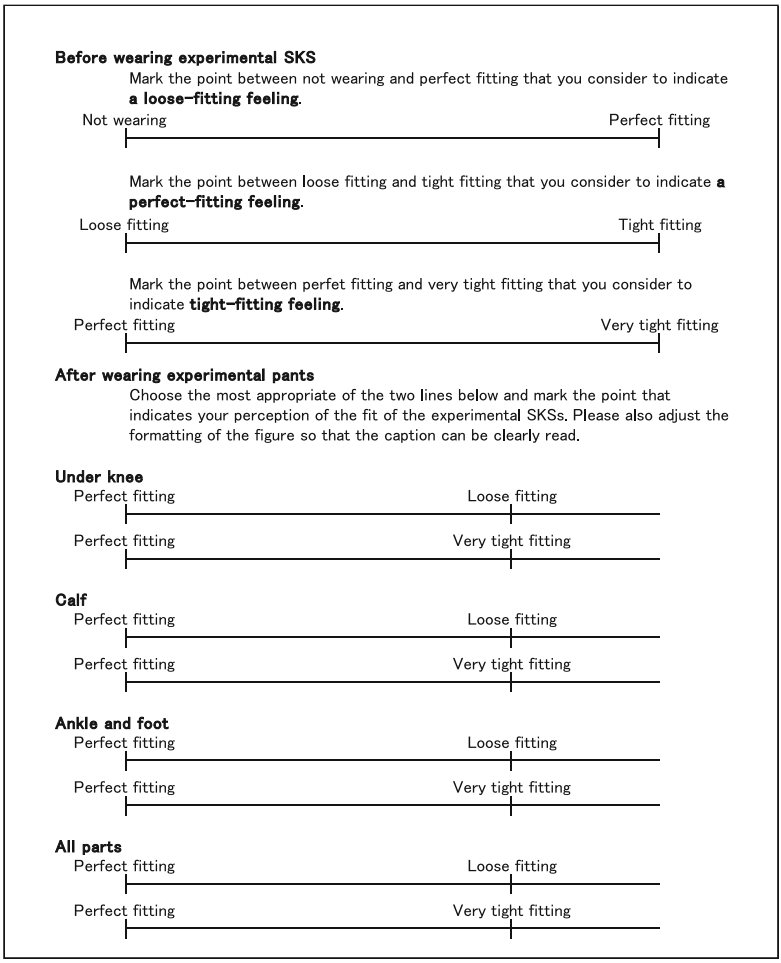


Fig. 5. Questionnaire of the pressure feeling when wearing SKSs

Before putting on SKSs, participants estimated what they considered a loose-fitting feeling, perfect-fitting feeling, and tight-fitting feeling. The participants wearing each SKS were asked to indicate individual pressure feelings to compare with the base feelings, and to mark points on a line in the questionnaire. The length of the line connecting the points marked by the participants to indicate the loose-fitting feeling, perfect-fitting feeling, or tight-fitting feeling was measured. Numerical values for the pressure feeling were obtained by supposing that a feeling of no tightening had a score of zero and a perfect-fitting feeling had a score of 1. In other words, the numerical value exceeded 1 if participants felt the SKS was tight while it was less than 1 if they felt the SKS was loose. The data for each body part (i.e., the lower leg, ankle, foot, and overall) were analyzed by one-factor repeated-measures analysis of variance and, once significance was confirmed, analyzed through multiple comparison employing the Tukey method.

3 Results

3.1 Development of Clothing Pressure of the SKS on a Leg Model

Figure 6 presents clothing pressures of SKSs recorded for the leg model of a Japanese female having an age of 20–30 years (shown on the left). The average clothing pressures along horizontal lines are shown for each SKS. The clothing pressures of sample A were significantly higher than the clothing pressures of samples B and C, while the clothing pressures of B were significantly higher than those of sample C (i.e., A > B > C).

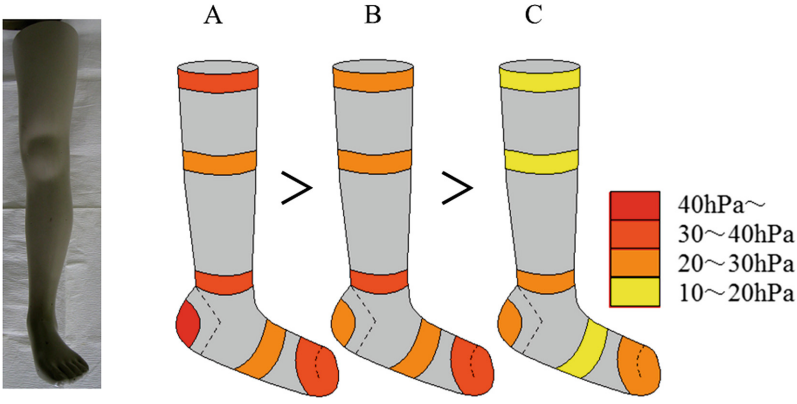


Fig. 6. Clothing pressures of SKSs on a leg model

3.2 SKS Stretching Rate

The stretching rates of SKSs are shown in Fig. 7. The SKSs stretched easily in directions 1–4 and 6 but not in direction 5. All SKSs were produced with greater horizontal stretch than vertical stretch. Sample C had the greatest stretch under the knee

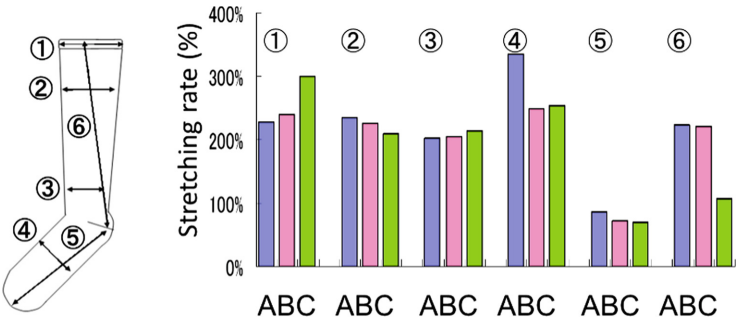


Fig. 7. Stretching rates of SKSs

(i.e., direction 1) and little vertical stretch (i.e., directions 5 and 6). In contrast, sample A/B had grater stretch in the six directions than in sample C.

3.3 Measured Clothing Pressures of SKSs Worn by Participants

Clothing pressures measured for participants wearing the samples are shown in Fig. 8. The overall clothing pressure decreased significantly in the order of samples A, B, and C. The pressures for samples A and C decreased in the order of the foot, ankle, and calf while, for sample B, the clothing pressures of the ankle and foot were almost the same and higher than the clothing pressure of the calf.

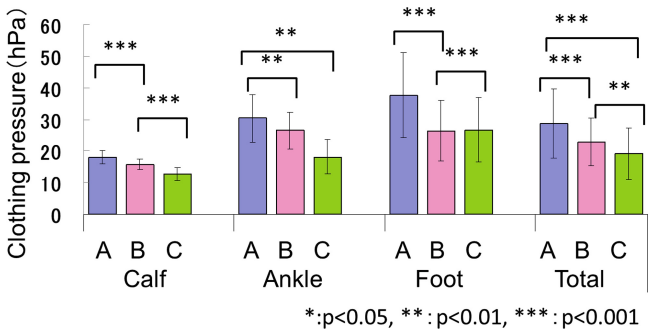


Fig. 8. Clothing pressures measured for participants wearing SKSs

3.4 Evaluation of the Pressure Feeling

The reported feelings of pressure when participants wore SKSs are shown in Fig. 9. The feelings of pressure did not have the same order as the measurements of pressure. There was no significant difference in the feeling of pressure between samples A and B (sample B was slightly tighter than sample A) while sample B felt significantly tighter than sample C.

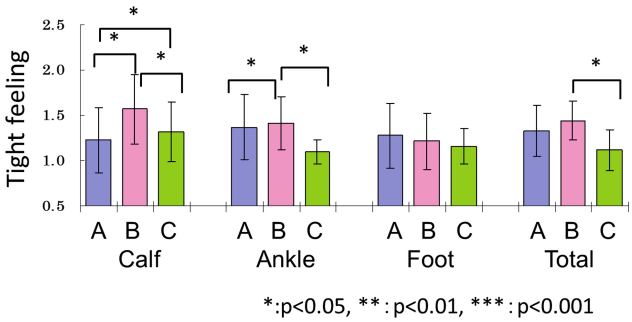


Fig. 9. Pressure felt while wearing SKSs

4 Discussion

The feeling of tightness depends on the position on the body. The distribution of clothing pressure is thus important in the development of SKSs. The skin is not equally sensitive over the body because mechanoreceptors are not equally distributed over the body. Preferred clothing pressure thus depends on the body part, with high pressure being most preferred on the lower leg [7]. The present study found that the preferred pressure order on the lower leg is calf < ankle < foot. That is to say, the preferred clothing pressure becomes higher centrifugally. The order of the overall clothing pressure in the present study was sample A > sample B > sample C; however, the order of pressure feeling was not the same (A/B > C) because the clothing pressures on the ankle and foot were almost the same for sample B. The sequence of pressure that should become higher centrifugally was disturbed. An overall evaluation can thus be established anew by evaluation of the tightness of the ankle. The body surface from the knee to the ankle will have more mechanoreceptors than the foot and the preferred SKS thus provides higher pressure for the foot than for the calf/ankle.

Acknowledgments. Part of this work was supported by the Japanese Society for the Promotion of Science KAKENHI Grant Number 17H01954. We thank Glenn Pennycook, MSc, from Edanz Group (www.edanzediting.com/ac) for editing a draft of this manuscript.

Trial Registration. This study was carried out after the review by the Ethical Review Board for Humans of Shinshu University (approval number 173).

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Woven Fabrics Specially Designed for Thermal Protection and System Recovery of Air Vehicles

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Abstract. The textile industry is an innovative field, a generator of competitive products, absolutely indispensable to many other fields (aeronautics, medicine, shipping, agriculture, environmental protection etc.)

In this philosophy, important researches have been carried out in order to develop new generations of textile products for strategic applications.

The paper presents important issues regarding: the role of helicopter thermal protection system as well as parachute recovery in the main system (supersonic aircraft); design of thermal protection woven structure for thermal protection of the helicopters as well as the woven structure for main parachute of recovery systems for landing of the supersonic aircraft, based on aerodynamic characteristics and areas of use; the main fabric structure characteristics used in the two systems; description of the phenomena occurring on the main parachute canopy at landing of the supersonic aircraft; structural analysis of the main parachute canopy of the aircraft deceleration system; the interdependence between the aerodynamic, geometric and mass characteristics of the considered systems and the characteristics of the fabric. The design and realization of these product types are based on the specific requirements imposed by its fields of application, which governs the system and the selection of components. Typical design and delivery criteria have been considered: safety in operation (the criterion of the greatest importance); mass and volume in order to efficiently use the loading value; stability; reproducibility of performance, etc.

Keywords: Helicopters · Aircraft landing · Supersonic aircraft

1 Introduction

The researches dealt with the identification and solving of some specific objectives substantiated on the exigencies represented by aeronautics industry performances. Base on relevant accomplishments in the aeronautic and textiles fields, a new generation of woven structure with special characteristics for the main parachute surface of the aerodynamic decelerator of supersonic aircraft and thermal protection of the helicopter installation for heating and ventilation was realized, experimented and implemented at the beneficiaries.

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To explain the phenomena occurring on the main parachute canopy, for supersonic aircrafts deceleration at landing, both the theories of the Fluid Mechanics were used, referring to: - the rapidly variable transient movement, - the continuity hypothesis, - the physical properties of the fluids, - the operations the motion of a continuous medium, the limiting layer, the turbulent shuffling, etc., and those specific to the aeronautics field related to the flow of fluid around a sphere [1].

2 Material and Methods

By the scientific design of an original fabric, there was identified and solved, the technological problems represented by deceleration at landing of the supersonic aircrafts and by the thermal protection of the helicopter installation for heating and ventilation.

For establishing the main directions for mechanical processing in order to obtain the textile structures for the two types of products, the constituent filaments of a para-aramid filaments were analyzed (Fig. 1).

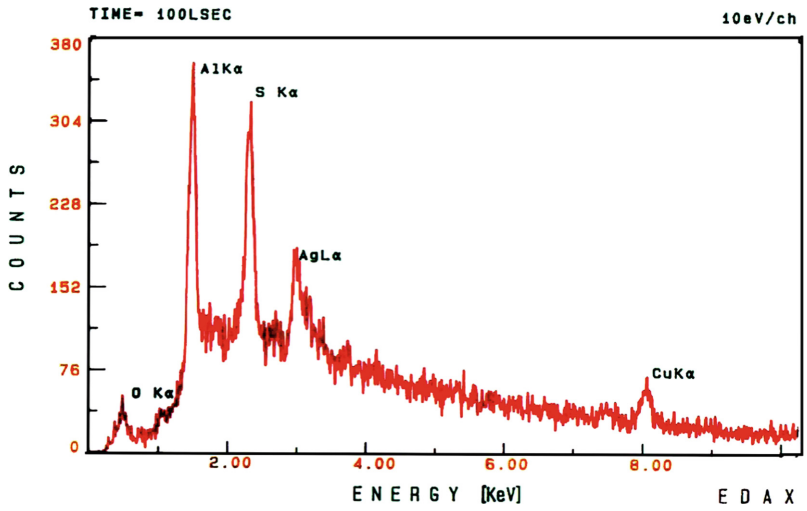


Fig. 1. X-ray spectrum for para-aramidic filament

Considering that this yarn will be used for the thermal protection of the helicopters and the supersonic aircraft deceleration parachute, it has been found that the surface treatment of the filaments revealed by the X-ray spectrum confer to the fabric the necessary characteristics represented by: high thermal conductivity for rapid heat transfer, flame resistance for a long exposure time, good resistance to friction wear, very good resistance to microorganisms during storage.

Designing and accomplishment of the woven structured for the corrugate tube of the thermal protection of the helicopters' installation was based on the specific

requirement represented by weight: max.100 g/m^2; tensile strength warp/weft: min.300/320 daN/5 cm; elongation: max.7,5%; tearing resistance warp/weft: min.14/16 daN; permeability: max.100 l/m^2/s [2].

The final product was tested in real conditions and demonstrate its functionality after at least 10.000 flight hours.

The theories of the fluid mechanics enabled to explain the complex phenomena occurring during the supersonic aircrafts landing that enabled us to design and accomplish the textile structure of the parachute according to the requirements imposed by the application domain.

Thus, in order to discuss the motion equation at the contact with the moving canopy surface was considered that its surface is impermeable and on both sides of the fabric there is a pressure difference comparable to the dynamic current pressure.

Upon landing the aircraft, the fluid is initially in stagnation, then, after a very short time, when the braking parachute enters into operation, the fluid in which this phenomenon occurs is in motion.

At one point (t = 0), the braking parachute enters fully in deceleration mode. In this situation, the fluid particles at boundaries are suddenly stopped, causing the kinetic energy to be transformed into pressure energy and thus a Δp increase in the pressure near it and implicitly an increase in the density of the fluid, causing swelling of the canopy.

Thus, a turbulent motion occurs and the air velocity in front of the canopy is decelerated to zero at the stagnation point [3]. Behind this point there is a turbulent flow, which causes a very high static pressure inside the parachute compared to the static pressure in the undisturbed fluid around the canopy.

The positive pressure inside the canopy and the negative pressure outside it form a high-pressure gradient allows the inflation of the canopy.

Designing of the geometry of the recovery system was carried out by using a dedicated software that allowed to preview the specific phenomena-taking place during the landing.

Thus, the unitary effort on the parachute surface was determined, and the obtained value was considered in counting the density of the fabric used for the decelerating parachute surface.

The usage of this program permitted to the highlight of the fact that, for the landing deceleration of the supersonic aircraft, a fabric made of yarns of para-aramid type should be used in order to correspond to the requests imposed by the final application.

The membrane theory was used in order to determine the specific parameters for woven fabric design (i.e. weft and warp density, breaking force and elongation in static and shock conditions etc.).

3 Results and Discussions

The necessary air permeability of the woven structure of the canopy from the deceleration system was determined by performing a complex programme of experiments in subsonic aerodynamic tunnel (Fig. 2).

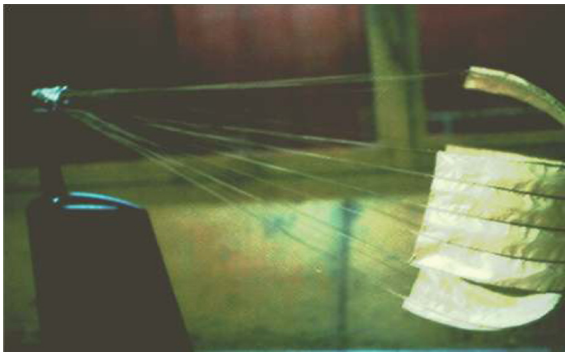


Fig. 2. Experimental model of brake parachute during the experimentation in aerodynamic tunnel

Testing programme demonstrated that the optimum interval for the air permeability of the woven fabric is [400,700] l/m^2/s that will fulfil the following requirements:

- low oscillation angles of ±3°, recommended for cross deceleration parachute, and therefore good stability of the recovery system at landing;
- low opening shock coefficient of 1.1–1.2.

Ground testing of the recovery system was conducted under the temperature between 4 and 8 °C; atmospheric pressure: 750 mm Hg and wind speed between 4 and 6 m/s.

The obtain results demonstrated that the accomplished system is functional, ensuring the safety opening of the brake parachute at the supersonic aircraft.

This conclusion was validated by the results obtained during the testing programme performed at landing conditions. Thus, after the trials and verification of flights and landing in wet and dry conditions, the deceleration parachute demonstrated to be operational (Fig. 3).

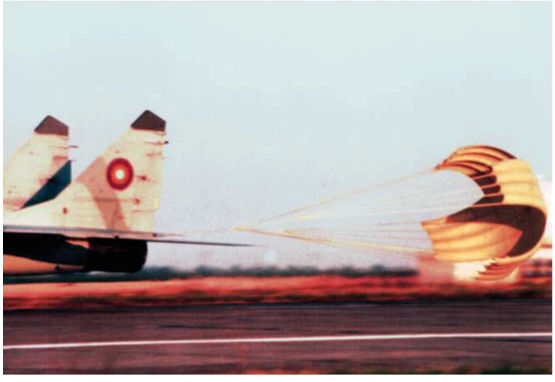


Fig. 3. Deceleration at supersonic aircraft landing with the main parachute

The estimation of the running distance of the open parachute landing was made by the pilots, ranging from 680 to 800 m (depending on opening speed, track condition, wind direction and intensity).

The aerodynamic braking was very good, reaching a normal speed for actuating the mechanical brakes.

4 Conclusions

A new generation of woven structure with special characteristics for the main parachute surface of the aerodynamic decelerator of supersonic aircraft and thermal protection of the helicopter installation for heating and ventilation was realized, experimented and implemented at the beneficiaries.

During the researches was identified and solved, the technological problems represented by deceleration at landing of the supersonic aircrafts and by the thermal protection of the helicopter installation for heating and ventilation.

The complex phenomena occurring during the supersonic aircrafts landing was explained using the theories of the fluid mechanics and aeronautics.

Designing of the geometry of the recovery system was carried out by using a dedicated software that allowed to preview the specific phenomena-taking place during the landing.

Typical design and delivery criteria have been considered: safety in operation (the criterion of the greatest importance); mass and volume in order to efficiently use the loading value; stability; reproducibility of performance, etc.

The specific parameters for woven fabric design (i.e. weft and warp density, breaking force and elongation in static and shock conditions etc.) was determined based on membrane theory.

A complex programme of experiments in real condition validated the functionality of the accomplished systems.

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A Pilot Study of a Hygienic Mask Sheet Pattern to Prevent Air Flow Through Gaps

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Abstract. Hygienic masks are highly useful in healthcare. However, when a commercially available mask is worn, the air gap at the upper edge of the sheet can allow contaminants to reach the wearer's nose and mouth. Here, we aim to identify a novel pattern for a hygienic mask sheet that does not form an air gap. Three-dimensional (3D) scans of the facial shapes of a female mannequin and female human subjects were obtained using a 3D analyzer. A two-dimensional sheet pattern was derived based on the facial coordinate data and a prototype sheet was fabricated using the optimized pattern for the mannequin. In a fitting test, the sheet was well fitted to the face, especially on the upper edge. Moreover, the facial coordinates relative to the nose tip in the subjects were similar to those in the mannequin. Thus, the proposed approach is expected to be applicable to other females.

Keywords: Mask · Fit · Pattern

1 Introduction

A hygienic mask is worn over a wearer's nose and mouth to prevent exposure to external particles such as pollen [1], dust, volcanic ash [2], and atmospheric particulate matter (PM) 2.5 [3]. The mask is one of the most useful textile personal protective measures in healthcare. However, an excellent fit is required to effectively protect the wearer's nose and mouth from harmful substances in the outside environment.

There are three types of facemasks: industrial, surgical, and hygienic. The industrial type of respiratory equipment includes particulate respirators (JIS T 8151:2018) and gas respirator (JIS T 8152:2012). For such respirators, adhesion between the mask and the wearer's face must be measured qualitatively or quantitatively using a fit check or fit test according to national or international standards. For surgical type masks, the fit performance is tested according to international standards. Contrastingly, there are no standards or specific test methods for hygienic masks.

The effectiveness of various commercial hygienic masks has been verified in previous studies [4, 5]. However, in actual use, there is often an air gap between the hygienic mask sheet and the wearer's face. Further, it has been reported that the air gap

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between the face and the upper edge of the sheet of a commercially available molded mask allows contaminants to reach the wearer's nose and mouth [6].

To overcome this issue, the objective of this study was to develop a novel pattern for a hygienic mask sheet that does not exhibit such an air gap, thus, effectively prevents contaminants from reaching the wearer's nose and mouth. Herein, a three-dimensional (3D) analyzer is used to map the facial shapes of a female mannequin head and several participants. To prevent air flow beneath the upper edge of the sheet to the wearer's nose wing, points along the contour from the nose to the cheek are included in a set of points. Based on the measured coordinates, two-dimensional (2D) patterns are calculated using a triangular combination with the tip of the nose as the origin [7]. A prototype mask sheet based on the analyzed pattern for the mannequin was created and evaluated. Moreover, the mannequin pattern was compared with those of the subjects to verify the adequacy of the proposed approach for human subjects.

2 Experimental Methods

Here, facial shapes of a female mannequin with average head characteristics and young female participants were measured using a 3D analyzer. Then, 2D patterns were generated based on the acquired 3D data. Subsequently, a prototype sheet was fabricated based on the identified pattern. Next, the fit of the mask on the mannequin face was visually evaluated. Finally, patterns for the mannequin and those for the human participants were compared to verify the applicability of the approach to other females.

2.1 Mannequin and Participant

In this pilot test, a mannequin head and five human participants were evaluated. The mannequin was built using a 3D printer (FORTUS360mc; Stratasys) from data about the average head shape of an adult Japanese female published by the National Institute of Advanced Industrial Science and Technology (Anthropometric Database of Japanese Head 2001, H16PRO-212 as collected by the National Institute of Advanced Industrial Science and Technology).

Five young female subjects (Mean age: 22.6 years; Standard deviation (SD): 2.5) were recruited for the study. The head circumference of each subject was measured using a measuring tape and the head length, head breadth, and bigonial breadth of each subject were measured using a spreading caliper; on average, these measures were 557.6 mm (SD 20.4), 181.8 mm (SD 8.1), 150.0 mm (SD 3.7), and 103.6 mm (3.2), respectively. These measures were in the mean ±standard variation ranges for Japanese head characteristics. The study protocol was approved by the ethics committee at the Institute of Human and Social Sciences Ethics Committee of Kanazawa University (IRB permit no. 2017–33).

2.2 Measurement of Facial Shape

The facial shapes of the female mannequin and participants were measured using a 3D analyzer. At each of the landmark points, 3 mm-diameter hemispherical reflection

markers were fixed with double-sided medical tape. Figure 1 shows the landmark points. The first ring of points comprised 18 landmark points on the nose and mouth and the second, third, and fourth rings comprised 24, 26, and 26 points, respectively, in concentric circles spaced at 10 mm intervals. To ensure proper fit of the upper edge of the sheet to the wearer's nose wing, the points along the contour from the nose to the cheek were included in the set of points. The facial shape was evaluated based on the positions of the markers in the closed-mouth position, as observed by three infrared cameras. The 3D coordinates (x, y, z) of the markers were computed using the 3D analyzer system.

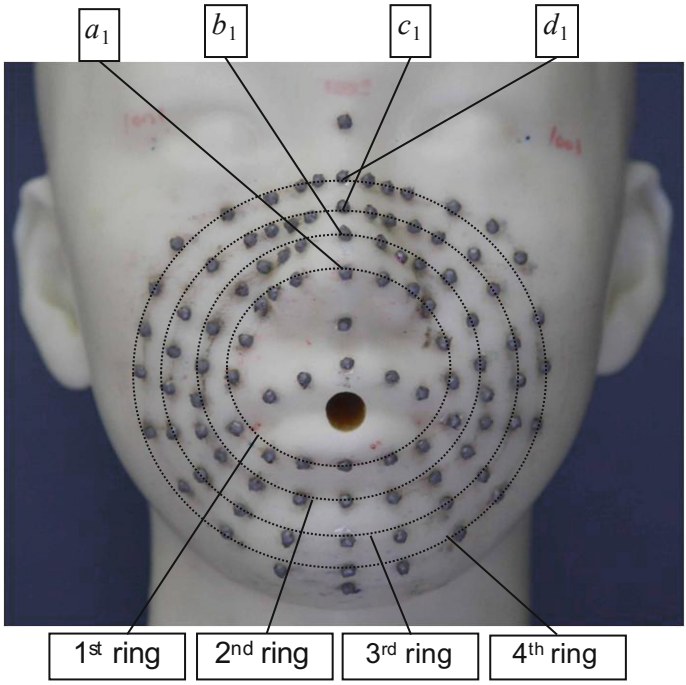


Fig. 1. Measurement point.

2.3 Determination of Mask Sheet Patterns

Using the computed 3D coordinates, 2D patterns were derived by the combinations of triangles method. Briefly, the 2D coordinates of the triangle between the origin point (the nose tip, a_1 (x_0, y_0, z_0), as shown in Fig. 1), each point (x_n, y_n, z_n), and the next point (x_{n+1}, y_{n+1}, z_{n+1}) on each ring were computed based on the distance calculated according to Eq. (1) and the interior angles derived based on the cosine formula.

$$d = \sqrt{(x_n - x_0)^2 + (y_n - y_0)^2 + (z_n - z_0)^2} \tag{1}$$

Then, half of the mask sheet (i.e., the right or left side) was formed by an affine transformation using the integrated inner angle between the nose tip and center of lower lip as an axis for points on the first ring or the angle between the nose tip and the center of the jaw as the axis for points on the other rings. The points in the right side were rotated clockwise based on the integrated inner angles and those on the left side were rotated counterclockwise based on the corresponding integrated inner angles.

3 Result and Discussion

3.1 Analyzed Pattern for the Mannequin

Using the acquired 3D coordinates for the mannequin, 2D mask sheet patterns of four different sizes corresponding to the four rings of points were derived. Figure 2 shows the identified pattern for the mannequin (broken lines). In the pattern reaching the first ring, the ideal pattern required to cover the participant's nose and mouth was found to be nearly elliptical. In the larger patterns reaching the second, third, and fourth rings, the dorsum points of the nose (b_1 in the second ring, c_1 in the third ring, and d_1 in the fourth ring as shown in Fig. 1) were located in the first and second quadrants. When the two points in each quadrant were combined, the 2D pattern evolved into a 3D elliptical cone. The shapes of the analyzed patterns were not awkward.

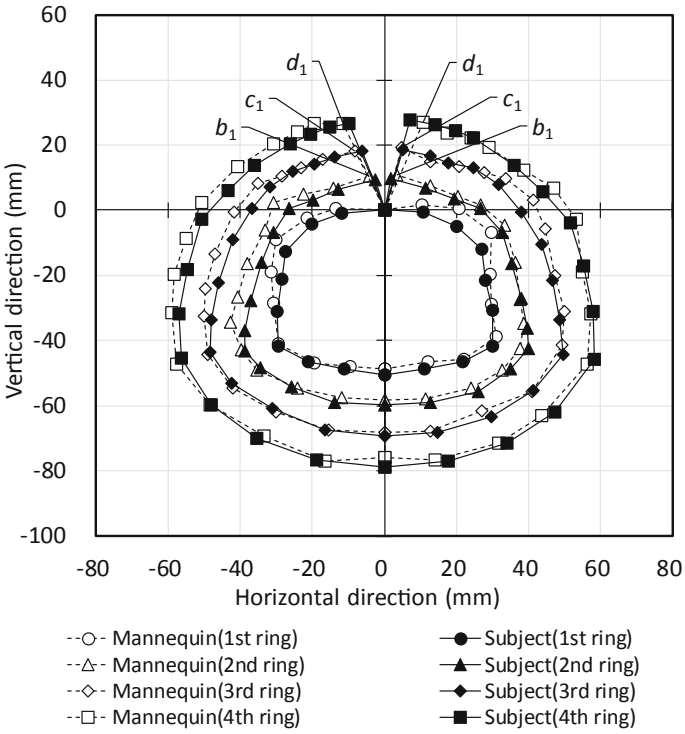


Fig. 2. Analyzed patterns for subjects and the mannequin.

Furthermore, the patterns for the mannequin showed left–right symmetry. The distances between the nose tip, a_1, and each point in the pattern were calculated for both sides. Mean and SD of absolute values of the difference between them were 1.0 ± 0.9 mm in the pattern corresponding to the first ring, 1.6 ± 1.2 mm that corresponding to the second ring, 1.6 ± 1.4 mm in that corresponding to the third ring, and 1.9 ± 1.0 mm in that corresponding to the fourth ring.

In a previous study, fewer measurement points were used in the second, third, and fourth rings compared to the present study. However, the differences between the shapes were smaller in each ring compared to those in the results of the previous study. Further, the outer perimeters of the rings exhibited small differences compared to those in the previous study: −2.6, 0.4, and −0.3 mm in the second, third, and fourth rings, respectively.

3.2 Fit Performance of the Prototype Sheet on the Mannequin

Based on the derived pattern, a prototype sheet extending to the fourth ring was fabricated from non-woven rayon fabric (Torakurosu 30301; Taketora) and put on the mannequin as shown in Fig. 3. It was visually observed that the sheet followed the contour of the mannequin's face very well. The top view shows that the sheet was along the boundary between the nose and cheek. From these results, it was confirmed that the analytical method resulted in a mask sheet pattern that provides a close fit on the upper edge of the sheet. Moreover, it was revealed that the selected markers yielded an effective pattern with high fit performance.

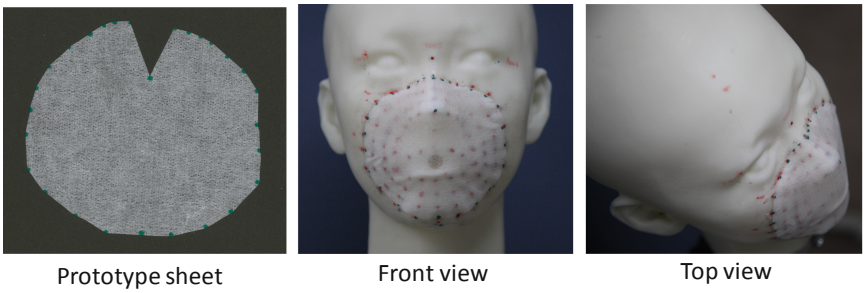


Fig. 3. Prototype sheet and demonstration of how it is fitted to the face.

3.3 Analyzed Pattern for the Subjects

Using the acquired 3D coordinates for each subject, 2D mask sheet patterns in four different sizes were derived using the method that was used for the mannequin and averaging the coordinates for each point over all subjects. The SD in each coordinate averaged 2.0, 2.3, 2.6, and 2.9 mm in the first, second, third, and fourth rings, respectively; the maximum SD for any coordinate was 4.1, 4.5, 5.1, and 6.0 mm, respectively. Thus, the variability between individuals was low so average patterns could be evaluated.

Figure 2 shows the average patterns (solid lines). The shape for each ring was nearly the same as the corresponding shape for the mannequin. Moreover, the analyzed patterns for the subjects exhibited left–right symmetry. The distances between the nose tip, a_1, and each point in the pattern were calculated for both sides and the averages were 0.3 mm in the first ring, 0.6 mm in the second ring, 0.8 mm in the third ring, and 0.6 mm in the fourth ring.

3.4 Comparison of the Analyzed Patterns for the Mannequin and Subject

To evaluate the applicability to a variety of wearers, the analyzed pattern for the mannequin was compared to the pattern for the five subjects. The differences (±SD) were 0.4 mm (±1.2 mm) in the first ring, −0.6 mm (±1.7 mm) in the second ring, −1.1 mm (±1.9 mm) in the third ring, and −1.2 mm (±2.4) in the fourth ring. These small differences indicate that the proposed analytical method using a female mannequin is applicable to the design of masks for human subjects. In future studies, we expect the adjustment of shape and the length of the ear strings will reduce the difference between the mannequin and human subject patterns and the differences between patterns for different individuals.

4 Conclusion

In this study, a 2D pattern for a mask sheet was derived that does not exhibit an air gap between the upper edge and the face. The pattern was derived based on the 3D coordinates of a female head mannequin with average features and the faces of female participants as a pilot test as measured using a 3D analyzer. 94 landmark points on the face were radially set with 10 mm intervals covering the nose and mouth. Patterns of four different sizes for the mannequin and the subjects were compared and the differences were found to be small. Moreover, a prototype of the sheet that was designed for the mannequin was fabricated and shown to fit the female mannequin well, especially, around the nose. Therefore, it was concluded that this approach is appropriate to develop a novel mask sheet and can be applied to human subjects. In future studies, a larger number of participants will be evaluated and the fit will be investigated further.

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Research on the Characteristics of Hand Shape in Different Countries

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Abstract. For a long time, science has been dedicated to revealing various indicators of the human body, including height and weight. The same purpose is also for this paper. Based on data on the hand of people from ten different countries, this paper do some research with the help of multi-variate analysis tools. According to the different characteristics of the data, this paper first carried out the analysis of variance on hand length. Then, according to the different dimension of hand shape, including the vertical length of the palm, the metacarpal and the length of the index finger, factor analysis was carried out, and two influence factors were extracted. Then, multiple regressions were performed on these variables, at the same time, stepwise regression method was adopted, and the main independent variables were chose from the constructed model. Finally, gender is set to a dummy variable to study the impact of gender differences on the hand length.

Keywords: Hand · Analysis of variance · Factor analysis · Multiple regression · Dummy variable

1 Introduction

Most scientific research is about people's intuitive physical data, indicating height and weight. However, research on details, such as the study of the hands and feet, is more conducive in other disciplines. For example, reference [1] mentions the improvement of suggestions and opinions on the production of Chinese shoes by analyzing the data of the collected feet. The measurement of the hand has different measurement methods. Reference [2] gives two methods in detail. Overall, there are little literatures discussing the hand characteristics. [2] also gave some comparison of hand anthropometry of females in three ethnic groups: Western Europeans, Indian and West Indian. Additionally, appreciation of the gender differences in hand shape is essential to the proper design of both men's and women's hand tools, gloves. Traditionally, women's gloves are often made using a small version of a men's glove with all dimensions proportionally scaled according to hand length. However, if women's hands differ in shape from men's hands, this is an inappropriate model and could lead to improper gloves fit in women. Courtney [3] carried out an anthropometric study of hand dimensions of Hong Kong Chinese female workers compared to other ethnic groups. Twenty-three hand dimensions were measured and compared with data from the United Kingdom,

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Japan and the United States of America. Other research referred to hand anthropometric study, please see literatures [4–6].

The data information we analyzed is from ISO/TR 7250-2:2010 "Basic human body measurements for technological design—Part 2: Statistical summaries of body measurements from national populations". This technical report is intended to serve as a continually updated repository of the most current national anthropometric data. It also provides statistical summaries of body measurements together with database background information for working age people in the national population.

2 Method

At first, we conduct the direct comparison among these countries based on analysis of variance (ANOVA). It is because we want to know whether hand length are significantly different among these countries as well as between male and female in these countries. We take hand length as response variable, gender and country as two factors. Analysis of variance is used to analyze the effects of factors, which may have impact on the result of an experiment.

Secondly, we performed factor analysis on the five variables that affect the hand length to extract more intuitive data features. The five variables are the vertical length of the palm, the metacarpal, the length of the index finger, the width of the proximal end of the index finger, and the width of the distal end. We want to know if there are any internal dependencies between these five variables.

Thirdly, we construct a multiple regression analysis of the above five variable opponents, and study how these five variables affect the human hand length, because the stepwise regression method is adopted, resulting the fifth independent variable removed from the model.

At last, we also want to know how much influence the gender has, so we set gender as a dummy variable. The study found that men's hands are about 2% taller than female hands.

3 Results

3.1 Results of ANOVA for Hand Length

The general linear model procedure is used to do analysis with the help of SPSS software. The general linear model procedure has the following advantages: (1) it could be used in unbalanced designs; (2) it can evaluate differences between individual level means; (3) it allows covariates, random factors and nested factors.

As we know, ANOVA based on three assumptions: (1) the dependent variables of each population are normally distributed, (2) the variance of each population is equal, and (3) the samples of each population are randomly sampled independently. Then, first we perform homogeneity tests through Levene's method. The results are in Table 1. From the p-value we can conclude that the data has equal variance.

Table 1. Levene's test of equality of error variances

Dependent variable: hand length			
F	DF1	DF2	P-value
.073	19	40	1.000
Test the full hypothesis that the error variance of the dependent variable is equal across groups			

In Table 2, DF stands for degree of freedom. Without loss of generality we take nominal significance level as 0.05. That means if P-value of one factor is less than 0.05, we think it is significant; otherwise it is not significant.

Table 2. Tests of between-subjects effects

Dependent variable: hand length					
Source	Sum of square	DF	Mean square	F	Sig.
Corrected model	5463.400[a]	19	287.547	1.221	.290
Intercept	2040939.267	1	2040939.267	8663.343	.000
Country	2289.067	9	254.341	1.080	.399
Gender	3024.600	1	3024.600	12.839	.001
Country * gender	149.733	9	16.637	.071	1.000
Error	9423.333	40	235.583		
Total	2055826.000	60			
Corrected total	14886.733	59			

[a]R squared = .367 (Adjusted R squared = .066)

Table 2 provides the results of the analysis of variance for the model. The first line (Corrected Model) is the overall test of all the effects of the model. The significance of two factors, country and gender, is 0.399 and 0.001, respectively. Gender is significant, but country is not significant. However, the test result of the interaction effect between the two factors (country * gender) is extremely insignificant. The table also provides that determination coefficient (R Squared) of the model is equal to 0.367, indicating that the main effect and interaction effect of the two factors in the model together account for 36.7% of the total variation of the dependent variable. However, although the sample analysis shows that the effects of the model have some explanatory ability for the dependent variable, the statistical test of the effects shows that only one effect is beyond the random fluctuation range but that cannot be inferred to the whole.

Figure 1 is the interaction plot for hand length. From Fig. 1, we can obtain the following information: (1) Overall, the hand length of men is larger than hand length of women in all ten countries. (2) The ten countries fall into about three groups: The Netherlands and United States had significantly larger hand length than the other eight countries; The India had the smallest hand length. (3) On average, the hand length of

male in the Netherlands and the United States are largest and the hand length of female in United States and Kenya are the largest. The hand length of people in Germany and Italy is similar.

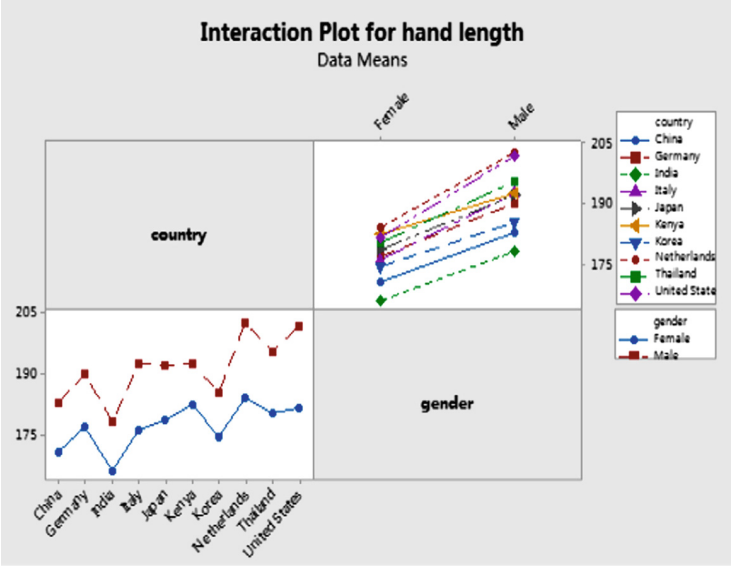


Fig. 1. Interaction plot for hand length

3.2 Results of Factor Analysis

As the original data has some missing values, especially the United States, we do some basic data pretreatment under the help of R software. At first, in order to make sure the accuracy of the data, we delete the information about USA's hand data, then, we make use of R software to multiple interpolate missing values. Furthermore, we try to find some common factors which effect the length of hand in nine countries (except the United States) no matter women or men. Aiming at above purposes, we take the method of Factor Analysis followed.

The purpose of factor analysis is to simplify the data or find out the basic data structure. Therefore, the premise of factor analysis is that there should be a strong correlation between observed variables. If the correlation between variables is small, they cannot share a common factor. Therefore, we produced the correlation coefficient matrix of the five variables in the table and conducted Bartlett's test of sphericity and KMO measures.

Table 3. Correlation matrix

		x1	x2	x3	x4	x5
Correlation	x1	1.000	.843	.838	.754	.750
	x2	.843	1.000	.867	.785	.816
	x3	.838	.867	1.000	.710	.957
	x4	.754	.785	.710	1.000	.650
	x5	.750	.816	.957	.650	1.000

x1 indicates Palm length perpendicular
x2 indicates metacarpals
x3 indicates Index finger length
x4 indicates Index finger breadth, proximal
x5 indicates Index finger breadth, distal

Table 4. KMO and bartlett's test

KMO measure of sampling adequacy		.823
Bartlett's test of sphericity	Approx. chi-square	325.618
	df	10
	Sig.	.000

The correlation analysis of five variables (Table 3) shows that there is a strong correlation between Index finger length and Index finger breadth, distal, which reaches about 0.957. The other three variables have a mutually strong correlation as well. All of these correlation values reach above 0.65. Looking at Table 4, the KMO measured value reaches above 0.8, and the significance level of Bartlett spherical test is extremely high, which indicates that factor analysis can be conducted on this data.

According to the eigenvalues criterion, only one factor can be selected for the hand data including nine countries (except USA). In order to illustrate explicitly, we have selected two factors. From Table 5, it shows the concrete information. The first column "Component" indicates the different kinds of factors, the following three columns are the initial eigenvalues, "Total" column refers to the eigenvalues, "% of Variance" is the percentage of Variance, and "Cumulative %" is the cumulative percentage of variance. For instance, the first two factors explain the data's variance 83.902% and 8.425% respectively. While these two factors explain the vast majority of the total data variance accumulatively, reaching more than 90%. The middle three columns show the two factors selected, as well as their explanatory variance ratio and cumulative ratio. The last three columns are the variance explanations of each selected factor after factor rotation.

Table 5. Total variance explain

Component	Initial eigenvalues			Extraction sum of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	4.195	83.902	83.902	4.195	83.902	83.902	2.546	50.914	50.914
2	.421	8.425	92.327	.421	8.425	92.327	2.071	41.413	92.327
3	.215	4.307	96.634						
4	.138	2.764	99.398						
5	.030	.602	100.000						

Extraction Method: Principal Component Analysis

Communalities is also one of the important judgment principles for determining the number of factors. Table 6 provides information in this respect. In the table, "Initial" is the Initial value, while "Extraction" is the communalities of each variable. The results show that the communalities of the five variables is very high, and the information of each variable contain more than 84%.

Table 6. Communalities

	Initial	Extraction
x1	1.000	.849
x2	1.000	.891
x3	1.000	.976
x4	1.000	.940
x5	1.000	.960

According to the order in which factors are extracted, we portray the screen plot about the change of factor eigenvalues (vertical axis) with the number of factors (horizontal axis). Actually, the number of factors is also judged according to the shape of the figure. It can be seen from the scree plot: from the first factor, the curve goes down rapidly, then becomes gentle, and finally becomes an approximately straight line. The factor load after rotation with the "varimax" method shows in Fig. 2 as well. We can conclude that "Index finger breadth, proximal" (x4) is close to the second factor, and "Index finger length" (x3) and "Index finger breadth, distal" (x5) are closer to the first factor.

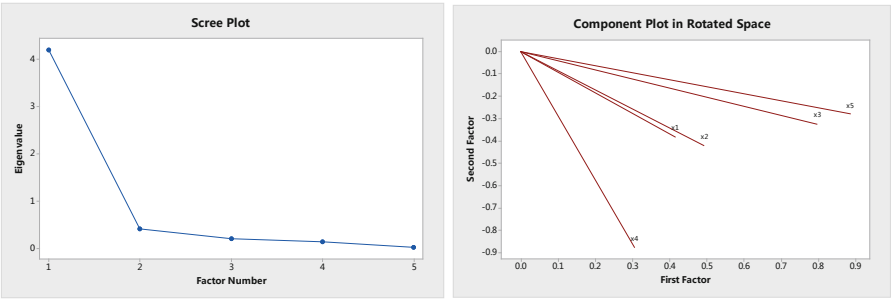


Fig. 2. Screen plot and component plot

3.3 Results of Multiple Regressiom

In order to study how the five variables in the data affect the hand length including nine countries, we build a linear regression model with the stepwise method. Since more than one variable is included in the independent variable, we take multiple linear regression model. The model structure is as follows:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + \varepsilon \quad (1)$$

Among them, y indicates hand length, x_1 = Palm length perpendicular, x_2 = metacarpals, x_3 = Index finger length, x_4 = Index finger breadth, proximal, x_5 = Index finger breadth, distal. b_1, $b_2 \ldots\ldots b_5$ are model parameters, b_0 is intercept value.

Table 7. Model summary

Model	R	R square	Adjusted R square	Std. error of the estimate	Durbin watson
1	.941[a]	.886	.884	5.304	
2	.972[b]	.946	.944	3.694	
3	.979[c]	.958	.956	3.271	
4	.981[d]	.962	.959	3.152	1.192

[a]Predictors: (Constant), x3
[b]Predictors: (Constant), x3, x1
[c]Predictor: (Constant), x3, x1, x2
[d]Predictor: (Constant), x3, x1, x2, x4
[e]Dependent Variable: y

Table 7 shows the interpreting proportion of each model by means of stepwise regression. The order of taking independent variables into the model is Index finger length (x3), Palm length perpendicular (x1), metacarpals (x2), Index finger breadth, proximal (x4). The last model has accounted for hand length more than 95%, but the Durbin-Watson test value of the model is 1.192, which cannot support the premise of error independence, so the regression model is only for reference.

Table 8. Coefficients

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		Beta	Std. error	Beta		
1	(Constant)	40.186	7.178		5.598	.000
	x3	2.039	.102	.941	20.083	.000
2	(Constant)	19.086	5.738		3.326	.002
	x3	1.226	.130	.566	9.458	.000
	x1	.741	.099	.448	7.494	.000
3	(Constant)	23.016	5.180		4.443	.000
	x3	.936	.137	.432	6.834	.000
	x1	.580	.097	.351	5.983	.000
	x2	.413	.106	.249	3.882	.000
4	(Constant)	21.093	5.068		4.162	.000
	x3	.931	.132	.430	7.055	.000
	x1	.635	.097	.384	6.568	.000
	x2	.503	.110	.303	4.557	.000
	x4	−.604	.275	−.103	−2.200	.033

Dependent Variable: y

Table 8 shows the coefficients of each model after stepwise regression. In the first step, there is only an independent variable, and the regression coefficient is a large positive value (2.039), reflecting that the larger "Index finger length" (x_3) is, the larger hand length is. The second step regression model increase the independent variable "Palm length perpendicular" (x_1), whose standardized coefficient is 0.448, that is similar to "Index finger length" (x_3). The third step takes "metacarpals" (x_2) into regression model, the fourth step increases the "Index finger breadth, proximal" (x_4).

$$y = 0.384x_1 + 0.303x_2 + 0.43x_3 - 0.103x_4 \tag{2}$$

The above formula is the standardized performance of stepwise regression in the last model. From the standardized coefficients respectively, "Index finger length" (x_3) has the greatest influence on the hand length, each unit it increases, the hand length increases by 0.43 unit. In addition, both "Palm length perpendicular" (x_1) and "metacarpals" (x_2) have positive effects on hand length. From their standardized coefficients (0.384 and 0.303, respectively), the effects of the two variables are similar. Finally, "Index finger breadth, proximal" (x_4) has a negative effect on hand length, whose coefficient is -0.103.

Then, we draw four-in-one residual plot (Fig. 3), we explain the figures in the following:

Normal Probability Plot – Because the points on the normal probability plot roughly follow a straight line, we can assume that the residuals do not deviate substantially from a normal distribution.

Histogram – Use the normal probability plot to make decisions about the normality of the residuals. With a reasonably large sample size, the histogram displays compatible information.

Versus Fits – The constant variance assumption does not appear to be violated, because the residuals are randomly scattered about zero.

Versus Order – The plot of the residuals versus order does not show any pattern. Therefore, there is no time dependence in the residuals.

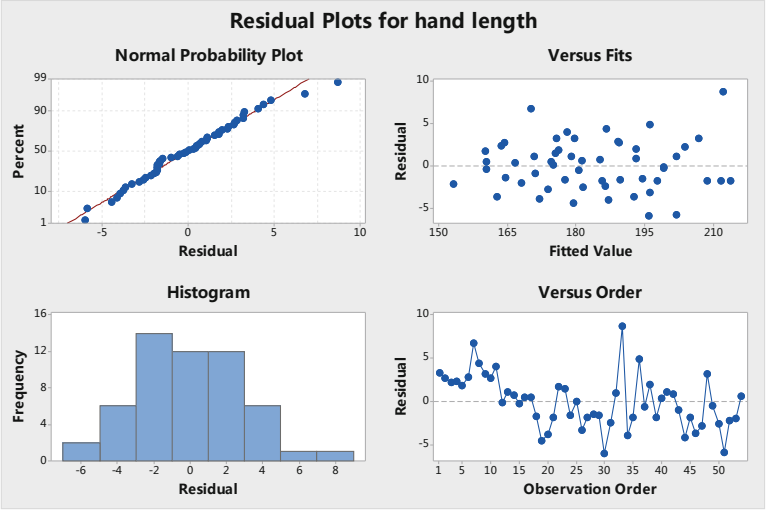


Fig. 3. Residual plots for hand length

3.4 Results of Adding Dummy Variable

Next, considering the impact of gender on hand length in the data of these nine countries, we take gender as a dummy variable in the regression equation, and the other independent variables do not change. Building a multivariate regression equation with dummy variables, Table 9 provides a global test of the regression equation, showing that the F value of the regression equation is 199.989, which is statistically significant at the 0.000 level, indicating that there is at least one independent variable which owns a very significant linear relationship with dependent variable in the equation.

Table 9. ANOVA

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	12324.111	6	2054.019	199.989	.000
	Residual	482.722	47	10.271		
	Total	12806.833	53			

Dependent Variable: y
Predictors: (Constant), x5, gender, x4, x1, x2, x3

Table 10 provides the regression coefficients for the respective variables after adding dummy variables, including unstandardized coefficients and standardized coefficients. Among them, the last two columns of the table also provide collinearity test items for multiple regression. When the independent variables are completely linearly related, the estimation of the regression model no longer has a unique solution, so the least squares method is no longer applicable, neither. It can be seen from the test that the tolerance of x_3 and x_5 is less than 0.1, which means their variance inflation factors are all greater than 10 but less than 25, indicating that there is a certain degree of correlation between independent variables, and it is necessary to carefully apply multiple regression equations.

Table 10. Coefficients

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.	Collinearity statistics	
	B	Std. error	Beta			Tolerance	VIF
(Constant)	22.679	5.839		3.884	.000		
Gender	−.665	1.066	−.022	−.624	.536	.669	1.495
x1	.623	.106	.377	5.888	.000	.196	5.111
x2	.480	.118	.289	4.061	.000	.158	6.325
x3	.978	.299	.451	3.275	.002	.042	23.695
x4	−.588	.281	−.100	−2.095	.042	.351	2.853
x5	−.104	.825	−.014	−.126	.900	.066	15.053

Dependent Variable: y

We give the following regression equation for the dummy variable according to the column labeled the standardized coefficients in Table 9:

$$y = -0.022gender + 0.377x_1 + 0.289x_2 + 0.451x_3 - 0.1x_4 - 0.014x_5 \quad (3)$$

From the degree of significance of the coefficient, the t-statistic value of gender is -0.624, whose p-value is equal to 0.536 greater than 0.05, rejecting the null hypothesis. The index finger breadth, distal (x_5) is also not significant, rejecting the null hypothesis at the level of 0.9, so we should be careful when interpreting variables with the multiple regression model results. When constructing dummy variables, we use 0 for men and 1 for women. Therefore, the regression coefficient of gender shows that on average, men's hand length are 0.022 units higher than women, which is also a common sense that men's hands are larger than women's.

4 Conclusion

This paper mainly discussed the characteristics of body hand in ten countries based on the statistical data in ISO/TR 7250-2:2010 "Basic human body measurements for technological design—Part 2: Statistical summaries of body measurements from national populations". Based on the average data and percentile values of hand length we can conclude that the ten countries fall into about three groups: The Netherlands and United States had significantly larger hand length than the other eight countries, the India had the smallest hand length, other countries are in a same condition. We do a factor analysis for five variables, which indicates that we can extract two main factors. "Index finger breadth, proximal" is close to the second factor, "Index finger length" and "Index finger breadth, distal" are closer to the first factor. Finally, we do a multiple regression to find out what extended gender and other variables' impact on hand length. The results are "Index finger length" has a great significance and on average, men's hands are about 2% taller than female hands. The obtained results could be a reference for designing the export gloves to these countries. What's more, the obtained regression equations have a great reference value for forensic science and anthropology.

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Research on Human Factors Engineering for the Innovative Design of Work Clothes for Couriers

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Abstract. This research focuses on the investigation based on human factor engineering, and explores the relationship between human body and clothing from different aspects. It discusses that clothing materials, sizes, styles, and colors can better meet the physiological and psychological needs of couriers when they work, takes into account the relationship among courier, clothing, and working environment, points out the limitations of courier's work clothes at present, and proposes new design methods. Finally, according to the principle of design optimization, a more comfortable, multi-functional, healthy, safe, and fashionable couriers' work clothes is pointed out, which provides guidance for the improvement of the couriers' work clothes with multi-functional and innovative design.

Keywords: Couriers · Work clothes · Innovative design · Human factor engineering

1 Introduction

With the overall progress of human society and the continuous improvement of people's living standard, comfortable and suitable work clothes play an extremely important role in the designated work type and specific work environment, especially in the express transportation industry that frequently requires long hours of working.

At present, most express companies do not design or customize a standardized uniform for couriers, and currently the work clothes for couriers is also lack of innovation to a certain extent. In addition, in view of the urgent need to reduce costs, the overall form of courier's clothing gradually reveals its shortcomings, mainly due to the lack of consideration of the principle of human factors engineering. The work content of the courier is mainly to place and transport the parcels and other objects, which consumes a lot of energy from the human body. One is long-term work, and the other is because the distance they move about for carrying articles is relatively long. Therefore, considering that a complete set of work clothes can be designed on the basis of meeting the requirements of various indicators, the innovative design of work clothes for couriers has entered a new stage. And for how to effectively obtain the size information of the Courier and combine the requirements of its work content, the key is to apply the new concept into the design.

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The main research methods adopted in this paper are the observation method and the investigation method. Taking human and clothing as the research objects, this paper focuses on the study of the behavior changes of couriers in the process of investigation. For example, the frequency of repetitive movements, the range of movement changes and the time of continuous operation of a certain movement are frequently carried out in particular time by operators in different positions. And in combination with the inquiry method, the content obtained when talking with the courier is recorded as a data so as to study the new suggestions of the young male couriers on the color, style, size and materials of the work clothes, and take this as the entry point for the design so that the clothing can fully satisfy the principle that the human body can feel comfortable in a variety of motion. This paper mainly analyzes it from the following aspects. The first is the relationship between the physique of a courier and his clothes. And the second one is the analysis of clothing size and courier's body shape. The third point is the interaction between body movements, postures and work clothes. The fourth aspect is the analysis of the structure design and material composition of clothing. On this basis, this paper summarizes the data and extracts the important influencing factors for targeted analysis.

2 Investigation of the Couriers' Work Content and Specific Environment

2.1 Characteristic of Body Shape and Structure of the Couriers

The survey was conducted mainly from the aspects of gender, shape, and structure, taking several districts in Guangzhou as an example, combining with network data information. Among the types of personnel engaged in express delivery, 80% are male and only 20% are female. Usually, the work content of female may be related to customer service jobs such as information entry and consultation, but in the survey, female couriers are also responsible for classifying packages. According to the survey results, most of the young male couriers are between 18 and 30 years old, and their physical characteristics are mostly muscular and strong. The work clothes should form a unified design style, with male body characteristics as the main size for standardized design, which includes the proportional distribution of bright and dark chroma, and warm and cold chroma. The clothes should be inclined to simple and neat style, so as to convey the unique personality culture of the courier profession. In order to make the courier comfortable when wearing work clothes, it is necessary to study the characteristics of human body structure and shape in the process of design, and fully consider the size information of various parts of the human body, especially the key parts. It should focus on observing and measuring the following parts vertically: neck, shoulder, upper arm, forearm, chest, spine, buttock, thigh length, and shin length; and focus on observing and measuring the following part horizontally: neck, shoulder width, axilla, chest, bust, waist, abdomen, buttock, hip line, and other parts [1].

2.2 The Relationship Between the Angle of Movement Posture Change of Courier and Garment Size Space

In the process of packing, sorting, moving, and transporting parcels, the body posture of the couriers will change in many ways. Because most of the couriers are in the state of movement while working, besides standing, sitting, and squatting posture, there are body twisting postures such as bending, rollover, valgus, etc. The range of body changes is relatively large. The body has to bear the load for a certain period of time. Different natures of working posture determine that the design of work clothes should follow a variety of principles to meet the needs of changes in body posture and movement [2].

Although couriers do not have a very fixed commuting time, but their daily work duration is longer than other occupations, usually 10–12 h a day normally. According to different positions, the working time is also different. Figure 1 shows the frequently-used posture changes of the couriers in a high frequency in a fixed-point express store in a day. They repeat nearly similar movements every day. This paper analyzes the composition and structure characteristics of each part of the body of the courier and the relationship among them. When the body is in the active state, the upper part of the body extends more, but the range of changes around the neck, wrist, waist, and so on is smaller. The lower thighs and footsteps are more extensible horizontally. Shoulder is the flattest part. When doing chest enlargement movement, it is the most variable part. Axilla is the most changeable part. The axilla changes correspondingly according to the movement and angle. When the chest moves or the arms are lifted, the muscle of the chest also extends or contracts (Fig. 1).



Fig. 1. Frequently-used posture changes of express workers.

According to comprehensive analysis, the couriers have a wide range of physical activities and varied postures, so the design of work clothes should focus on local design. The load caused by suits is often due to the inadequate design of local details of existing work clothes, such as the movement space under the armpit, the difference between shoulders, the width of cuffs, the type of collar, the location of pockets, the type of zipper, design of the pants' elastic band, design of the length of trousers gear, flexible size design of the trousers feet, etc. Local defects of the work clothes can produce obstructive force, which affects the efficiency of the couriers and brings them a sense of fatigue.

2.3 Couriers' Opinion and Expectation Index of Work Suits

This part applies method of inquiry and interview, conducts field visits and small-scale interviews, and extracts part of the personnel engaged in express delivery work in different positions for communication. In the interview, most of the couriers said that a comfortable functional work clothes is naturally the best. Generally, according to the company's requirements, some are free, some are paid, and some are additionally purchased due to the needs of their own work. Generally large express logistics companies will provide unified suits for employees.

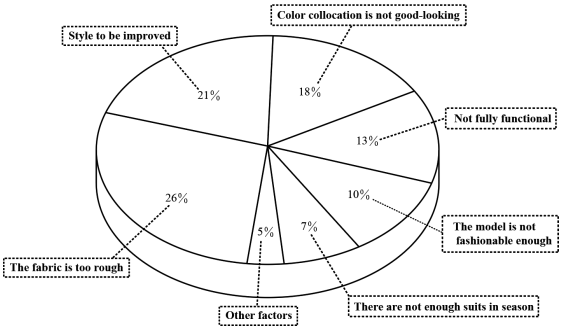


Fig. 2. Proportion of factors influencing the degree of dissatisfaction of couriers to the existing work clothes

The proportion of influencing factors pointed out by couriers to the existing work clothes is as followed. First, the material is too rough, and the fabric is impermeable. Secondly, the style and size are not in conformity, the number of pieces is incomplete, and the type is not fashionable enough. Comprehensive analysis of the impact index results show that: material, style, size, and color are the biggest reasons, and the main characteristics of the couriers' work clothes are comfortable and fit, followed by health, safety, and it is the best if upgraded to a high fashion taste.

3 Research and Analysis on the Orientation of Innovative Clothing Design

Throughout the whole process, the emphasis is laid on the relationship between people and clothing. The purpose of design needs to take the needs of users as the primary starting point. Since the functional and technical aspects required by reality are the main factors indispensable, but more importantly, it needs to be considered comprehensively from multiple aspects [3]. Based on the survey data, detailed rules for innovative design of couriers' work clothes are put forward.

3.1 Function and Decorative Design

For self-detachable hats, the relationship between the body and the hat is connected by zippers. When handling materials, driving, or doing other collective work in the warehouse, they can be dissembled whenever necessary. In front and back of upper and under suit, the pockets are designed with decoration and functionality, at the position where pens can be conveniently placed. In addition, the size of pockets, the types of shapes, and the direction of opening, are designed to meet the needs of the actual size of human hands, so as to make it more convenient and faster. For detachable glove design, the cuffs are connected by hidden buttons. In the specific parts of the cuff or trousers foot, flexible and adjustable size is designed, using anthropometric data to improve the design.

While designing the position of the logo, size, direction, location, identifiability factors such as the decoration and function of the reflex bar, the location of the logo are considered. Key details design is focused on, and local spatial details processing should focus on design and processing, shaping multi-layer anti-cracking process.

3.2 New Concept of Style Cutting

If a specific body area is exposed to excessive loads, there occurs muscle fatigue [4]. According to the size and structure changes of the human body, structural lines which are more in line with the body shape and body movement and posture change are found in the design and tailoring of the suits, and the position and size data are adjusted so as to form a reasonable spatial form with the human body while wearing the suits, reduce the load that hinders the work of the human body, and thus reduce more fatigue. There are many forms of garment line segmentation, such as line segmentation, curve segmentation, free segmentation, variability segmentation, and so on. The relationship between curve and line is fully used to achieve comfort and decorative visual effect. The courier has a large range of activities and consumes more energy. Therefore, the design of the suit style is loose but comfortable.

3.3 Principle of Color

Summer is suitable for light color. From the perspective of sunscreen, the darker the color, the more light and heat are absorbed, the hotter we feel. On the contrary, winter needs to consider protection from wind and cold. In addition to the standard

requirements of specific express companies, the choice of color should also meet people's daily visual aesthetic needs to a certain extent. The physiological role of color is mainly reflected in the impact on visual work ability and visual fatigue, and the eyes have different sensitivity to different colors of light [5]. Color also plays a psychological role in influencing people, that is, color will produce a series of psychological effects of color perception through visual stimulation. This effect varies with time, place, and condition. People may have different temperature sensations when seeing different colors, that is, interrelated but antagonistic. The distance sensation has the greatest influence on brightness and hue, and the higher the lightness, the stronger the protruding sensation. The weight sensation is concentrated on lightness. Brightness makes people feel lighter, while darkness makes people feel heavier. For the fatigue sensation, the more dazzling the color is, the greater the stimulation to people, and it is easy to make people feel fatigue. Generally, warm and hot make people feel more fatigued than cold does. The sense of attention, that is, attractive color can be clearly recognized in the unconscious state. The sense of personality has the emotional effect of exciting or calming people. We should play the psychological and physiological role of color in reducing people's fatigue and make people happy.

Work clothes follow "Three-color Principle" in a certain range. Its specific concept is that the work clothes on the body, including jackets, pants, shoes and hats, etc., generally speaking, should not exceed three colors. Such color matching can make the couriers' work clothes present a concise and generous overall style. Black, blue, brown, and grey give people a calm, professional, and formal feeling. On the contrary, red, orange, yellow, and white convey people a warm, bright, brave, and active atmosphere. It is suggested that two or three different types of colors be combined.

3.4 Material Types

The fabrics of working clothes must be constantly innovated, explored, and made. Nowadays, there are many kinds of fabrics on the market, and many types of fabrics are also in line with people's selection requirements. If we add creative design to work clothes fabrics on this basis, and design new different forms of fabrics, we may achieve better results. The key is to use them properly and not appear fancy.

Fabric moisture absorption, air permeability, heat preservation, tactility is the most important four factors to determine the comfort [6]. The material used in the design of work clothes should be sweat-absorption, fast-drying, and air-permeability. In summer, most of the materials used for couriers' work clothes are natural cotton, linen, and polyester fibers, which are cool and breathable. In addition, several kinds of fast-drying fabrics commonly used in the market are ACTIVENT (windproof and water-absorption), MONY-DRY (volatility and water-absorption), COOLMAX, (moisture-absorption and sweat-absorption).

In winter, couriers spend a lot of time working outdoors. The design of work clothes focuses on the attributes of windproof, cold proof and warmth keeping. In the winter, the couriers' work clothes are made of synthetic fibers, such as full-process polyester-cotton blended fabrics, which have double layers of wind-proof and warmth keeping, and are antistatic, thermal, dry, wrinkle-resistant and lightweight.

It is suggested that new textile and garment materials should be introduced to strengthen the skin safety. The selected materials should have good elasticity, wear resistance, dirt resistance, stain resistance, and moisture-absorption. One of the most important factors that influence the perception of comfort is the ability of the clothing to handle thermal [7]. For example, the outdoor jackets worn outside in winter have a significant impact on the heat exchange process. They not only should keep people warm, but also should have good moisture absorption, to maintain the balance of human heat. The factors of thermal environment influence and compensate with each other. The isolation effect of clothes reduces the heat loss of human body to environment [3]. In winter, the temperature difference between indoor and outdoor is large. The outdoor jackets can condense the heat generated by the body on the surface of the jackets through the principle of moisture absorption, releasing some heat, which can convert the heat generated by the human body into energy with the function of warmth keeping.

3.5 Complete Parts Number System

It can be worn single or combined. For example, cloth gloves, duck tongue caps, shoes and other accessories provide couriers with a complete set of work suit, which will standardize their professional areas, clear their job responsibilities, so that they feel more convenient when working outdoors in the city, and this will improve consumers' credibility of couriers' dedication.

4 Reflection and Evaluation

4.1 If we want to add more interesting and fashionable elements, we should make the color of work clothes brighter and brighter, the style more and more leisure, novel and diverse, and take active part in exploring and trying innovative work clothes types. In addition, the harmony between people, clothing and environment system constitutes a begin ecology of clothing behavior, in which environment is the condition, clothing is the means, and people are the focus [8].

4.2 For innovative design direction, first of all, the choice of style and type. Modeling sign can distinguish the different characteristics and applicability of work clothes, and highlight their social symbols and identity symbols. The second is the choice of fabrics. Couriers often shuttle around in the outdoors, and they often encounter windy and rainy days, so we should choose comfortable, skin-friendly, moisture-absorbing and breathable fabrics. The most commonly chosen is pure cotton work clothes, as pure cotton fabrics have good characteristics, making us comfortable, cool and breathable while wearing it. On this basis, we also need to collage reflective strips. After all, couriers have to run for a long time every day in the outdoor streets or alleys. There is a certain risk factor. Setting reflective strips can increase the safety factor of couriers. In thermal environment, perspiration is very important to maintain the balance of heat. Impermeable materials will lead to the generation of heat pressure. The permeability of clothing to moisture is an important factor affecting heat exchange. Then is the choice of color. According to

each express company's own personalized customization, brighter color can alleviate workers' fatigue. Finally, we need to design our own personalized logo. The corporate culture in the image of clothing is presented through printing or embroidery.

5 Summary

From the perspective of human factor engineering, we know that the starting point of the design of the couriers' work clothes is to meet the following requirements. First is to wear comfortable suits which are easy for couriers to move. The comfort of work clothes is put in the first place. The second is to have certain functions to make couriers more convenient at work. The third is safety, health, and environmental protection. The logo design of the work clothes should be proper, and the fabrics used should be healthy and environmental protection, so as to reduce irritant harm to the skin. In the research of human factor engineering, human is the most basic factor. Humans' physiological and psychological characteristics and ability characteristics are the basis of the whole system optimization. Its goal is to pay attention not only to human health, safety, and efficiency, but also to human value, comfort, satisfaction, and achievement. More attention should be paid to the research of the couriers, so that the design can truly serve consumers, so as to achieve the highest integration efficiency of the system.

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Biodigital Design and Functional Visualization of Multi-Class Personalized Compression Textiles for Ergonomic Fit

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Abstract. Functional compression textiles have been widely applied in fields of medical, healthcare, rehabilitation, sports and personal protection. The global compression wear market is expected to grow at a CAGR (Compound Average Growth Rate) of 5.1% during 2017–2022. The rising of chronic venous disorders (CVD) (e.g. varicose veins, deep vein thrombosis, lymphedema) and the steady rise of fitness and sports industry are the major drivers to push up the potentiality of compression textiles globally. However, user-oriented ergonomic fit and personalized pressure designs for precise individualized treatment have not matured. The aim of this study is to establish a new compression textiles design-development-assessment system including modular structured sections of 3D body scanning, 3D digital seamless knitting and 3D biomechanical visualization, based on medical magnetic resonance scanning images, leg anthropometry and finite element model, to enhance design efficiency, treatment precision, user fit and compliance of compression textiles in practice. The visualized pressure profiles along lower limbs lengthwise and crosswise as well as internal stress and tissue deformations can be quantitatively detected via new system to guide technical design and functional assessment of multi-class compression textiles. The pressure dosages calculated by FE model presented a favorable agreement with the experimental data, demonstrating its practicability. This new biodigital-based compression design approach raised functional performance of ergonomic design of compression textiles and enhanced our understanding on effects of varying textile design parameters on pressure dosages delivery for CVD treatment.

Keywords: Biodigital design · Biomechanical visualization · Personalized compression textiles · Ergonomic fit · Multi-pressure classes

1 Introduction

Textile-based compression modalities (e.g., compression stockings, leggings and bandages), as a significant prophylaxis and treatment approach, have become the mainstay [1] for management of leg heavy, tiredness, discomfort and chronic venous

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disorders (CVD) [2–4]. The force-elongation behavior of textiles shell and geometric morphologies and tissue stiffness of lower body determine the contact conditions, thus varying resulting pressure profiles and treatment efficacy. Gradient compression stocking (GCSs) has become one of most widely applied approaches for treatment of CVD through exerting controlled pressure from distal to proximal lower limb to counteract the gravity force and to oppose the increased venous hypertension [5]. However, high non-compliance affected their efficiency and use frequency.

A large-scale invegistration on 3144 CVD patients reported that 63% of them indicated inapplicability and noncompliance [6]. Nonuse of GCSs on a regular basis has led to persistence or recurrence of symptoms [7, 8]. In recent surveys, ill-fitting GCSs is highlighted, which is considered to be related to the skills, training, and competence of clinicians carrying out the assessment [9, 10]. Initiating a hosiery fitting service was recommended by 77% of respondents for effectively improving user concordance [11].

To date personalized medicine are highly demanded for realizing customized compression therapy. Most of the commercial GCSs follow standard size charts by manufacturers or brand companies, which commonly ignore the *inter-individual* variability and discrepancies between consumers in different geographic locations. For example, heights of male in UK are generally greater than that in China by approximate 10 cm, and their body weight is greater by 31.7% in kilograms on average. Such differences in body mass and dimensions would impact accurate delivery of pressure in practical wear. Liu *et al.* conducted a digital body scanning on over 200 subjects in Hong Kong and has established a stratified body shape-driven sizing system [S^4] including classified "balanced", "diamond", and "inverted trapezoid" leg shapes [12], as to improve fitting of lower-body compression garment. However, to date a holistic compression design and engineering system for ergonomic fit of specific users is still wanting.

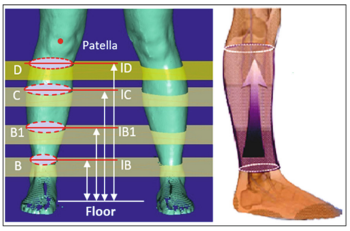
Three-dimensional (3D) digital body scanning and advanced digital knitting technologies provide a highly efficient and flexible fabrication approach to deliver tailored pressure for specific users. However, testing on wooden leg model or human body in lab is still hard to accurately assess overall pressure profile via a few pressure transducers. In our previous works, interactions between finite element (FE) lower limb and stocking has been simulated [13, 14]. In recent studies, effects of GCSs on flow and wall shear stress of deep venous system [15] and more sophisticated FE leg model have been developed [16, 17]. However, till now no study illustrates that how textile shells with different mechanical properties influence pressure function, and digital-based personalized design-knitting-assessment system has not been developed.

Therefore, in this study, a new compression textiles design-development-assessment system has been constructed and validated, including modular structured sections of 3D body scanning, digital seamless knitting fabrication and 3D digital simulation based on medical magnetic resonance scanning images, leg anthropometry and FE model. This digitized system not only contributes to improving personalized pressure design and function for raising ergonomic fit and user compliance, but also provide an operable reference for fitting diverse individual consumers' demands in compression treatment using compression textiles for healthcare, rehabilitation, sports protection and personal care, etc.

2 Methods

2.1 3D Digital Body Scanning for Morphologic Design of GCSs

To design ergonomic-fit GCS for specific subject, precise anthropometric measurement is the first step. A female subject aged 35 years old (height: 158.5 cm; body weight: 48.3 kg; body mass index: 19.2 kg/m^2) with no visible or palpable signs of CVD was recruited. 3D digital body scanning was conducted via a VITUS^{Bodyscan} scanner (Human Solutions of North America, Cary, NC) when the subject was standing still with her feet placed at two standardized footprints on the platform in a scanning booth. A true-to-scale 3D leg model with precise and reproducible capture (point density: 200 points/cm^3, scan time: 6–10 s) was obtained, which quantitatively determined the dimensions of the key anatomic positions along leg as shown in Fig. 1.



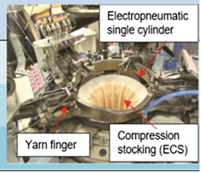
Positions	Height (cm)	Girths (cm)	Indication
Below knee	ID: 35.2	D: 33.9	Below patella center by 5 cm
Calf	IC: 28.0	C: 35.6	Calf with max. girth
Brachial	IB1: 19.1	B1: 28.3	Level at which the Achilles tendon changes into the calf muscles
Ankle	IB:10.8	B: 27.7	Ankle with min. girth

Fig. 1. 3D digital lower limb scanning of specific lower limb of the user

2.2 3D Digital Knitting Design and Fabrication of GCSs with Multi-Class Pressures

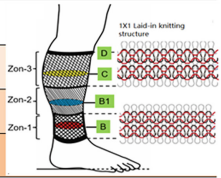
Custom-fit knee-high GCSs with multi-pressure levels (including Class I: 18–21 mmHg, Class II: 23–32 mmHg, and Class III: 34–40 mmHg) were designed, fabricated and evaluated. To achieve the proposed gradient pressure from ankle to calf, three graduation zones were designed along the hose, i.e., Zon-1, Zon-2 and Zon-3 (Fig. 2-a) using graphic system of Lonati knitting unit (45ME, Lonati S.P.A., Italy). GCS hoses were knitted by 1X1 laid-in structures via small-circular cylinder with a diameter of $4^{1/2}$ inches and set with a total of 352 needles. The polyamide covered elastomers as ground threads interlooped with polyamide covered inlay threads as illustrated in Fig. 2. GCSs in length of 260 mm were designed to achieve a minimum of 30% stretch in wale direction when being mounted on the subject's lower limb based on standard RAL 387/1.

Classes	Linear density of ground elastomers (set at all 4 feeders)		Linear density of inlay elastomers (set at the 1st and 3rd.feeders)	
	Core thread	Covered threads*	Core thread	Covered threads*
I	44 dtex	44 dtex/44 dtex/40F	233 dtex	44 dtex/ 44 dtex /40F
II	44 dtex	44 dtex/44 dtex/40F	294 dtex	44 dtex /44 dtex /40F
III	178 dtex	44 dtex/44 dtex/40F	405 dtex	22 dtex/22 dtex /20F



Gradient zones	Pressure residual ratio (%) **	Knitting height of zone (mm)	Mean knitting densities (stitches/inch²) Class I	Class II	Class III
Zon-1	100	86	3858	3561	3032
Zon-2	100-70	84	3116	2612	2574
Zon-3	50-80	90	2632	2522	2152

1x1 laid-in stitches



*Double covering: wrapping two spirals of non-elastic covered polyamide elastic threads in opposite directions around the elastic Lycra core. "dtex" indicates "decitex"; F indicates "filament"; **Standard GAL 387/1.

Fig. 2. 3D digital seamless knitting of GCSs with multi-pressure classes

Through adjusting the positive yarn feeding and Yoyo tension controller, the amount of elastomers can be controllably knitted to form GCS tubular with gradient pressure effects. The less the yarn fed, the smaller the loop sizes, thus the shorter the stretch, and higher the compression will be delivered.

2.3 3D Biomechanical Visualization of GCSs with Multi-Pressure Classes

Pressure performances were traditionally assessed via individual pressure transducers on a wooden leg model, which lacked capabilities to holistically reflect surface pressure and internal stress of compression exerted on user's lower limb. In this study, a subject-specific FE model has been developed to digitally visualize and intuitively evaluate GCSs with multiple pressure classes.

(i) Analysis of biomechanical interaction of GCS-lower limb. The interactions between lower limb and compression shell can be differentiated into three fundamental components, i.e., (a) GCS shell is stretched when being mounted to lower limb, exerting pressure on limb surface; (b) pressure compresses soft tissue and induces tissues deformation and internal stress redistribution, and (c) inner stress and skin pressures alter as GCS shell slide upward along lower limb. The contact mechanism between the two bodies (GCS and lower limb) can be depicted in Fig. 3.

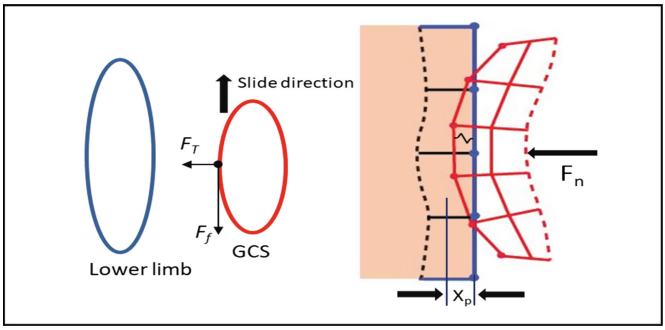


Fig. 3. Description of contact mechanism between GCS and lower limb

In this study, the lower limb and the GCS are assumed as hyperelastic models. The two interactive bodies follow a frictional non-linear connection, and the sliding resistance is proportional to the frictional coefficient. The contact pressure can be computed as

$$u(x,y) = \frac{1-\mu^2}{\pi E} \iint_{\Omega} \frac{F_T(x',y')dx'dy'}{\sqrt{(x-x')^2+(y-y')}} \tag{1}$$

where F_T is contact pressure, u is frictional coefficient, E is Young's modulus, μ is Poisson's Ratio, and u(x, y) is the surface displacement [18]. It is assumed that the interactive contacts of the two bodies do not penetrate each other, then penalty method was used to incorporate the contact condition into the finite element discretization to prevent penetration. The penalty method equation can be expressed as

$$F_T = K_n x_p \tag{2}$$

where k_n is contact stiffness, and x_p is penetration depth [19].

(ii) Reconstruction of geometries of subject-specific lower limb and GCS. The geometry of the subject's right lower limb was reconstructed from coronal images via Magnetic Resonance Imaging (MRI) scanning. The MR image slices in thickness of 2.0 mm and an in-plane voxel size of 0.98 mm × 0.98 mm were taken when the subject was in supine position. The MR images were processed via MIMICS software (v17.0, Materialise, Leuven, Belgium). Soft tissue and rigid bones are the two main components involved in FE model. The boundary surfaces of the two components, as solid sub-models, were processed via SolidWorks (v2013, Massachusetts, US). The geometric shape and gradient zones of GCS were reconstructed using FE Package ANSYS Workbench (v15.0, ANSYS, Inc.) (Figure 4) based on leg morphologies determined in section (i).

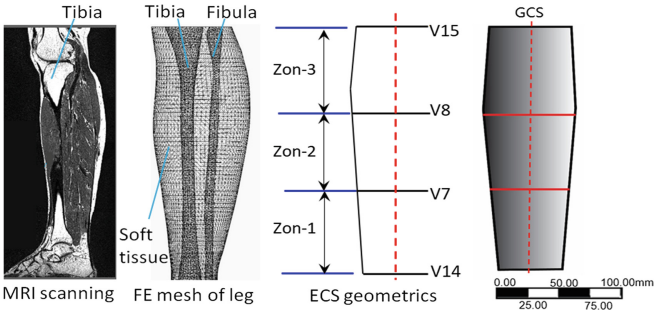


Fig. 4. FE leg mesh and gradient compression stocking (GCS) geometry buildup

(iii) Determination of material properties of FE sub-leg and sub-GCS models. Mechanical properties of soft tissues was modeled via Neo-Hookean hyperelastic model, in which $1/D_1$ and C_{10} were 7.14 MPa and 0.005 MPa, respectively [16], and the bone is designed as homogeneous, isotropic and linear elastic materials. The bone's young's modulus and Poisson's ratio were set to 14.0 GPa and 0.3 [20, 21], respectively. The GCS textile shell was assumed as homogeneous, orthotropic and linear elastic materials. The mechanical properties of GCSs (Young's modulus, shear moduli, mass density, Poisson's ratio and thickness) were obtained through instrumental tests under a standard condition (ISO13934-1:1999). Biaxial tensile tester (KES-G2) and shear tester (KES-FB1) (Kato-Tec Co., Ltd., Japan) were used to determine tensile and shear moduli of GCS fabrics. Table 1 illustrates the mechanical properties of the studied GCSs with multiple pressure classes, which were assigned to the FE model to visualize biomechanical function of different GCSs.

(iv) Finite element mesh and boundary condition. Digital biomechanical assessment of GCS was conducted using ANSYS Workbench modeling system (v15.0, ANSYS, Inc.). The GCS shell was meshed using 4-node quadrilateral shell elements, and the lower limb was meshed using 8-node hexahedron elements. The displacements of bony parts were zero in all degrees of freedom at x, y, z directions. The GCS shell slided onto the leg with displacement of 100 mm from the ankle to top edges of leg in pulling. When GCS reached stable status, the contact between leg and GCS was activated. There was no displacement boundary on the GCS at the end of the simulation.

(v) Validation on the developed subject-specific FE model. Interfacial pressures between GCS and the subject's lower limb were measured *in vivo* to validate the developed subject-specific FE model. PicoPress® pressure sensor was used to test skin pressures at twelve typical locations over three key height levels (ankle, brachial and calf) and around four key directions (anterior, posterior, medial and lateral) underneath GCSs with multi-pressure classes along leg surface in standing position. The average values of the three times of pressure tests were employed for model validation.

Table 1. Mechanical properties of GCS materials with multi-pressure classes

Pressure Classes	Gradient levels	W ($\times 10^{-10}$ tonne/mm^3)	E_1 (MPa)	E_2 (MPa)	G_{12} (MPa)	V	T (mm)
(I) Mild	Ankle-B	3.25 ± 0.12†	0.28 ± 0.02	0.19 ± 0.02	0.11 ± 0.01	0.27 ± 0.02	1.0 ± 0.1
	Brachial-B1	2.75 ± 0.11	0.21 ± 0.02	0.15 ± 0.01	0.08 ± 0.01	0.33 ± 0.03	
	Calf-C	2.30 ± 0.10	0.15 ± 0.01	0.10 ± 0.01	0.05 ± 0.01	0.37 ± 0.03	
(II) Moderate	Ankle-B	3.57 ± 0.13	0.35 ± 0.02	0.21 ± 0.02	0.14 ± 0.01	0.25 ± 0.02	1.1 ± 0.2
	Brachial-B1	3.02 ± 0.13	0.27 ± 0.03	0.15 ± 0.01	0.11 ± 0.01	0.27 ± 0.02	
	Calf-C	2.53 ± 0.11	0.19 ± 0.0	0.09 ± 0.01	0.07 ± 0.01	0.29 ± 0.01	
(III) Strong	Ankle-B	3.74 ± 0.14	0.41 ± 0.03	0.17 ± 0.02	0.17 ± 0.01	0.23 ± 0.01	1.2 ± 0.2
	Brachial-B1	3.16 ± 0.13	0.32 ± 0.03	0.13 ± 0.01	0.13 ± 0.01	0.25 ± 0.02	
	Calf-C	2.65 ± 0.11	0.22 ± 0.02	0.08 ± 0.01	0.08 ± 0.01	0.27 ± 0.01	

Note: W: mass density; E1 and E2: Young's modulus in wale and course directions of fabric; G_{12}: shear modulus; V: Poisson's ratio; T: mean thickness of fabric specimen; †Mean ± standard deviation of the six measured values.

3 Results and Discussion

Figure 5 illustrated the comparison results between the simulated and the measured interfacial pressures at the twelve positions along subject's lower limb beneath GCS with three pressure classes (I, II and III). Most of the testing points presented consistent trends, especially for Class I, which demonstrated the reliability of the developed FE model in biomechanical assessment of GCS. The larger deviations at B1 and C beneath GCS with classes II and III were potentially due to bony anatomic structures at anterior regions of the lower limb.

Figure 6(a–d) quantitatively displayed skin pressures along anterior and posterior sides illustrating more clearly gradient distributions and magnitudes under exertion by GCSs. Skin pressures near anterior tibia crest and posterior Achilles tendon were remarkably higher than those at brachial and calf levels along the same direction lengthwise. Reversed gradient pressures occurred at medial and lateral sides along the lower limb (Fig. 5b–d), where calf pressures were generally higher than those at ankle, largely due to the relative flatter anatomic surface above bilateral tarsus with ellipse cross-section.

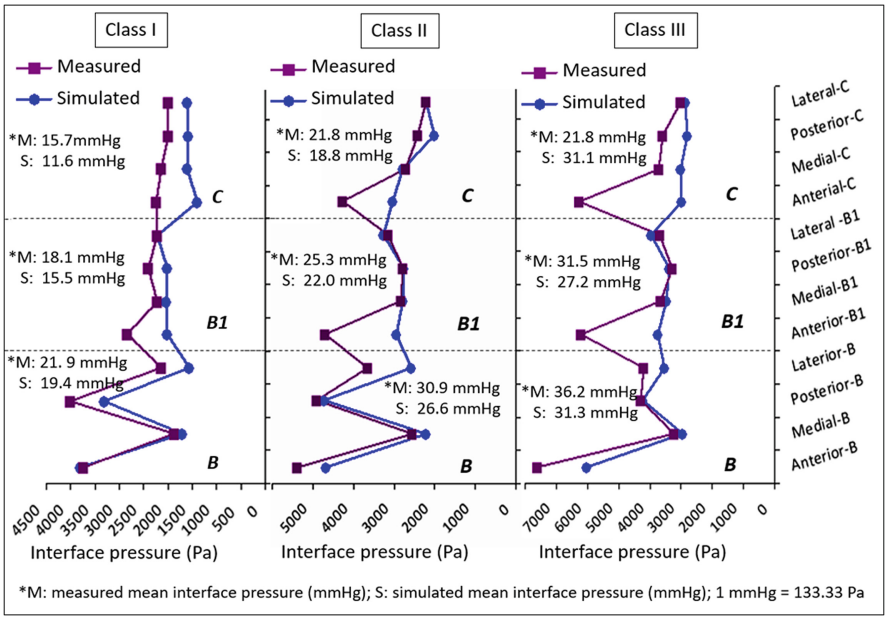


Fig. 5. Comparison on the simulated and measured skin pressures by GCSs with multi pressure classes

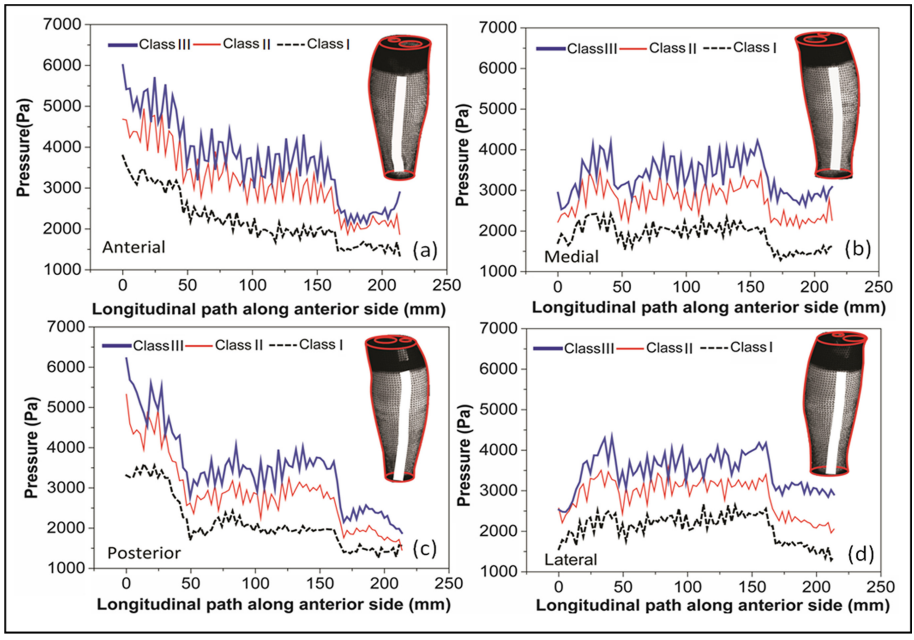


Fig. 6. Quantitative skin pressure gradients along four longitudinal paths of lower limb

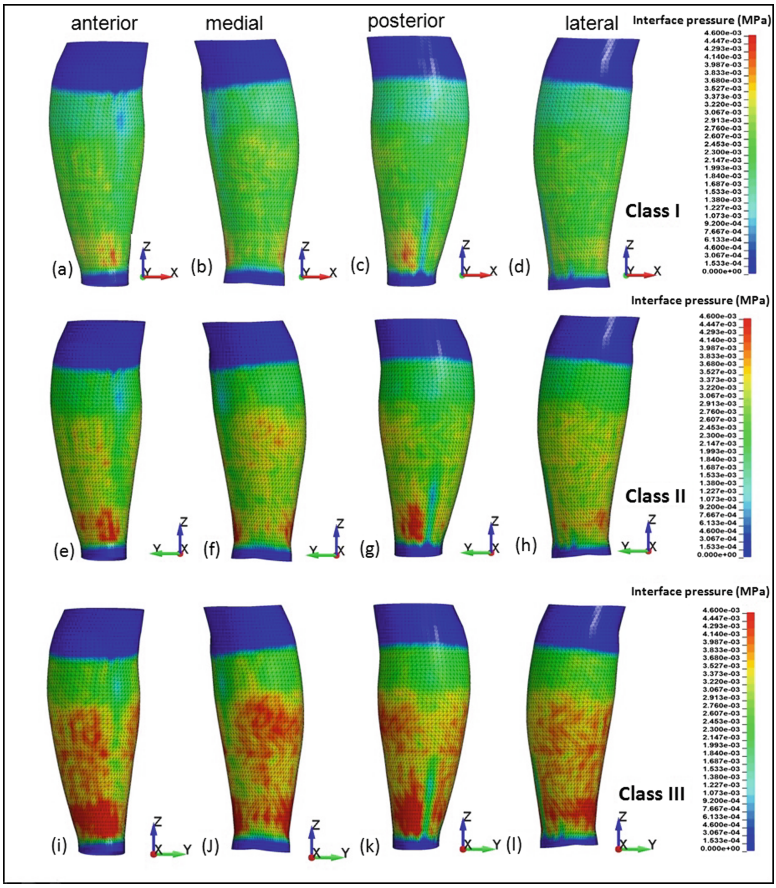


Fig. 7. Simulated gradient pressures along lower limb under multi-pressures classes

Figure 7 illustrated interface pressure profiles by the developed GCSs with three pressure classes in view of the four different directions (anterior, medial, posterior and lateral). It can be seen that degressive gradient pressures distributed from the ankle to calf, especially for Class III, which follows the pressure profiles depicted in RAL387/1 standard on compression stockings, and the gradient external pressures were gradually transmitted into the deeper tissues.

Figure 8 further shows the resultant heterogeneous internal stresses within soft tissues of lower limbs beneath GCSs with different pressure classes (I, II and III). It can be seen that the higher stress zones became more concentrated under higher pressure exertions, especially at anterior and posterior sides with larger curvature and at areas near rigid tibia and fibular bones. The protruding muscular tissues located at bilateral and posterior calf is one of the major factors to raise encircled recoiling forces by elastic textile shells. The decreased knitting densities and enlarged shell dimensions around calf via 3D digital knitting design counteracted the raised limb dimension, thus generating degressive pressure profiles from ankle to calf to prevent tourniquet effect which could impede venous return.

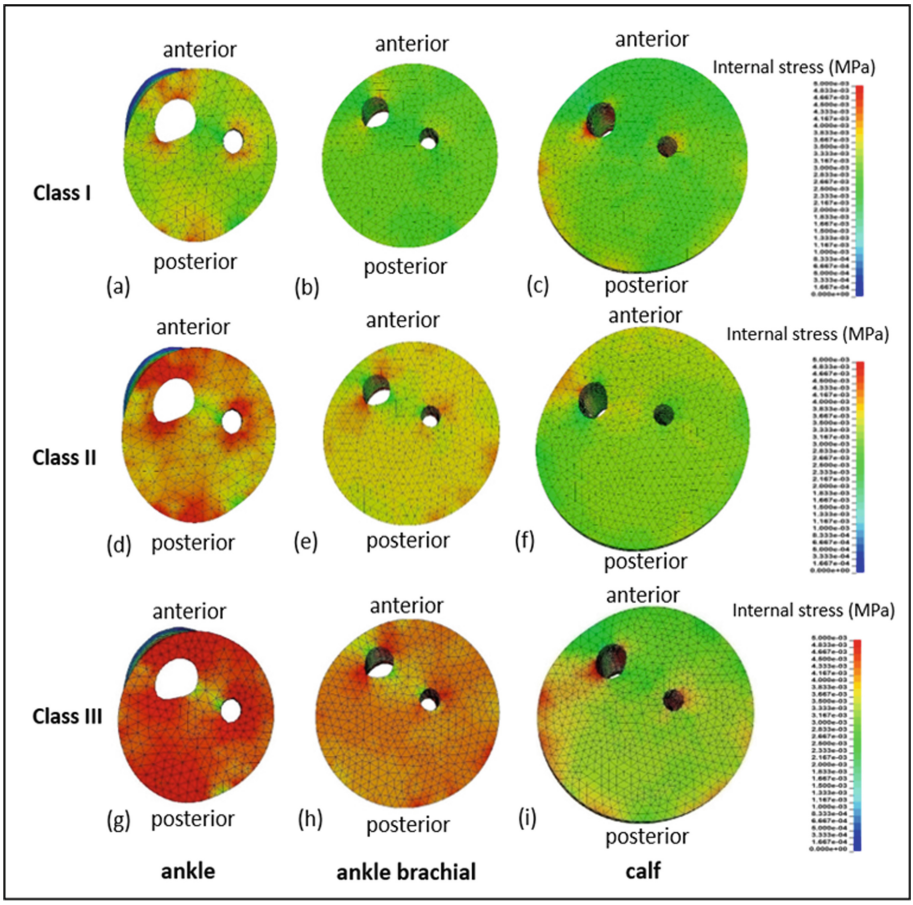


Fig. 8. Internal tissue stress distributions by GCSs with multi-pressure classes

4 Conclusion

Design and development of functional compression textiles is a complex process which requires interdisciplinary cooperation among textile engineering, ergonomic design and biomedical knowledge to cater for personalized compression therapeutic requirements. The present study demonstrated a new approach for designing, fabricating and assessing performances of compression textiles to explore more possibilities of computational-based design and development in modern customized healthcare and medical industries. Applying 3D digital body scanning, hybrid elastic materials, seamless knitting fabrication and finite element modeling, personalized compression textiles (e.g., GCSs) can be developed to realize the expected pressure dosage delivery and ergonomic fit. The digital model visualized pressure and stress profiles with varying textile parametric design, which would largely facilitate pressure design efficiency, and enhance our understanding on effects of material properties on pressure dosage delivery for treatment of chronic venous disorders in practice.

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The Application and Development of Smart Clothing

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Abstract. Smart clothing is a hot research topic in recent years, it is also the application and exploration of intelligent manufacturing in the textile and clothing field. This paper analyzed the design focus and the development trend of the smart clothing through expounding the application, the characteristics, and the domestic and international research progress of smart clothing.

Keywords: Smart clothing · Design focus · Application · Future development

1 Introduction

A prominent feature of the Made in China 2025 strategic mission is the emphasis on upgrading and transforming traditional industries through intelligent manufacturing. As an indispensable part of people's lives, the functional attributes of clothing are expanding constantly with the increasing competition in the clothing industry and the development of modern research technologies. Based on the traditional clothing industry, smart clothing is formed and developed by integrating the concepts and technologies of material science, computer engineering, and fashion design. Its main task is to use new technology to change and improve the traditional functions of clothing.

2 The Basic Concept of Smart Clothing

As an emerging interdisciplinary field, wearable technology mainly explores and creates science and technology that can be worn directly on the human body or integrated into the user's clothing or accessories [1]. Clothing is an essential part of people's daily life. The idea of smart clothing integrates wearable technology into traditional clothing to provide clothing with dual functions of perception and feedback [2], that can not only sense the external environment or internal changes but also react to those changes in real time through a feedback mechanism.

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Smart clothing is mainly developed in two ways: one is to use intelligent clothing materials, such as shape memory materials, phase change materials, color-changing materials, etc. in clothing design and production. The other is to introduce sensing technology, microelectronic technology and information technology, such as flexible sensors, low-power chip, and low-power wireless communication devices, into everyday wear to perform certain medical testing, track user's vital signs (i.e. heart rate and other vital signs), or to provide fitness guidance (such as calorie consumption, stress level, heart rate).

3 Application of Smart Clothing

Smart clothing was originally created for special occasions, such as military applications to improve combat defense capabilities. With the development of science and technology and the increasing market demand, smart clothing not only plays an essential role in the military field, but also is used in medical field, high-performance sportswear, and high value-added casual wear.

In the past few years, communication and sensors technology have been integrated into clothing and accessories design such as shoes, shirts, belts, and even jewelry or watches to meet the different needs of people or occasions [3–5]. Overall, the application of smart clothing is mainly in two areas: medical monitoring and sports and fitness.

3.1 Medical Monitoring

Smart clothing represents an advance health care system, which attaches mobile devices to everyday wear to provide uninterrupted information transmission between patients and remote telemedical providers through information and communication technologies. Smart clothing can help provide medical support, collect clinical data, and monitor important life characteristics of the wearer. It can be used for collecting important health parameters for the elderly and chronically ill patients and transmitting the information to the smartphone or computer of the wearer or his or her family member(s) via LAN. Therefore, based on the information, remote telemedical provider can decide whether it is necessary to carry out emergency treatment and/or issue a medical alert in time. The home-based e-health care can help the elderly or chronically ill patients to obtain real-time medical monitoring at home, and the diagnosis and treatment can be performed between the patient and the doctor anytime and anywhere. The United States launched the marketing of smart shirts in 1999 [6]. The shirt was equipped with sensors to measure heart rate and lung activities. In addition, it also had an option to transfer the medical data to the control room via the Internet and provide data analysis.

3.2 Sports and Fitness

Utilization of smart clothing in the field of sportswear is mainly embodied in new fiber materials (such as antibacterial fiber, phase change fiber, etc.) and smart devices (such

as heart monitoring sports bras). The Athos smart sportswear and shorts developed by the University of Waterloo in Canada [7] incorporated the myoelectric motion sensor into the fabric to analyze the physiological data, such as the movement progression and muscle fatigues of the body part, by measuring the fluctuation range of muscle fiber contraction. The information is then transmitted to the software on the user's smartphone to provide an evaluation of movement progression and monitor the accumulation of stress on muscles throughout training in the form of various charts.

4 Design Focus and Development Trend of Smart Clothing

The design of smart clothing is different from the design of ordinary clothing. In addition to aesthetic performance, factors such as wearability, usability, reliability and durability also need to be considered. The design focus of smart clothing is summarized in the following aspects.

4.1 People-Oriented

In the process of transforming the seller's market into the buyer's market, the organic combination of the various elements of the clothing must satisfy the subjective needs of people's psychological and physiological needs on the premise of satisfying their objective needs. People's acceptance of new technologies is influenced by their sociality, values, gender, and educational experience. As the material carrier of wearable devices, smart clothing is designed to meet the diverse needs of users. Therefore, the people-oriented ergonomic design conducted by observing users' acceptance of smart devices and parameters from their cognition and emotions assessment becomes a problem that needs to be focused on and resolved [8, 9].

4.2 Wearability

In order to broaden the utilization of smart clothing, the overall design shall meet the basic need of comfortability as while as satisfying the functionality of smart clothing. Foreign researchers pay special attention to the comfortability in the design of smart clothing, which include the thermal and humidity comfort of the clothing, the sensory comfort of the contact of sensor and human skin, and the safety of use. Using the flexible sensing technology, the sensor and the apparel fabric are integrated into one, which becomes the basic fabric of smart clothing. It can sensitively understand and react to the changes of various physiological parameters and environmental parameters of human body.

4.3 Enhance Human Body Function

The emergence of smart clothing has also played an important role in improving human body functions to a large extent. A Japanese technology company has recently developed a set of exoskeleton, which provides external strength to the human body when lifting heavy objects through a hydraulic pump device. It is mainly used to help

the elderly with limited mobility or partial self-care ability, or people doing longtime physical labor work. The user's physical body function has been improved significantly.

4.4 Accessibility

The accessibility of smart clothing means that the product provided to the end user must be easy to operate and convenient to use. Especially for the elderly and the chronically ill population, the simple and convenient experience is especially important.

4.5 Ergonomics

Smart clothing has many forms to serve different purposes and requirements, but the core factor is the human body. Human has four core elements: shape, movement, physiology, and psychology. Therefore, ergonomic requirements should be considered when designing smart clothing, so that the human body can maintain the most natural movements while wearing smart clothing.

4.6 Provision of Software and Services

Affected by the Internet and Industry 4.0, the development of smart clothing is based on software systems and Internet platforms and is combined with the Internet of Things, big data, and cloud computing to achieve intelligence. The development of smart clothing has also integrated with mobile computing, application software and social media to achieve on-demand customization, such as based on the information transmitted through the LAN to the patient's smartphone and computer, the doctor can decide whether emergency treatment is needed according to the situation.

5 Conclusion

Smart clothing is not only one of the implementation strategies of Made in China 2025, but also one of the means to upgrade and transform the clothing industry. Therefore, an era of rapid development of smart clothing is coming. As one of the manifestations of wearable devices, smart clothing focuses on "wearability". At present, smart clothing has various forms, but the general problem is that the wearability is not high. Therefore, how to improve the wearability and aesthetics of smart clothing as well as how to broaden the applications of smart clothing become very important in the design and the development of smart clothing in the future.

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A Classification of Care Apparel Characteristics for Disabled User Requirement

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Abstract. Care apparel market for disabled customers in Hong Kong is substantially grown up over last decade. Disabled users could hardly find their required apparel products. It was found that the clothing needs of disabled users tend to have the functional and aesthetic elements of apparel product, which are key factors to determine the feasibility of production method. The study aims at to classify the apparel characteristic based on disability level of users, in order to assist care apparel development in production and market. Observation and interviews were made with the disabled customers. The result revealed that the user expectations for apparel product were classified into three groups based on characteristics of current products.

Keywords: Care apparel · Disabled user · Apparel market · Apparel design

1 Introduction

Nowadays, the apparel industry is converting from manufacture-oriented to customer-oriented, in which consumer requirements has determined the production process. The demand of products from the disabled people is increasing, but the supply of satisfactory specially design apparel is still not efficient, and the situation is even worse for the disabled apparel market in Hong Kong. From the experience in the Care Apparel Center in Hong Kong, which offers special design with both medical requirements and appearance satisfaction to maintain the well-being of disabled users, it is extremely hard for the disabled customers to find proper care apparel products in the market. Questions has been raised about why the accesses to care apparel could not satisfy the demand and requirements of the disabled users. Referring to the previous production of the care apparel center workshop, the lead-time could be as long as several months, depending on the complexity of the product design. Product design and characteristic is the key factor to choose proper manufacture method. Therefore, a study has been designed to identify disabled user requirement, and further investigate the care apparel characteristics, in order to prepare a foundation of proper production selection.

1.1 Care Apparel Definition and Features

The awareness of apparel for the disabled people has been proposed since the 1980s, during which the topic of 'what to wear' was discussed about the apparel design

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adjustment for disabled elders [1], and it led to the discussion of clothing design. Adaptive clothing, as defined by the 'Disabled world', are designed for people who have difficulty in dressing themselves, including the ones with disabilities, elderly, and patients [2]. 'Inclusive design and product' is introduced in the year 2002 by Keates and Clarkson [3], successfully focuses on the needs, wants, and aspirations of other users (aging population, marginalized minorities, and people with disabilities), and arises conscientious attention to both mainstream market for the abled users, and all other consumers, including the disabled, children, and the older segment [4].

Care apparel, as a part of the concept, has been further identified in Care Apparel Center. It has been defined for users with difficulty in dressing or other special clothing needs [5]. The products of care apparel have three features in common:

(1) The clothing designs permit more independence and enabled the wearers to take care of their personal needs as much as possible.
(2) The clothing can meet functional and appearance requirements, thereby contributing to the social adjustment of the wearers.
(3) Psychological and physical comfort are taken into consideration in order to enhance a sense of well-being for the wearers.

In the review of Ng et al. [6], medical garment (previous name of care apparel) are mainly for three purposes: (1) for protective function purpose, (2) for treatment function purpose, and (3) for care function purpose. Caring function design in the apparel has been the key consideration in care apparel design to maintain the well-being of disabled users.

1.2 Disabled User Classification

The disabled people suffer from different challenge. The evaluation of disability level is used as a measurement in some of studies regarding product development for the disabled users. In general, two approaches were discussed and refined for the measurement. One is to identify the disability level directly into the seriousness of body functions, such as Washington Group general measurement on disability [7]; and the other is to assess the adaptive capability of the disable person into real life activities, as described in Activities of Daily Living (ADLs) [8].

The earliest appeared definition regarding disabled patients' recovery and functional ability is Barthel Index (BI) [9] and modified Barthel Index (MBI) [10, 11]. It has been considered as the golden standard to assess one's performance in self-care tasks, and in the criteria, there would be three to four scales for assessment. Similar index was also developed as Katz's ADLs index [12], in which six elements were examined and scored in difficulty scale and assistance scale separately. The scope covers core activities including bathing, dressing, transferring, using the toilet, continence, and eating [13], and later was extended with more activities such as shopping, cooking, managing money, mobility [14], with more social activities and participation of disabled persons.

Based on the foundation of BI model, Wang et al. [15] have proposed an evaluation system of functional clothing for wheelchair users, referring to a five-scale frame of activity of daily living (ADL) in order to measure the personal capability to handle

apparel dressing on and off of the users, which was used in the investigation of trousers trials. The system has divided the personal capability into the levels as: (1) totally dependent, (2) very dependent, (3) partly dependent, (4) slightly dependent, and (5) independent.

1.3 Apparel Characteristics and Production

Assessing the care apparel product should consider both production feasibility and customer expectations. The criteria of apparel design for a variety consumer needs include three elements: functional, expressive, and aesthetic, as the framework combined with the culture background of the target consumer [16]. Especially for the physically disabled user, the functional element and expressive elements determines their reaction in choosing [17]. Function and aesthetics are also identified to be connected in the design of garments for disabilities [18]. Yu and Rahman [19] has proposed the attributes of inclusive apparel for consumer shopping experience, including tangible attributes and intangible attribute. Tangible product attributes include design/styling, comfortability/fit, and material, and intangible attributes include price and product assortment. Product development oriented factors such as comfort, fit, style, value/low cost, and function are most desired attributes to the consumers when accepting the garment [20, 21].

Regarding the various consumers in mainland China and Hong Kong, Yu and Rahman [19] has generated two types of customers based on psychological appeals: (1) practical and convenience-seeking consumers, and (2) fashionable and hedonic consumers, that different groups have various criteria regarding care apparel purchase. Eleven items include utility, comfort, price, appearance, easy to wear, non-outstanding, fitting, easy care, material, durability, and delivery have been identified to be related with disabled user purchase preference [22].

The selection of production strategy is based on the feature of the apparel product. Currently mainstream method in apparel productions include mass production, customization, and mass-customization, which was discussed in many studies. Mass production is low-cost manufacture determined by high demand capability, and also the long runs of identical product based on market orientation and specialization of labor [23]. As the opposite, customization 'uses a flexible production system to deliver a product to our that matches the needs of an individual customer or user', in order to maximize user satisfaction through product design [24]. Mass customization is the strategy combining mass production and customization in order to provide tailored products and service to fulfill the individual consumers based on specific needs and wants [25]. Techniques and design will vary between the production application, which is to be considered with apparel characteristics.

2 Methodology

In this study, a thorough evaluation over care apparels in the Care Apparel Center which is located in the Hong Kong Polytechnic University has been conductions. In order to clearly understand the purpose of choosing care apparel for disability users,

their capability in performing daily activities are also considered. First, disability level of different users was defined based on the previous studies, dividing the capabilities into three different categories: low disability level, moderate disability level, and high disability level. Observations about the disability level for each person, individual purchasing preference, and ordered care apparel types and characteristics were recorded for the further classification of care apparel products.

The care apparel characteristics regarding functional design and aesthetic design were evaluated. Details in the apparel design including cutting, structure, opening, closure, accessories were also extracted. Similarities in the deign to fulfill several purposes have been identified, and a classification of the care apparel characteristics from the perspective of production feasibility has been generated. The information from the investigation was summarized to generate an overall classification of care apparel features.

2.1 Disabled User Observation

Disabled clients to the Care Apparel Center have been observed with their preference, personal requirements from care apparel products. The disability level model from Modified Barthel Index (MBI) [10, 11, 15] have been modified in this study, setting the criteria regarding dressing capability of care apparel users in to three levels: (1) low disability level, (2) moderate disability level, and (3) high disability level.

Interviews were conducted after each client having explained about their personal description on disability challenges and product expectations. Open-ended questions were prepared for each client, and the disability level was assessed after they have purchased the order for specific care apparel. The procedure was processed in an experience-base direction, because the clients and their required care apparels were randomly collected from the regular activity in the care apparel center, which was difficulty to control with the amount and detailed requirements.

2.2 Care Apparel Characteristic Classification

Care apparel characteristics were investigated in two directions. Firstly, the description of disabled clients was recorded for analysis. The interviews about each personal requirements and expectations regarding individual conditions have been reviewed in the form of text, and key words have been extracted to identify the determinants of care apparel characteristics for disabled user consideration. Understanding of disabled client types were referred from study of Yu and Rahman [19], and characteristic extraction has integrated the FEA model of Lamb and Kallal [16] and Xie et al. [22].

Secondly, historical orders have been investigated to identify the most frequently ordered products with specific detail modifications. Product type and characteristics in design and application were identified into a general list. Similar types and functions regarding characteristics were classified using the list of all care apparel information. The classification was further applied with the disability level settings of the care apparel users. Finally, a summary of care apparel characteristic regarding different disability levels and feasibility production method was proposed.

3 Result

3.1 Care Apparel Overview

The feature of the garment provided for disabled users are different in design, pattern, material. Application of easy-handling accessories for disabled people are also various. The investigation in the Care Apparel Center in Hong Kong has collected data with totally fifty-four types of products to identify characteristics. Then they were discussed with its functions and production procedures.

In the design of care apparel, structures are adjusted to adapt with the special body movement restrictions. Openings are changed to the side seams in order to add up the easiness in dressing through arms and legs. Accessories such as hooks or buttons are also substituted by sticking fabrics with its soft surface friendly to the sensitive skins of the users, or changed into snap-fastener that could quickly assist the nursing service of the care givers. As a summary, from the perspective of design and material, the care apparel has the following features:

- *Use zippers and VELCRO® fastener as main closure design*
- *Side-open and back-open for easy do-on and do-off*
- *Elastic bands to substitute fixed length waist*
- *Magnetic buttons and zippers to keep the closure oriented*
- *Less structural cutting*
- *Adjusted measurements in tightness or allowance*
- *Knitted fabric to keep warmth and softness*

The similarity in the designs has showed the possibility of production optimization. Even though the structures of the care apparel are different from the regular fashion styles, the large demand from potential consumers still form a foundation of mass production into the market.

3.2 Interview About Care Apparel User Preference and Expectation

An interview with randomly selected disabled people and care givers was conducted to identify the preference and expectations about care apparels. In this study, there were 20 disabled respondents, and 20 care givers. The detailed information of respondents is listed in Table 1.

From the interview, it could be identified that functional-oriented designs are the focus of disabled user expectations. In the responses from the disabled persons, stylish choices are also the main topics about apparel selection. Price and staff engagement in the apparel purchase are also highly discussed during the interview, indicating the relationship between care apparel production cost and related service in the market.

The most participants claimed their requirement in the design of easy do-on and do-off. As in some specific occasions such as toilet or medical examination, disabled users have to manage with self-dressing because their care givers are not allowed to accompany. One of the interviewee as care giver for her mother has mentioned:

Table 1. The statistics of disabled elderly purchase orientation

Disabled users			Care givers		
Items	N	%	Items	N	%
Easy Do-on & Do-off	7	35%	Self-dressing in toilet	11	55%
Easy button up	5	25%	Easy button up	8	40%
Adjusted opening	3	15%	Adjusted opening	2	10%
Fastening	6	30%	Fastening	4	20%
Suitable size & fit	2	10%	Comfort & Function	2	10%
Stylish choice	9	45%	Stylish choice	4	20%
Low price	4	20%	Affordable price	1	5%
Ready-to-wear garment	3	15%	Time-saving	5	25%
Functional design	3	15%	Functional design	3	15%
Physical store	10	50%	Physical store	5	25%
Online shopping	1	5%	Online shopping	9	45%
Require qualified staff (know about special needs)	7	35%	Require qualified staff (know about special needs)	7	35%
Require regular sale	2	10%	Require regular sale	2	10%
Have other to buy clothes	3	15%	Other considerations	5	25%
Average age	74.6 (66 ~ 88)		Average age	39.3 (21 ~ 58)	

Since my mother always need to go hospital for follow-up medical checking. When she carries out X-ray checkups, she needs to change to specialized clothing. It is good that having an easy managed fastening then she can dress and undress by herself, because I cannot to go inside the X-ray clothing chasing room.

From the perspective of psychological impact, the allowance for the disabled to dress themselves could further enhance their confidence, which is essential for them to keep a healthy relationship with families. Some has mentioned his delightfulness of adopting mass customized products for disabled relatives:

They will feel that they are useless when I help them dressing or undressing. Many times, he foes to the toilet by himself. The service you proposed can help them a lot in their daily live. I think it can help them become more confidence.

More disabled interviewees claimed about the unsatisfactory appearance of existing garment that provided from elderly home and rehabilitation centers. Such complaints have expressed the appeal from some of the disabled users who have mild difficulties in daily life:

I do not want to wear the clothing that elderly center promoted, I think those are like the hospital clothing. I don't want wear this just because of missing three toes.

The clothing provided from the elderly center without is aesthetic element. I prefer to buy clothing from the market, but fastening is the main challenge for me.

Psychology for such group of people still weigh much, for the fact that they have enough time for social activities but less choices as entertainments. Whereas the

apparel design is limited in the market, resulted with a lack of expectation of them for social participation.

3.3 Care Apparel Characteristics and Classification

Based on the observation of disabled client orders in the care apparel center, and the experience of care apparel procedure, a new classification regarding the marketization of care apparel production has been generated. It has been found out that the users in high disability level tend to pay attention to the functional design of the care apparel. Contrarily, users in low disability level tend to focus on the aesthetic design of the care apparel products. The moderate disability level users have a mixture consideration on both functional performance and aesthetic expression of the care apparel product.

From the perspective of production feasibility, the care apparel can be classified into three categories: a. Highly individualized products, b. Low individualized products, c. Universal products (Fig. 1). The new classification can be refereed as a pre-selection of proper production method before the product is put into the market.



Fig. 1. Three-level classification of care apparel characteristics

Firstly, highly individualized apparel and products require full body measurement, with strong personal preferences, or styles of formal occasions. The highly individualized property of care apparel requires a dedicated manufacture on the product, and different measurements causes the main challenge in production. Therefore, a proper production method could be customization, which will allow for modification on single item based on the body contour or functional innovation specifically. Secondly, low individualized products require partial body measurement, or contain replaceable assembly parts in the design. From the investigation of current care apparel products, key functions remaining at the opening design, closure solutions for self-care, and effective assessors to maintain the easy-wear purpose of the apparel product. The main part of the product which could hold the silhouette could be remained in the mass-customization, with only small part of the apparel requires customization by the users. The universal products require the minimum fitting accuracy in measurement, with a standardized sizing system (or free size) to meet with low personal preference. Such type of care apparel is often in unified size with simple design, in order to maintain the one-for-all purpose for users. The simplified design could be applied into mass production, which could reduce the cost in manufacture and provide the product at a short lead-time to the potential disabled users. Table 2 presents the detailed classification of the characteristics of the care apparel products.

Table 2. Criteria of three-level characteristics for care apparel production

Key items	Highly individualized	Low individualized	Universal design
Measurement modification	Full-body measurement	Partial-body measurement	Standardized measurement
Personal requirement	Strong personal requirement	Medium personal preference	Little personal requirement
Fitting requirement	Highly accuracy	Moderate accuracy	Low accuracy
Wearing occasion	Formal garment, Medical garment	Casual apparel Some treatment purpose	Casual apparel Few medical purpose
Product lifespan	Long-time	Partial duration	Short-time Disposable
Design complexity	Very complex	Medium complex	Not complex
Production difficulty	Very difficult	Medium difficult	Not difficult
Production requirement	Customization Exquisite design	Mass-customization Information system	Mass production High-efficient network

4 Conclusion and Future Study

In this study, the investigation regarding care apparel in Hong Kong has been conducted. The products in Care Apparel Center, which is located in The Hong Kong Polytechnic University has been reviewed and analyzed with its characteristics based on requirements of different user disability levels. Firstly, from observation it has been found that the different disabled users tend to have various clothing requirements regarding care apparel purchase. Functional-oriented garment characteristics were highly related with a high disability level of the users, while aesthetic-oriented garment characteristics were highly related with low disability level of the users. To further identify the relationship and classification of the care apparel features, a thorough investigation has been conducted using the products in the Care Apparel Center, and a three-level classification regarding the feasibility of care apparel production based on its characteristic property could be obtained.

The direction of further study focuses on the investigation of perceived barriers in care apparel application for disabled persons in Hong Kong. Topics regarding care apparel design optimization and specific market business model is also to be proposed and evaluated. Apparel market in Hong Kong has been an international scale platform with high influence to the world industry, however, the development of care apparel in local market still lacks further strength. Hopefully the clothing requirement of disabled customers in Hong Kong could be identified to instruct the market development of care apparel.

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Author Index

A
Abou Khaled, Omar, 186
Accolla, Avril, 110, 206
Aceves-González, Carlos, 129, 196, 215, 282
Adam, Dominique Leite, 117
Almendra, Rita Assoreira, 292
Alqahtani, Yahya, 229
Andrade, Yanira, 387
Angelini, Leonardo, 186

B
Bieger, Isabel, 399
Bozza, Francesca, 239
Brischetto, Alessia, 22
Brito, Lays Campos, 35

C
Cabral, Alexandra, 337
Cao, Xinyu, 469
Caon, Maurizio, 186
Caporusso, Nicholas, 47
Cardenas, Leslie, 387
Carreto, Catarina, 438
Carreto, Rui, 438
Caruso, Ivo, 251
Carvalho, Cristina, 329, 358, 399, 411
Chakraborty, Joyram, 229
Chávez-Sánchez, Ileana, 129
Chen, Dongsheng, 500
Cortes-Chavez, Fabiola, 282, 301
Cristallo, Vincenzo, 251
Cui, Yangyang, 47

D
da Silva, Caelen Teger, 117
Di Bucchianico, Giuseppe, 15
Dominguez, Francisco, 387

E
Echavarria-Bustamante, Blanca, 365
Ekambaram, Karthikeyan, 215
Elvas, Mariana, 292
Ene, Alexandra, 382, 406, 457

F
Feng, Jinjuan Heidi, 229
Feng, Qilong, 505
Fernández-Rivera, Claudia M., 129
Ferrari, Paolo, 69
Figueiredo, Carlos Manuel, 337
Filipe, Ana, 411
Forero, Boris, 176

G
Giacobone, Gian Andrea, 57
González-Muñoz, Elvia, 196
González-Torres, Paula, 129
Goto, Yoshiaki, 79

H
Hechavarría, Jesús, 176
Herssens, Jasmien, 100
Hu, XiaoPing, 480

I
Imaji, Asibi, 47
Imbesi, Silvia, 91

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J
Jiang, Xuewei, 430
Jipa, Cristian, 382, 406

K
Kajita, Masashi, 3
Khalid, Ahmad Mukhtar, 422
King, Alex Pui-yuk, 149
Kose, Satoshi, 79

L
Leal-Pérez, Adrián, 196
Lee, Hyunjung, 319
Li, Yanjun, 47
Lima, Thaíla Santos, 35
Liu, Rong, 488
Luo, Hong, 140
Luo, Longlin, 480
Lyu, Jia, 500

M
Maher, Mona, 350
Manzano-Hernandez, Paulina, 282
Marchi, Michele, 271
Martino, Carlo, 251
McGuire, Michael, 229
Mihai, Carmen, 382, 406, 457
Mincolelli, Giuseppe, 57, 91, 271
Mitsuno, Tamaki, 449, 462
Montagna, Gianni, 329, 358, 372, 399, 411
Morais, Carla, 329, 358
Morishima, Mika, 462
Mugellini, Elena, 186
Munno, Maria Giovanna Trotta, 301

N
Neto, Maria João Pereira, 372
Nunota, Ken, 79

O
Okimoto, Maria Lúcia Leite Ribeiro, 117

Q
Qureshi, Ijaz A., 422

R
Ramos-Tachiquín, Maricela, 215
Ran, Linghua, 140
Raymundo, Carlos, 387
Rey-Galindo, John, 196, 215
Rinaldi, Alessandra, 22, 186
Rizo-Corona, Libertad, 196, 215
Rocha, Luís, 35
Romeiser, Spencer, 47
Rosales-Cinco, Rosa, 215
Rossa-Sierra, Alberto, 282, 301

S
Santos, Luís Ricardo, 372
Sheikh, Javed Anjum, 422
Shin, Su-Jeong Hwang, 319, 350
Smythe, Kelli C. A. S., 117
Spagnoli, Francesco, 163
Sui, Yue, 500

T
Takenaka, Mayuko, 449
Tanaka, Shinji, 79
Tao, Hui, 430
Tejada-Gutiérrez, Andrea, 129
Trotta, Maria Giovanna, 282

U
Udenze, Kingsley, 47

V
Vega, Robinson, 176
Viacava, Gino, 387
Vidana-Zavala, David, 301
Visileanu, Emilia, 382, 406

W
Waheed, Muhammad Faisal, 422
Wang, Haitao, 469
Wang, Yongbin, 263, 310
Wu, Gang, 469
Wu, Xin, 140

X
Xu, Bo, 488

Y
Yamagishi, Aya, 449
Ye, Chongyang, 488
Yu, Jian, 263, 310

Z
Zallio, Matteo, 91
Zapata-Roldan, Felipe, 365
Zhang, Fan, 469
Zhang, Jun, 430
Zhang, Xin, 140
Zhao, Chao, 469
Zhao, Chaoyi, 140
Zhao, Jing, 469