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Giuseppe Di Bucchianico
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Advances in Design for Inclusion

Proceedings of the AHFE 2016 International Conference on Design for Inclusion, July 27–31, 2016, Walt Disney World®, Florida, USA

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Proceedings of the AHFE 2016 International Conference on Design for Inclusion, July 27–31, 2016, Walt Disney World®, Florida, USA

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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 is considered to have a primarily political repercussions. US President Obama spent his mandate championing inequality and social disparity as a necessary milestone towards economic revival, among other things, while a vital role in the strategies adopted by the European Union's Horizon 2020 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 globalisation, 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' to the enlightened awareness that there are no such concepts to fit the standard human being, this has immediate, direct repercussions on the specialised dimension of designing. The realisation 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 psycho-physical 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 favour 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 first international conference on design for Inclusion (AHFE 2016, Orlando, FL). On this occasion, the numerous research papers presented were collected together into twelve different thematic areas, corresponding to different sections of this book:

- Design for disability and social inclusion;
- Design for inclusion and product development;
- Designing for inclusion in the public sector and cultural heritage;
- Designing for inclusion: methodologies and future trends;
- Inclusive design is good design: future strategies and challenges of inclusive design;
- Multisensory designing;
- Inclusive and universal design in clothing, footwear and accessories;
- Designing for inclusion in learning experiences;
- Designing for inclusion of an ageing population;
- Designing for inclusion in the information society;
- Global perspectives on people-centred design;
- Design for inclusion in the living environment.

Lastly, two additional groups of research papers report on experience from specific countries. These are:

- Dissing the dis: the Swedish concept;
- Design for inclusion: the Japanese perspective.

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:

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Contents

Part I
Design for Inclusion and Product Development

“Tutti a Tavola!” Project. A Didactic Experience on Design for All Applied to Ceramic Objects for Food and Beverage

Giuseppe Di Bucchianico and Stefania Camplone

Abstract In recent years Design for All has faced the question of food at different scales: from that of the rest areas, to that equipment to ease to everyone the preparation and consumption of food and drink, to the enhancement of diversity within the same food and wine culture. Here is presented the development and the results of a didactic experience, entitled “Tutti a Tavola!” (“The dinner is ready for All!”), Developed in the Department of Architecture of the University of Chieti-Pescara. During the course of Industrial Design students have faced an experience that led them to design, according to the inclusive approach of Design for All, a product for the preparation and consumption of food and drink. A selection of twenty projects have been developed up to ceramic prototypes that form the basis of a collection for a traveling exhibition which has also been presented during one of the events related to Expo Milano 2015.

Keywords Design for all · Ceramic tools · Food for all

1 Introduction

Social inclusion, diversity and equality among individuals are now on the agendas of the world policies. President Obama considers the fight against inequalities and social inequalities as a necessary step also to boost the economy; The European Union has built its motto around the concept of cultural diversity[1]; between the

[1]“United in diversity”, the motto of the European Union, has been used for the first time in 2000.

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European strategies of Horizon 2020 arise those designed to boost equality, participation and accessibility of all goods, services and opportunities in life.[2]

What better environment to experience these principles than the daily preparation and consumption of food? And among the many possible design approaches to diversity and inclusion, which one encourages more participation?

1.1 DfA: The Appeal of an Emerging Word

The “Design for All” (DfA) is the “design for diversity, equality and social inclusion” (EIDD_Stockholm Declaration, 2004). It is a design approach based on innovative principles, which in recent years has developed an emerging discipline that has created an articulated scientific, professional and associative international community. DfA considers the diversity among individuals as a resource rather than as a limit or a constraint for the project, and equality between individuals, communities and peoples as a strategic and inalienable argument for the sustainable development of contemporary society.

A DfA project is not intended for “standard” man, i.e., adult and young, healthy, perfectly able and totally polished, attentive and aware in all circumstances: actually this profile does not represent anyone or, at least, just a insignificant percentage of all individuals. In contrast, DfA is concerned with real people, with diversified skills, abilities, cultures, knowledge, aspirations and desires, in the idea that everyone should have the same opportunities to use the environments, products and services in an autonomous and comfortable way.

Actually, in parallel with the political declination of social inclusion and equal opportunities, in the last thirty years has also developed a design practice, that in the international arena was divided into different approaches and methodologies, the most significant of which are Universal Design, Inclusive Design and Design for All.

The first one proposes seven design principles,[3] easy to be applied and thus of rapid spread around the world, but tending, however, to an extreme schematization of the design action and especially not to take into account the individual’s complexity and the diversity and variability of humankind.

Inclusive Design defines a real careful approach to human diversity and is based on the idea that no criteria, standard or guideline to be absolute but must always

[2]Among the initiatives related specifically to the issue of disability, we note the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 15 November 2010 “European Disability Strategy 2010–2020: a renewed commitment to a Europe without barriers”. [COM(2010) 636].

[3]Equitable use; Flexibility in use; Simple and Intuitive Use; Perceptible Information; Tolerance for error; Low Physical Effort; Size and Space for Approach and Use.

confront the multiplicity of users, contexts and objectives. Inclusive Design, in fact, bases its approach on three “dimensions”: recognize the diversity and uniqueness among individuals, the inclusiveness of the tools and design methodologies, the amplitude of the effects in terms of benefits.

Design for All (DfA), finally, focuses mainly on “process”, that is, the path definition of the project, which involves, in different forms and moments, all the actors of the “chain of the project”: decision-makers, designers, producers/makers, users. This in the idea that to achieve truly “inclusive” projects are not sufficient the skill and experience of the designer and the project can not be reduced to a simple debate between client, designer and experienced employees, but the solution must come from a widespread social consciousness of participation, involving in different ways other social, economic and above all political “decision-makers”.

A social benefit, therefore, in addition to unequivocal economic and strategic conveniences for companies wishing to adopt the DfA approach, including, for example, an immediate enlargement of the potential market, higher customer loyalty, a differentiation from competitors and a corporate image improvement in terms of perception spreading of their social commitment and at the same time aim to innovation.

1.2 Design for All and Food: Recent Experiences

In recent years DfA was confronted with the theme of food at different scales: from the rest areas, to equipment facilitating to everyone the preparation and consumption of food and drink, to the enhancement of the diversity within the same food and wine culture.

For rest areas, for example, the “Autogrill case”, with the realization of the rest area “Villoresi Est” in Italy, can be considered a milestone in the spread of even a corporate awareness (and thus in terms of affordability) that adopt the DfA approach in the design of spaces and services can be also a strategic objective for companies dealing with catering, compared to the current socio-demographic trends [1].

The meeting between DfA approach and food has recently also materialized in extremely innovative initiatives offering consulting services of food and drink that take into account the importance of identifying the different needs and tastes: from allergies, to the most common diseases for which is important to follow a specific diet, up to those who intend to follow certain dietary principles or to recover the wealth of certain local traditions at risk of disappearing in an increasingly globalized and standardized world.

The increasing popularity of real communities on the net, in fact, contributes in its own way to the affirmation of the culture of inclusion and of enhancement of diversity in contemporary society. Among them, for example, deserves a special mention the case of “Cucina Mancina” (left-handed kitchen), an Italian social network that collects the food needs of intolerant and allergic persons, diabetes and with cholesterol but also people with hypertension, vegetarians and vegans, or the so called “differently omnivores” who eat differently out of necessity or by choice.

1.3 Equipment for an Inclusive Kitchen

Many, finally, are also the examples of objects (equipment, instruments and tools) designed and manufactured to facilitate or encourage the autonomous and comfortable preparation and consumption of foods and drinks, such as cutting boards, cutlery, boxes, dispensers, decanters, bottles, up to entire systems of furniture for home kitchens: all innovative products, based on a so-called “aesthetic of fruition,” or characterized by simplicity and pleasantness of use for all, rather than for specific categories of users with specific needs or difficulties.

Many of these “inclusive” products are inspired by the difficulties expressed by some kinds of users, for whom also attend to the daily household routine can become an obstacle to their independence.

Are thus proposed one-handed equipments, blades with sure grip, decanters that must not be lifted by in order to spill their contents, dishes with a firm and easier grip, tools that simplify the preparation: all design solutions that can transform the daily cooking activities in a pleasant and comfortable experience that gratifies the individual through the feeling of conscious autonomy.

In May 2015, for example, the association Design for All Italy has organized in Cascina Triulza, in Expo Milano 2015, the “Food for All” conference. There designers, chefs, companies, teachers, etc. were invited to present their products and project experiences related to food, to the places where the food is eaten and to the equipments, furniture and furnishings related to food and having as a common denominator the attention to human diversity, social inclusion and equal opportunities for all in preparing and consuming food and drink autonomously.

2 Objective

The principle of conscious participation and awareness on inclusion issues, on which the Design for All approach is based, is at the basis of the didactic experience “Tutti a Tavola!” (The dinner is ready for All!) presented in these pages, developed in the Department of Architecture of the University of Chieti-Pescara. The initiative led to the creation of a collection of ceramic prototypes of objects useful to help the greatest number of individuals in the preparation and consumption of food and drink: this to foster the spread of a social consciousness of awareness about the inclusion and the human diversity issues.

3 Method: From the Brief to the Ceramic Prototypes

The initiative "Tutti a Tavola!", starts from a teaching design experience conducted in the Department of Architecture of the University of Chieti-Pescara, during which, through the definition of a brief and a subsequent concept, the students were asked to develop a new useful object related to the storage, preparation or consumption of food and drink.

Actually the whole process in which the initiative has developed, thanks to the direct involvement of a complex system of actors, became a pretext to spread the awareness of issues of diversity among individuals and of equal opportunities for everyone to enjoy daily experiences independently and comfortably, thus promoting the social and cultural inclusion, according to the approach of Design for All.

So the "Tutti a Tavola!" initiative, by teaching experience, through different stages was soon transformed into a multi-dimensional promotion event, with moments of reflection and discussion internal to the working group, alternating with moments of public exposure of partial results obtained.

3.1 The Brief Definition and the Concept Development

The teaching of Design in Architecture 2c of the master degree program in the Department of Architecture of the University of Chieti-Pescara for many years deals with issues related to the design for inclusion. Starting from the basics of ergonomics applied to industrial products, the teaching focuses primarily on the innovative approach of Design for All, both with lectures, with collective reflections, and through the identification of a specific applicative thematic hambit of the project.

In the academic year 2014–2015 the applicative hambit of design experimentation has been identified in products related to the enogastronomic sector, with the aim of developing ideas of inclusive products for storage, preparation and consumption of food and beverages, whose autonomous, comfortable and pleasant fruition could be extended to the widest number of individuals with different needs and abilities.

The only constraint was that products should refer to the ceramic technology, so that the design solutions had to refer specifically to the formal and productive constraints of production technologies of pressing and turning the clay.

In particular, they have been identified some specific food sectors, for which the students had to develop product briefs: pasta, coffee, milk, tea, wine and "arrosticini" (a local meat skewers specialty).

The brief had to be developed from the identification of specific and unusual contexts of use, and from the description of the limit target users compared to the preparation and consumption of food and drink chosen: this to also inspire novel approaches and strategies of use of the new products.

Based on the brief as well defined, each student has subsequently developed a proposal for a concept, which was to refer strictly to the formal constraints and production of ceramics, with respect to which they have also received specific lectures.

3.2 The Projects Selection and the Realization of Prototypes

A group of private "actors" immediately expressed interest in the teaching initiative, by providing facilities, professionalism and equipment for the concrete realization of the prototypes. On the other hand, the extension of the project to the realization of physical prototypes, would have allowed the spread of the "Design for All" approach to a wider audience, thus not limited only to the "insiders" who can interpret the technical drawings of the projects.

Thus, out of a total of about fifty new proposals, nineteen projects have been selected, on the basis of the originality of the proposals, their ability to interpret the theme of human diversity and of ease of use in particular contexts, and their easy feasibility.

The company "L'Officina delle Invenzioni" from Pescara was responsible for the realization of ceramic prototypes of the selected projects.

In particular, the start of the realization of the prototypes, to which also collaborated the master potter Claudio Reginato (multiple potter world champion), has offered the opportunity to organize a first public event held within the Pescara university campus (Fig. 1), during which the master Reginato has performed in a demonstration at the lathe for the production of the first prototypes in clay.

The prototypes were all made in the following weeks, under the supervision of the same students who created them (Figs. 2, 3).

The whole initiative was made possible thanks to the logistical coordination and the economic contribution of the company "Area Artigianato Artistico" from Pescara and the co-financing by Artitalia, the Innovation Pole of Artistic Crafts of the Abruzzo region.

In this way, therefore, around the initiative gathered the interests of students-designers, companies and economic and political stakeholders.

Fig. 1 Start event of prototyping clay prototypes, with the exhibition of 19 projects, which took place within the Pescara university campus

Fig. 2 The realization of prototypes in clay took place under the supervision of the authors

Fig. 3 Some prototypes in clay

4 Results: The Exhibition and the Publication

Thanks to the co-financing it was possible to design and carry out the installation of a traveling exhibition of the nineteen ceramic prototypes, which have thus formed the basis of a collection of products “for all” and that represent an important initiative of dissemination and promotion of the Design for All approach related to Food Design, and, in particular, to the preparation and consumption of food and beverages.

The traveling exhibition had its first stage in Pescara, at the “Area Artigianato Artistico” headquarter, and later in Milan, both at the Società Umanitaria and, above all, at “Casa Abruzzo” in Brera area, both events linked to Milano Expo 2015 (Fig. 4).

The exhibition is also followed a publication [2], which reports the results of the teaching laboratory.

The initiative “Tutti a Tavola!” (Facebook/progetto TAT), finally, has also assumed the dimension of an experimental research. In fact, through the application of AR (Augmented Reality) technology, you can have even a more immersive visual experience of some drawings of the projects that have been included in the publication.

This is due to the development of a specific app on Google Play (Tutti a Tavola!!!), which lets you see the individual projects in 3D visualization, directly from a smartphone or tablet by simply framing the renders printed on the book.

Fig. 4 The exhibition of ceramic prototypes, held at "Casa Abruzzo" in Milan, during Milano Expo 2015

5 Conclusions

The kitchen, as a physical place and as an activity, seems to be an effective and unique setting for testing the principles of design for inclusion. This through both the possibility of using autonomously places, systems and products for the preparation and consumption of foods, both the comparison and appreciation of differences between food cultures and among people in terms of tastes and food and beverages preferences.

In this Design for All, with his attention to the design process, seems the most promising and effective approach to test and promote social inclusion and equality among individuals, peoples and cultures, including through daily activities related the individual's basic needs related to food.

The inclusion can be achieved primarily through a slow process of convincing all social stakeholders: not only designers, but also companies, institutions and end-users.

This is possible through projects and initiatives that, at different levels and divided into various stages, provide and encourage the participation and the "awareness of all" on the economic and social benefits by considering human diversity as an element of value and opportunity, for a richer and more mature society.

In this, the experience described can certainly be considered as a good practice because it has cut the interests (and sometimes the enthusiasms) of all stakeholders involved: the faculty, the department of Architecture, the selected students and those who have just attended the several stages of development and promotion, the professionals and local companies involved, the institutional representatives, who co-financed the initiative and have encouraged the promotion through participation in high-profile events such as Milan Expo 2015.

6 Credits

This text is the result of common discussion and elaboration work, but the writing of the various sections can be attributed to: Giuseppe Di Bucchianico for Sects. 1–3; Stefania Camplone for Sects. 4 and 5.

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From “Liquid Kitchen” to “Shared Kitchen”: Human-Centred Design for Innovative Services of Social Inclusion in Food Consumption

Alessandra Rinaldi, Francesca Tosi and Daniele Busciantella Ricci

Abstract The world population is progressively ageing with some clear social implications. People will live longer and also the family structure will change. The emerging socio-cultural trends are opening up great opportunities for innovation in the sphere of contemporary living. The need for a greater mobility and the nomadism now demanded by work, influence people’s lifestyles and consumption models. As regards to the home, flexibility, adaptability and versatility are the emerging characteristics, and these factors also affect the kitchen environment. In parallel to this, urban space experiences of participation and sharing are multiplying, and new social practices are spreading. These aspects are also connected to the way people prepare and consume food. The *Kitchen 4.0* research project can be placed within this macro-context. It aims to define a design-orienting scenario which affects the way of preparing and consuming food through the definition of a kitchen-sharing service.

Keywords Design · Human-centred design · Design for inclusion · Sharing economy

1 Introduction

The current transformations in socio-cultural trends, lifestyles and needs generated by the emergence of new user profiles and modes of habitation are opening up new visions and opportunities for innovation in the sphere of contemporary living. More specifically, it is a fact that the European urban population is increasingly multicultural and is progressively ageing [1]. Also, the world’s population aged 60 years or over will double from about 11–22 % between 2000 and 2050; from 900 million in 2015–1400 million by 2030 and 2100 million by 2050. Europe will have about 34 % of its population aged 60 years or over by 2050 highlighting that ’the old

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continent' will have the oldest population [2]. People will live longer and the ageing population will have some clear social implications [3]. Also the family structure will change. As people live longer and have fewer children, family structures are transformed with important implications in terms of providing care for older people [4]. For this reason population ageing cannot be considered as a process that concerns only the elderly but involves people of all ages [5].

It is also known that as people age they become more susceptible to disease and disability. The prevention of the risk factors such as injury, poverty, social isolation and exclusion, can reduce the burden of ill health among older people [6].

In this framework large Europe with the 'Europe 2020 Strategy' for a smart, sustainable and inclusive Europe by 2020, has expressed 'inclusive growth' as one of the main priorities. This means fostering a high-employment economy delivering social and territorial cohesion [7].

It is a fact that the economic divides are being accentuated and that the metropolitan areas consume an excessive quantity of resources. The last ten years have also witnessed significant changes in the traditional family in favour of new models. There is an increase in single-unit families, irrespective of age; the types of family have become more diversified, and while there is an increase in extended families, there are also couples where each member lives with his or her parents to an advanced age, as well as new forms of co-habitation between *strangers*. Greater mobility and nomadism are now demanded in work and in lifestyles. An increasing number of people work at a distance from where they live and have to travel regularly, using small residential units for five days out of seven and returning home at the week-end to their families and social relations [1].

As regards the home, in the large cities increasingly frequently the residential units are of small size. Destructuring and flexibility are the buzzwords that emerge from the market demand, especially the younger brackets. On the one hand the classic layouts and the distinction between public and private have been superseded, on the other there is the chance to easily convert properties for different uses depending on the stage of life of the inhabitant or the activities to be performed in them. There is a part of the urban population that is pressing for the possibility of using public and communal spaces in new ways which can furnish answers to the emerging social and residential needs, the need for collective practices aimed at integration and the support for sustainability. In this scenario, we are witnessing a progressive passage from convivial consumption to shared consumption. After mobility (car sharing, car pooling and bike sharing), after the workplace (co-working and the FabLabs), the sharing economy is now also investing the way of preparing and consuming food. The generation of the new millennium is making it clear that it does not want to live in a world of impoverished values, that it wants to possess less and be more connected with others, thus aiming at optimising economic and energy resources and strengthening social and community bonds [8]. On the one hand, in the private sphere the preparation of meals features an alternation of the everyday—more fast/individual and limited—and the lengthier, more complex and *cumbersome* preparation for the convivial occasions that are on the increase, although less formal than in the past. This trend boosts expectations in terms of the multi-functionality of the kitchen area, which is becoming increasingly hybrid and tends to merge with the living area [1].

If the notion of fluidity can be a pertinent metaphor to understand the nature of our modernity, we can define now the kitchen space as a "liquid[1]" space featuring major adaptability in terms of the ease of dismantling the system, flexibility and versatility making it possible to adapt to different requirements over the course of the day and the week, with ample possibilities for customisation and, in general, an improvement in the usability of the accessories and components. In parallel, in the urban space, experiences of participation and sharing are multiplying, and new social practices are spreading which transform the way of preparing and consuming food: from occasions of family reunion, to those of meeting and getting to know the neighbours. Hence a shift from the individual residential units to the urban spaces: collective kitchens, garden cooking, solar cooking, city allotments and practices such as co-housing and shared gardens. The emerging trends and changes in the lifestyles of the urban population, as described, are beginning to find answers in the sphere of interior design, urban design and services design, spawned by projects of experimental applied research [1].

The *Kitchen 4.0* research project, developed within the Laboratory of Ergonomics and Design (LED) at the University of Florence, intends to delineate a plausible design-orienting scenario for the way of preparing and consuming food in a more inclusive and shared way. The projects aims to create conditions for social meetings and possible social cohesions. The project is based on a methodological approach inherent to Ergonomics and Design in its more traditional components of Human Factors—focusing study and evaluation of human characteristics and capacities—and its more recent components of human-centred design, targeting the human well-being and the environment. The idea of *Kitchen 4.0* is a service of 'kitchen sharing' that envisages the possibility of sharing the cooking experience in communal areas remote from the home environment and for the greatest number of people. The project stems from the conviction that cooking in the company of other people exposes the individual to potential social relationships and hence potential social supports. This in turn might foster the well-being of the individual underlying the close connection between social support and well-being [10]. We think that sharing-based contexts that expose the individual to possible relationships with other people could create the condition for social support, therefore in the direction of people being happier and healthier. "Research has demonstrated that happy individuals tend to have larger social rewards, better work outcomes, greater coping abilities, better immune systems, to be more cooperative, prosocial, and charitable and to live longer than individuals who are not happy" [11] and for happiness good social relations are necessary [12].

The *Kitchen 4.0* service also permits a reduction in costs and energy consumption in the home, in favour of a centralised management of services with

[1]The term liquid refers to Bauman's definition of contemporary society. He defines our current epoch as liquid modernity in which the only constant is the changing and the only certainty is the uncertainty [9].

functionally valid features in terms of the possibility of choice of the products and nutritional education. Booking, shared cooking and consuming of the prepared food are the three fundamental phases of the service. The research was carried out in four main phases: definition of the research; identification of the macro-context and the macro-trends of reference; identification of user needs using a human-centred design approach and inclusive approaches; definition of the design concepts. Therefore, the research moves in the direction of the service design as a process that "applies explorative, generative and evaluative design approaches" [13]. Service design is also considered as a discipline that "conceives and develops solution ideas that take into account the quality of the interactions involved" [14].

2 Methodological Approach and Development of the Research

2.1 The Action Research: The 'Well-Living in the Kitchen' Workshop

The Laboratory of Ergonomics and Design has intensified its research activity in the kitchen sector since 2012 through a research project financed by the Tuscany Region and developed in collaboration with Effeti Industrie. The guidelines identified within this project were experimented and verified in a phase of action research. This research phase was based on the organization of a Design Driven workshop and on the elaboration of the methodological tool of participant observation. The aim was to observe and analyze the development of new concepts in a real context and in real time, interacting with the key interpreters involved in the design discourse. The *Well-living in the Kitchen* design workshop involved recent graduates and undergraduates in design who were integrated directly within the productive context of the company, thus establishing a close relation between designers and company personnel for around three months. The design discourse was also extended to various external professionals, including artists, cooks etc. The designs generated by the workshop were based on a user-centred approach, conceived to consider all the variables of the context of use and to evaluate the complexities of their interactions [15, 16].

2.2 Human-Centred Design for Inclusive Services: The Kitchen Sharing Service

With a view to exploring systems that foster the wellbeing of individuals in the most inclusive way possible, in parallel with the design workshop a human-centred design approach was adopted. In this approach the design processes that addresses on the whole user experience [17] are defined in order to analyse user needs and the context of use. Also, all the process phases were driven according to the vision of inclusive design approach. This approach can make a significant contribution on the desirability of social cohesion and inclusivity and the accessibility of public buildings, spaces and services, that can promote social inclusion [18]. This vision was transferred into the human-centred process, considering a large range of possible user needs with different capability demands both in the user involvement and in the concept design phase.

Attention was focused on:

- Identification of “need profiles” [19], with a view to discerning the variables of the context of use in accordance with more inclusive approaches;
- Market research in the sectors involving the kitchen system and the food chain, with particular focus on the commercial catering sector, in addition to that previously investigated and closely tied up with the kitchen as a product;
- Search for elements of criticality through the active involvement of stakeholders and deriving directly from the inclusive approach;
- Identification of a design-orienting scenario for a “kitchen sharing” product/service.

2.3 User Involvement

In order to acquire a picture of the demand profiles, a sample of potential users with specific needs and professionals working in the catering sector was involved, hypothesizing possible scenarios in which the kitchen system could be meshed with the commercial and collective catering system. Several macro-areas of research were also identified on which planning of the user involvement was then focused, namely:

- Interactive systems of smart communication;
- Eating habits and the relations with the kitchen system;
- Food distribution and catering services.

After this, on the one hand potential users with specific needs were involved through semi-structured interviews, while on the other professionals working in the collective catering sector were involved through direct observation and the “thinking aloud” method. Finally a mapping on the needs deriving from the interview and the think-aloud activities were used to create personas profile with specific needs.

2.3.1 General Users Involvement: Semi-structured Interview

Starting from the consideration that every type of product that is used has an impact on user experience [20], influencing the quality of the interaction, a sample of generic users was involved with the purpose of focusing the main issues on the basis of elements previously hypothesised.

The user sample involved was aged between 15 and 80 years, comprising men and women of different nationalities. It also included persons with mobility impairments, with cognitive difficulties, social disorders and eating disorders. A total of thirty participants were involved. The interviews were based on a questionnaire drafted at the Laboratory of Ergonomics and Design.

The structure of the interview featured an initial section concerning general information about the user. The second part was aimed at investigating the user's relation with the most common ICT, starting with questions on relations with devices such as smartphones, tablets and PCs, through to questions designed for insight into the difficulties encountered by the interviewee during online purchases, and his/her expectations in the case of interaction with systems/services. Finally, the third section of the interview dealt with questions regarding the eating habits of the interviewee from food purchase through to the relation with commercial catering.

2.3.2 Professional Users Involvement: Thinking Aloud

The thinking aloud technique in this case is very effective for conducting a quick exploratory survey [21] in a short space of time. This technique was used to grasp the relation between working activities and the reference context. Consequently, the professionals working for the canteens managed by DSU Toscana (Rights to Higher Education agency of the Tuscany Region) were involved, inside the kitchens where they work every day. The main objective was to bring forth the problems inherent to the activities performed during the preparation of the food in terms of the equipment used and the management of the spaces. Another objective was to identify solutions considered advantageous in a context characterized by short timeframes, large quantities of food to be prepared and constantly monitored conditions of hygiene. The sample of participants was aged between 19 and 57 years, comprising both men and women belonging to two main macro-categories: professional personnel, for example chefs working in the sector for over 10 years, and general workers, including volunteers or non-specialised operators, who have been working in the collective catering sector for over 5 years. More than 15 workers were observed simultaneously, with 8 being involved in a direct manner.

The evaluations were conducted within the different areas making up the kitchen: the area allocated to the preparation of hot dishes, the oven and hobs area, the area for the preparation of cold dishes, the area for the preparation of hot second courses and side dishes, and the washing area. Within these areas, video and photographic material documenting the activities, the equipment, the spaces and the most important details within all the sections of the kitchen during the preparation of lunch—starting from 8 o’clock up to the end of the shift—was collected. During the observation, interviews lasting on average 20 min were organised for each worker in the course of the most important phase of work for each area of the kitchen.

2.4 Personas

The semi-structured interview and the thinking-aloud data was adopted to represent personas in order to identify the context of use for possible design scenarios in the field of the food consumption. 7 profiles were created to represent target users for the project [22]. These profiles represent typical behavior patterns [21] as a synthesis of multiple people who share similar goals and motivations [23]. They also represent people with specific needs that can help the design phase summarizing user diversity, which also includes physical, social and cultural contextual factors [24]. The 7 profiles were graphically organized and were set according by parameters such as name, age, sex and marital status; occupation; description of lifestyle; general description (including problems, needs and desires).

3 Results

3.1 The Smart Table

The *Well-living in the Kitchen* workshop gave rise to six concepts re-interpreting the kitchen environment by working on optimisation of the areas and the elements necessary for the conservation, preparation and consumption of food; the design brief was to cut down on the waste of space and materials and succeed in delineating the concept of “just enough” in what can be defined a *liquid kitchen*: in other words characterised by transformability, versatility and adaptability.

The designs focused on four different types of product identified as highly innovative for the sector: the *smart table*; the wall unit systems, the wearable utensil and the smart floor. The *smart table*, which has now reached the phase of prototyping and presentation to the market, features a central panel incorporating the functions of wiring, disposal and utensil storage. The hob is made up of plug and play induction plates which can be stowed away when not in use. The sink is also conceived so that it can be closed and folded away, and consists of two basins designed to restrict water wastage and facilitate waste collection. Once everything has been put away, the table can be used as a desk or as a living-room table. A characteristic feature is the insertion of *‘assistants’*. Lightweight containers on sliding guides ensuring that everything required for cooking is within easy reach (Fig. 1).

Fig. 1 The smart table: prototype. *Photo* by Flavia Veronesi and Stefano Visconti

3.2 The Variables of the Context of Use for the Kitchen-Sharing Service

The responses that surfaced from the interviews and the thinking aloud observations were collected in tables with a view to highlighting: the problems declared by the users involved; the problems and observations encountered by the researchers, and the possible solutions. Also, the profiles summarized by the personas technique helped to identify the context of use about the possible users specific needs, according to their economic status, their ability to use common information and communication technologies, eating habits, physiological and cognitive impairments.

One of the results that emerged was the definition of a design process in the field of shared and inclusive services. The process was aimed at understanding the variables that can affect the user experience. The process can be synthesized through the following phases:

- Conceptualizing possible scenarios clarifying the right problem;
- Identification of requirement profiles through direct involvement of the stakeholders;
- Definition of the variables of the context of use aimed at the system/service;
- Comparison with the reference markets;
- Conceptualization of other possible scenarios and identification of the dominant one;
- Design alternatives guaranteeing the definition of three aspects considered fundamental: communication system, characteristics of the physical places and products involved and essential to the use of the service.

These phases should be considered as an expression of a part of the iterative cycle of the human-centred approach that consider four activities: understanding, creating, prototyping and evaluating [25].

3.3 The Kitchen 4.0 Commercial Catering Service

Finally, another result is represented by the concept of a new service for the food consumption. The *Kitchen 4.0* service is a sharing-based service for the commercial catering sector. The *Kitchen 4.0* service moves away from the domestic environment and goes to join the forms of catering presented on the market. This are potentially aimed at the greatest possible number of individuals, offering an alternative both to the current forms of such catering and to the possibilities offered at present by the rigidity of the home environment.

Booking, shared cooking and consuming of the prepared food are the three fundamental phases involving not only the end users, but also the food distribution system and that of commercial catering. The service has been conceptualized with three fundamental elements: the communication system; the physical sites in which the service is provided and the cooking utensils (Fig. 2).

3.4 ICT Concept System

Consequently, the initial phase was hypothesized where the user interested in the service is involved in a system of input and output of information. According to the user requirements and with aims to create a service as inclusive as possible. The available systems of communication will guarantee the choice between:

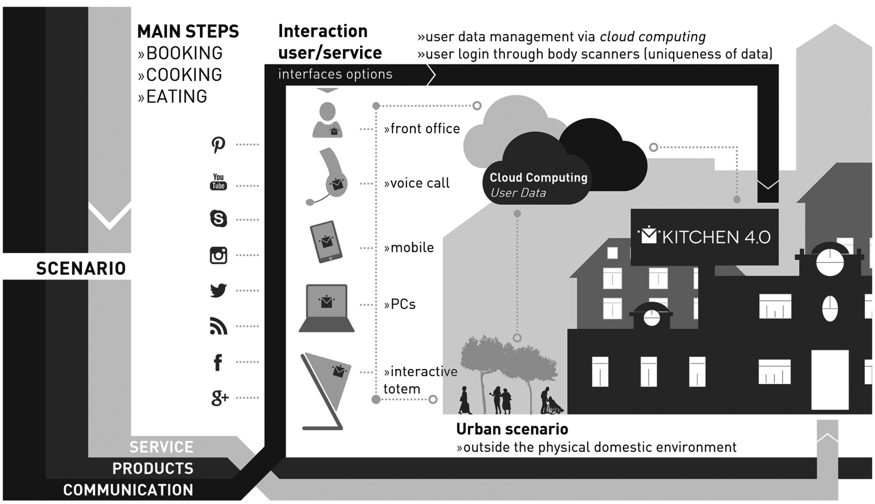

Fig. 2 Kitchen 4.0: design orienting scenario. Interaction phase and urban scenario

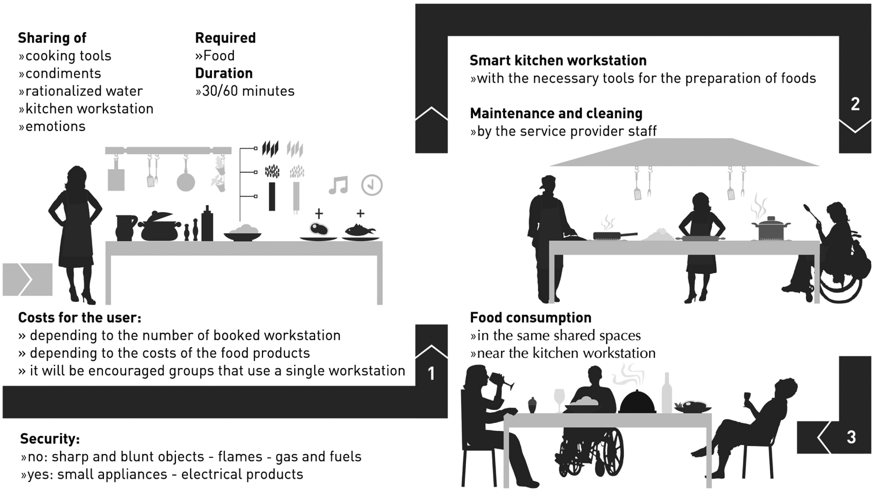

Fig. 3 Kitchen 4.0: design orienting scenario. The sharing phases

- Interactive systems connected to the web and available by personal devices;
- Interactive systems connected to the web located in nodal points of the urban area, such as interactive totems managed by the same network that provides the service;
- Front office with operators belonging to the service network;
- Networks of operators that can be reached via phone and text messaging.

This communication network will allow the users to:

- Receive all the necessary information about the service;
- Record their personal details;
- Perform identification operations for use of the service on site;
- Make payments.
- The user data will be managed by a cloud computing system which is constantly accessible from all points of the system (Fig. 3).

3.5 Physical Sites and Urban Scenario

The *Kitchen 4.0* service could be situated in places within the urban territory that can be easily reached. The idea is to integrate the kitchen stations within or very close to the food distribution locations. This integration would permit an optimisation of costs and consumption. Moreover, a series of operations have been theorised that would render the kitchen stations self-sufficient in energy terms. Starting from the premise that the places in question would occupy a considerable space, flooring exploiting piezoelectric technology and systems of renewable energy exploiting solar energy could, for example, optimise the flows of electricity required by the kitchen stations.

3.6 Products and Kitchen System

The concept of the kitchen system features smart characteristics, and starts from a base module composed of: two burners for each hob, a sink with energy-saving system for water, a system for differentiated waste collection, a storage system for the basic utensils required for preparing and cooking food. The same container will also be used for replacing the dirty utensils after use. Another theoretical possibility is that the kitchen station is capable of recognising the user via body scan and hence capable of modifying certain formal features based on the user characteristics recorded among the data on the cloud system.

3.7 Synthesis of the Scenario

The service could be summarized as follows: the user receives information about the kitchen-sharing service; he or she registers as a member; he or she can book the nearest kitchen station; he or she then goes to the *Kitchen 4.0* point where it is possible to purchase foodstuffs and access the kitchen station. The service provider staff will proceed to the preparation, cleaning and maintenance of the *Kitchen 4.0* workstations. The user will thus be able to prepare, cook and eat the chosen food while sharing this moment with other people.

4 Conclusions

The identified approaches can integrate the instruments of Ergonomics and Design with inclusive approaches. Defining the needs of individuals simplifies the understanding and the conceptualization of the user experience in a more creative and inclusive way. This approach can involve both the service and the physical context, the communication systems, and the physical products. Moreover, in the era of shared consumption, the natural predisposition of services design to creating innovative scenarios becomes a potential resource for managing the changing aspects of consumer goods.

Finally, this research presents some limitations that enable future opportunities for research in the design field. In particular, the *smart table* is a product prototype now. It should be tested and evaluated to close the circle of the human-centred design approach. Also the *Kitchen 4.0* concept should be tested by a pilot project.

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Does Design for All Need Marketing?

Daniela Gilardelli and Avril Accolla

Abstract Design for All merits to be universally applied because of its enormous social and human worth. It has successfully developed in the cultural world but its applications in people's life do not match this success. Why? The producer needs to make profits and so very seldom embraces DfA, seeing it as an extra cost, which can be afforded only for image's sake. Marketing is necessary to show the business world that DfA is capable to enlarge a company's market and increase its profitability. This paper will show that DfA is a sound business proposition. It will also describe "Idea DfA", the first Italian project promoting DfA in the small business's world. This 2010 project demonstrates not only marketing's role in spreading DfA in the small business's world, but also marketing's role as a determinant operative tool within any DfA process.

Keywords Design for all · Inclusive · Marketing · Small business

1 Introduction

I am not standard … nor are standard the people who are very tall, or wear glasses or have thick fingers, or are in a wheelchair … nor are standard the elders or the foreigners, who cannot read the language. Even the hypothetical standard man is not standard when he uses a product with a child in his arms!

The consolidated design doesn't care about us and designs for the hypothetical standard user: in doing so it marginalizes or penalizes more than 90 % of the population. The design answer to overcome this penalization or marginalization is Design for All, which satisfies the single individuals, enhancing their peculiarities. In DfA, diversity is not an obstacle to overcome, but a richness: a product that is easy and comfortable to manage for a man who has only one arm is easy and comfortable also for the man with a child in his arms!

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This inclusive, sustainable, holistic and multidisciplinary methodology has successfully developed in the cultural world but its applications in people's life do not match this success. Why? Because very few DfA solutions are in the market. The producer needs to make profits and so very seldom embraces DfA, seeing it as an extra cost, which can be afforded only for image's sake. People cannot ask for things that don't exist and that they don't even know can exist, so the producer assumes that there is no demand for DfA solutions.

The first part of this paper briefly defines the advantages DfA offers the producer, who, I believe, is determinant for the introduction of DfA in the people's life. Marketing has an important role in divulgating these advantages.

The second part of this paper is a short description of the "Idea DfA" project. This project gives not only an example of marketing divulgation of DfA in the small business world, but shows also how marketing is a determinant operative tool within any DfA process. Marketing is shown to be especially useful at the beginning of the process as it helps defining "what to design for whom", thus avoiding designing a beautiful commercial failure. DfA commercial failures cannot advance a world in which diversity is enhanced.

2 Why Is DfA Profitable for Business?

2.1 Because It Wins a Larger Customer Base

A. Design for All satisfies specific unsatisfied needs and desires of the people who are not standard, therefore attracts new customers, catering to their specific requirements and enhancing their individuality.
B. Design for All satisfies also the universal human need for beauty, designing solutions that are not for disabled people but are usable also by disabled people.

For example a hotel can have to refuse a disabled client because it has no rooms left with a special needs bathroom, but at other times the hotel can lose a "so called standard" client because it has no rooms left with a standard bathroom and the potential client does not feel comfortable in a special needs bathroom. If a beautiful DfA bathroom satisfies all the requirements of a bathroom for disabled, but does not look like a bathroom for disabled, a hotel can have all rooms with these bathrooms and never refuse a client.

2.2 Because It Wins a More Profitable Customer Base

Design for All products and systems differ substantially from the competition designed for the hypothetical standard man, they offer different and/or more features. Therefore they are something near a monopoly, which frees them from a tight price competition. Furthermore when DfA products and systems are properly introduced the customer feels this is special for me. It is human nature to think: if it is special for me it cannot be cheap, because I am not cheap!

Many are incensed at the idea of charging more for a DfA product or system, because DfA has been born as an ethical solution to the marginalization of the non-standard mankind. But, if the producer does not see a profit in investing in a new idea, very few DfA solutions will be born. It is possible to foresee a future in which people will demand that the market offers DfA solutions, but till then the producer has to be rewarded for his readiness to innovate.

2.3 Because It Increases Profitability

A. By satisfying individual specific needs DfA builds strong customer loyalty. The customers identify with the DfA solution. Customer loyalty is extremely important in a world in which customers are often led to buy the last sale or promotion and in which acquiring new customers is so costly.
B. Companies often invest in several targeted projects to satisfy different targets, but with Design for All they can invest in only one project to cover all targets. The reduced costs of designing, launching and managing only one project make their DfA products and systems more profitable.

2.4 Because It Satisfies the Needs and Desires of the Whole Value Chain

Satisfying the whole value chain guarantees the unchecked flow of the product or system. It also obtains better and more profitable relationships with every link of the chain (Fig. 1).

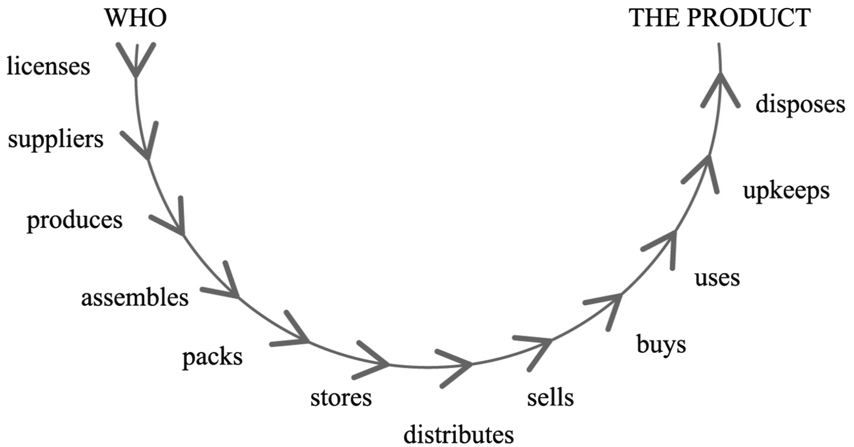

Fig. 1 The value chain

Very often a promising product or system has performed badly in the market because it did not satisfy the specific needs and desires of one link. For example a DfA product usually needs to be explained when first introduced in a market and the wholesaler is often not structured to give explanations. A DfA project takes also this in consideration.

2.5 Because It Outstands the Competitors

In a world in which products and systems are increasingly similar DfA solutions distinguish themselves functionally and socially. These solutions are also innovative because to satisfy diversified needs and desires it is necessary to innovate introducing new or modified features.

2.6 Because It Obtains Greater Visibility and a Better Image

In a world in which the social responsibility of business is increasingly important for the stakeholders, employees and customers, DfA offers solutions that are ecological, sustainable and inclusive. This not only makes them desirable, but recipient of unpaid media awareness, especially so in the 23 countries in which there are DfA institutes and associations.

In Italy, where Design for All Italia has started to certify the DfA quality of DfA solutions, the companies, whose products or systems have been awarded, are important testimonials of the visibility and image advantages. Among them there is Autogrill [1].

2.7 Because It Designs for the Future

DfA includes the more rapidly increasing targets:

The disabled who lead an active life. The statistics show that more and more people with disabilities use tools and participate in activities that were once thought to be only for "normal" people. One example of their growing activity is tourism: editor Jeremy Smith reports that in 2013 the tourists with impairments were 1.3 billion worldwide and that in 2015 their number is expected to increase by 25 % in the USA only [2].

The people from different cultures moving briefly (tourists, students, workers) or permanently (immigrants) to other countries. Editor Crawford Killian states that ¼ billion people leave home every year [3].

The elderly. The percentage of the population over 60 years of age will grow from 12 % in 2013 to 21 % in 2050 [4].

3 Why Is DfA Advantageous for the Designer?

Because it offers an innovative content which will help him/her to stand out from the other designers as an innovator, the developer of commercially successful and socially worthy solutions.

Because it gives him/her a specialization, the DfA, that is valid in every industrial sector and therefore frees him/her from the cage of being the "chair" designer or the "interface" designer or the "web" designer, etc. Specializations that confine him to a work that in the years becomes more and more repetitive. In fact a DfA designer can be effective in any sector and field (material or virtual).

Because it is a holistic methodology that requires the cooperation of professionals from different disciplines. This cooperation brings numerous fruitful networking opportunities.

Because it brings the professional satisfaction of confronting new challenges: working with professionals with a very different culture (like for example the marketing strategists), blending the many requirement of an easy and pleasurable usability for All with beauty, and building a systemic approach.

Because for all the above-mentioned reasons it will offer him/her more work opportunities.

4 Why Is DfA Marketing Necessary for DfA's Success?

DfA Marketing is the most efficient tool to divulgate DfA's existence and social value to the business world, and to convince the producer and the designer that to pursue DfA solutions is not only morally and socially deserving, but is also profitable for business and career.

DfA Marketing is one of the disciplines necessary in all the phases of the DfA process, especially in the first phase in which it helps to define the new idea which has to be developed.

The next part of this paper describes *"Progetto Idea DfA", an Italian example of how DfA marketing can work in small businesses.*

5 Progetto Idea DfA

In 2010 management and marketing consultant Daniela Gilardelli, who was on the board of directors of Design for All Italia, designed a project to divulgate Design for All in the world of small business and proposed it to the Milan Chamber of Commerce, which accepted it. To manage the project she formed and led the multidisciplinary DfA team, formed by herself as the marketer, Luigi Bandini Buti as the ergonomist and Avril Accolla as the designer. It was the first Italian project aimed to the small businesses and has opened the way to other similar projects. It is described in detail in the booklet commissioned by the Milan Chamber of Commerce [5].

The project had two aims: to divulgate the DfA methodology and advantages in the small businesses of Milan, igniting national repercussions, and to build DfA best practices and guidelines for small business. Before this project, DfA had been applied in Italy only in large businesses and organizations.

5.1 The Divulgative Part of the Project

The Opening Conference. Sponsored by the Milan Chamber of Commerce it attracted more than a hundred and fifty participants and the national media. It was probably the first time Design for All got national attention outside the specialized press.

During the conference, opened by the Chamber's keynote, the DfA team explained the DfA methodology, its social worth and the opportunities it offers to the businesses. A round table discussed the case histories of 3 market leaders' successes. All participants received a complimentary copy of the book "Design for All, il progetto per l'individuo reale", the first Italian book developing a DfA process methodology.

It was given a call for bids to the small businesses willing to participate in the operative project.

The Booklet. The chamber commissioned the author to write a booklet on this first Italian project introducing Design for All in small businesses and the guidelines derived. The chamber distributed it to its members and to the participants to the closing conference.

The Closing Conference. Sponsored by the Milan Chamber of Commerce it attracted more than a hundred participants and the national media. Main stars of the event were the owner/managers of the businesses who had worked with the DfA team to achieve a DfA Idea.

5.2 The Operative Part of the Project

The project methodology. The project follows the DfA process as described in Avril Accolla's book [6] (Fig. 2).

One of the project's aim has been to slightly simplify the DfA process in order to adapt it to the lesser resources of small businesses. One of the simplifications has been to find ways to define all the potential users (the All) and get their feedback at each stage of the process still remaining within the limited resources available to small businesses.

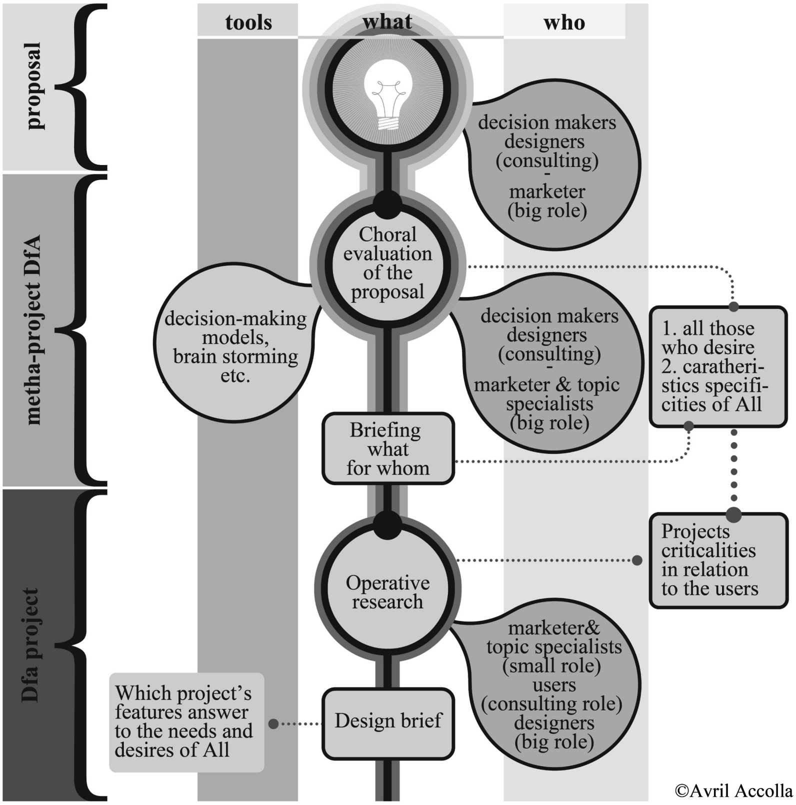

Fig. 2 The DfA process from the generic idea to the design briefing

The Choice of Businesses. The criterion has been to select businesses as diverse as possible to give more credibility to our assertion that DfA is valuable in any type of business and to develop a better benchmarking. The businesses were:

Arche' pannelli, a start-up, manufacturing customized panels in oleoresin for the private and public construction sector, promoting a new patent developed by the firm's owner.

Belloni, a jewelry shop, managed by the owners and only one employ, dedicated to the promotion of jewels with ethic diamonds (diamonds excavated and cut with guaranties for the miners' health and security).

Gruppo Confalonieri, the largest of the 5 businesses, manufacturing furnishings and accessories for furniture, with more than one hundred employees and a traditional management structure.

Kamital, a manufacturing business of ties and ceremonial gilets, managed by the owner, his wife, his daughter and 2 workers.

Sensitron, a manufacturing small business with a research and development department, working with more than a dozen employees in the industrial and residential areas of gas detection. It is known in the market for highly sophisticated solutions.

The Decision Makers. The DfA team required that each company appointed both a commercial and a R&D manager as sole referees. In the two smallest businesses the owner took both roles. The referees represented their company at each step of the process and were therefore called the decision-makers.

The First Step: the Formation. The decision-makers followed a seminar on DfA Methodology, Holistic Ergonomics and DfA Marketing held by the DfA team.

The most important result of the markeing formation session was that all the firms learned that to brief the designer in the traditional way kills innovation: if the manufacturer would have said to the designer to design a 10 cm long knife to peel potatoes (traditional firm's centered approach) he would have got a 10 cm knife with an appealing styling. Briefing him to design something to peel potatoes and discussing the idea with him, the marketer and topic's specialists (DfA approach) would have opened the way to a new idea like the potato peeler, which is now in most kitchens.

The Second Step: the Proposal. During the marketing class the decision-makers of each company expressed a new idea developed in the traditional way within the company. Then they went through the DfA process to define a new idea.

The decision-makers defined, with the marketer's help, the area in which they wanted to innovate and what was their main objective in that area (for example Arche' wanted to take advantage of its new brevetted panel and Sensitron wanted to transfer its technological leadership in another sector). Then they explored the defined areas with the marketer and the potential users (the 7 decision-makers of the firms who were role playing) to find universal not satisfied or not completely satisfied needs.

In each company the DfA idea was different from the former company's new idea and highly innovative.

The Third Step: the Proposal's Evaluation. Each multidisciplinary team constituted by the decision-makers of the firm, the marketer, the ergonomist and the designer evaluated the proposal. This meant to understand who are the All. They are the ones who can possibly use and desire to use autonomously the product or system. For example in designing a swing for kindergarten playgrounds the All are all the children between 4 and 6 years of age, included those with specific needs, but not all children in general (that means the swing will not need, for example, to stand the 50 kilos weight of a fat 10 years old child).

When each multidisciplinary team had defined all the All, it worked with representatives of the potential users to define *the All's needs and desires* related to the proposal.

During this process the proposals were continually refined and finally clearly stated what to design for whom. In this step the marketer had a prominent position.

The Fourth Step: the Operative Research. Each multidisciplinary team, which now included topic specialists, researched which were the features necessary to satisfy the needs and desires of the All, of the firm and of the value chain.

The research involved:

The marketing area. Evaluation of the possible positioning of the DfA Idea in relation to the company's strengths, weaknesses and image, to the competition, and to its target, the All. Definition of the market's opportunities and threats for the DfA idea.

The ergonomic area. Definition of the ergonomic criticalities that have to be successfully solved in the DfA product or system in order to satisfy the All. For example one of the criticalities for the DfA bracelet is its claps' closing.

The topic area. Definition by topic specialists of the aspects relevant for the satisfaction of the All. For example the topic specialist for the DfA tie was a fashion trends expert. In some case the topic specialists were within the company.

The design area. Analysis of the firm's production technology and design. Analysis of the competitors design. Definition of the company's design strength and weaknesses in relation to the All's needs and desires as emerged in the other areas.

The Fifth Step: the Design Brief. In the proposal it was clearly stated what to design for whom; the design brief mandates how the proposal must be actuated.

The designer, the marketer, the topic specialists and the ergonomist worked together, to define the design basis and guidelines, the requirements that had to be satisfied, the DfA features that must be realized. All during this process the team consulted the decision-makers, the potential users and the significant actors of the value chain.

The detailed design brief, completed by the market's motivations of success and the guidelines for the product's launch, is the Idea DfA, a more comprehensive product concept than the traditional one.

In this step the designer has the prominent position, becoming the protagonist and not the passive receiver of the design briefing.

The Sixth Step: The award. A prestigious jury, composed of members of the Chamber of Commerce, representatives of the academic and business worlds and of EIDD Design for All Europe, awarded the best Idea DfA.

The Seventh Step: the Realization. The Milan Chamber of Commerce sponsored the DfA team's support of the winning firm to help them bringing the DfA Idea from the design brief to the prototype.

The Eighth Step: the Benchmarking. At the end of the project the decision-makers of the 5 businesses and the marketer, dedicated a session to the discussion of the project they had gone through. They compared the results obtained with the process they followed and defined the guidelines of their best practices.

6 Does DfA Need Marketing? the Divulgative Project's Answer

Design for All Italia (former IIDD) has promoted Design for All since its establishment as member of the European Institute in 1994, but Design for All has risen for the first time to national awareness in Italy in 2009/2010 with this project, a marketing project.

The project “Idea DfA” has opened the way to other similar projects in Italy among which “Libero Accesso” held by Confartigianato di Vicenza that, with a different name and continuous adaptations, is still today promoting DfA. It has also brought to notoriety another DfA marketing initiative the Italian DfA Quality Marks, another marketing project born from a marketing idea of the author and developed by the DfA team for their association, DfA Italia, that still promotes them. The quality marks are now the marketing idea which best promotes DfA in Italy. Every new Quality Mark brings the the awarded solution and its producer to high media awareness.

The author hopes that these successful examples will encourage more marketers to enter the field.

7 Does DfA Need Marketing? the Operative Project’s Answer

The project “Idea DfA” has not only shown the power of marketing in divulgating and promoting Design for All, its benchmarking has confirmed the relevance of marketing in the process and more specifically:

The marketer is essential in helping the company to decide the area in which they wanted to innovate and what is their main objective in that area. All 5 businesses proposed ideas before the marketer’s intervention were at best non innovative and unable to outstand the existing competition, at worst not feasible.

The marketer is essential in finding and defining all the All the DfA Idea must satisfy and who else should be involved in every step (for example a group of potential distributors was consulted in the operative research for Gruppo Confalonieri). The DfA marketing methodology applied in the project was developed by the author in the marketing section of the previously quoted book [5] Chap. B.2a.

The marketer and the ergonomist define the needs that the designer must fulfill, but give the best results working with the designer to understand these needs with a holistic approach.

The marketer contributes to the operative research that is at the basis of a design brief that answers not only the needs of the All, but also the needs of the company and of the value chain. In fact some of the ideas had to be readjusted to meet the company’s and/or the forecast value chain needs like, for example, the needs of Belloni’s suppliers’.

A DfA solution that develops in a commercial failure does not advance a world in which diversity is enhanced.

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Improving Learning Technologies and Social Inclusion Through Human Centred Design and Universal Design Approaches: Novel Designing Scenarios

Alessia Brischetto and Francesca Tosi

Abstract In contemporary society, technology is increasingly the main tool for producing and promoting information and well-being. With special regards to the framework of ICT for learning, assistive and adaptive technologies as well as e-learning and m-learning platforms, are usually employed to provide equal access to knowledge regardless of any impairment or disabilities. However, due to several limitations of technology, people can be socially excluded. In the present work, to deeply understand such limitation, the most relevant learning theories in the creation of instructional environments were investigated. On the basis of this preliminary research, the work was aimed at analyzing the inclusive potential of current ICT and related standards of web accessibility, platforms and content format in order to assess what may be the contribution of Ergonomics for design and Universal Design for improving learning environments and social inclusion for the widest number of person.

Keywords Universal design · Human centered design · ICT · Social inclusion · Web accessibility · Learning

1 Introduction

Within a based-knowledge society, personal devices, social networks and most widely, all the emerging web technologies may be increasingly considered as the main tools for producing and promoting information and well-being. Consequently, the accessibility to technologies becomes the basic requirement in the way of living, working and sharing experiences. To date, the Information and Communication

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Technology (ICT), commonly in use every day in routine activities, play a primary role in improving and speeding up the above described processes, since they are seen suitable and powerful means able to enhance also the residual skills of the weakest people, especially elderly and most in general, all the disabled carriers [1].

Within the framework of ICT for learning, the assistive and adaptive technologies, which include a broad range of 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, e-learning and m-learning platforms, 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, due to several limitations, mainly ascribed to the lacking of accessibility, people with different types of impairments may not have easy access to information and hence, very often, are socially excluded.

At the same time, it is worth to note that the free market laws are mostly oriented towards groups of users considered “normal,” thus excluding all those persons who have special needs and that hardly manage the technology. Facing with the development of so-called “digital highways,” it should be avoided also that the continuous spread of technologies is dictated by methods purely economics, not only for reasons of social equity but also to avoid of having high social and economic costs to sustain. It is therefore clear the need to implement specific politics based on a strong sense of social responsibility and targeted mainly to enable people with disabilities to live independently in all aspects of life [3]. In this respect, for instance, the European Community policies, through the i2020 initiative related to the Lisbon Strategy, are actively engaged towards the creation of a unique information space. In particular, with the aim of building up an inclusive information-based society (e-inclusion, e-accessibility, European Action Plan, the diffusion of ICT policies), several funds in research and development of the ICT’s sector have been planned [4–6].

Besides, the UN convention on the Rights of Persons with Disabilities, whose the main purpose is to promote, defend and reinforce the human rights of all persons with disabilities, highlights the importance of sustaining the research and development in this field through dedicated projects including the Universal design (UD). The latter is clearly defined as the design of products, environments, programs and services to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. Additionally, UD shall not exclude assistive devices for particular groups of persons with disabilities where this is needed and underlines the importance of adopting a human-centered design approach in this field [7]. Thus, UD becomes an indispensable element by which, in a systematic and proactive way, can be provided accessible solutions to all persons in a perspective, therefore, inclusive.

In this scenario, the present work is mainly aimed at analyzing the inclusive potential of current ICT and assessing what may be the contribution of Ergonomics for design and UD in improving learning environments and social inclusion for the widest number of persons.

2 Methodological Approach

On the basis of the abovementioned framework, the work was focused in the first stage to examining the accessibility features that ICTs have in contemporary society. This was carried out by analyzing the major European strategies and Italian national policies[1] aimed at the development and integration of inclusive learning practices. To get a complete picture of European policies, reference to the Eurydice database was done [8]. In the mentioned database recommendations regarding the use of ICT for promoting equity in educational environments are described.

For understanding the psychological and cognitive aspects involved in human-machine interaction and related learning practices mediated by technologies, *behaviorism, cognitivism and constructivism* theories along with their respective learning models (i.e. transmission model, learner-centered model, participatory model) were explored and analyzed. The latter were developed during the evolution of the so-called "learning machines" and belong nowadays to Educational Technology field. These principles, even if theorized in the second mid of 20th century, are the focus of the international debate and still used for designing the most advanced technological solutions. In particular, these three models, moving the main focus from teaching to learning, allowed to develop new educational models and learning practices. The most recent theory of *connectivism* was also taken into account [9].

On the basis of such models, the types of technologies developed until now in the field of interest, including application examples, were also analyzed. Aspects related to the effectiveness and inclusive potential of these technologies were subsequently investigated for assessing the contribution of a combined approach between UD and Universal Design for Learning (UDL) and how and when assistive technologies (AT) should be used. At the same time, the existing web accessibility standards (WCAG) and standards ISO[2] were analyzed and possible integrations with UD-UDL approach evaluated.

[1]The main projects and initiative promoted are the EU "*Action Plan e-Learning*" and Scuola Digitale—*Cl@ssi 2.0*, *Nuove Tecnologie e Disabilità* (NTD) on Italian scale.

[2]ISO 9241-171:2008 provides ergonomics guidance and specifications for the design of accessible software for use at work, in the home, in education and in public places. It covers issues associated with designing accessible software for people with the widest range of physical, sensory and cognitive abilities, including those who are temporarily disabled, and the elderly. It addresses software considerations for accessibility that complement general design for 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).

3 Results and Discussion

3.1 ICT and Web Accessibility Standards

To define the factors that can promote social inclusion through the use of ICT, it is strictly necessary to overcome both the vision of computer as a set of hardware and software and the information technologies for the disabled as functional prostheses to allow its use [10]. The access to ICT is the result of the combination of a plurality of aspects not only physical, but also social and relational. With respect to the problems of persons with disabilities, it is possible to identify four different simplified visions of the computer science, which correspond to different ways of thinking about new technologies. They are summarized in the following as follows [7].

- calculator as a physical machine—the hardware;
- calculator as a virtual machine—the software;
- calculator as an information dissemination system—the Web;
- calculator as a two-way communication—Web 2.0.

The first 2 points include AT such as keyboards, braille printers, screen readers, screen magnifiers, special devices (pointers, expanded or reduced keyboards etc.), speech synthesis programs and speech recognition. They are therefore means allowing access to the computer merely as a tool. On the contrary, in step 3, all those systems useful for the dissemination of accessible information, as web sites, are included. The latter have become the main resource to access information and the network can enable disability carriers to break down the mobility constraints, allowing them to use the services not only through the physical way, but also through the virtual one. Web 2.0, associated to point 4, is the new frontier of communication exchanges in the network. Web 2.0 comprises the services based on directional communication "one to many" and provides the fruition and sharing of information through circular interaction between users and platforms, and among user groups [11].

In parallel to the evolution of software and hardware components, and more generally of ICT, grew up gradually issues concerning the use of such technologies, mainly related to accessibility of the information content, to interaction with system, as well as to access interfaces, systems and services for communication between people [12].

As regards the information content, guidelines for how the Web pages of information presentation to be built, were developed by the W3C-WAI [13]. Presented in a first version (WCAG 1.0) in 1999, the WAI guidelines were refined and republished in 2008 as WCAG 2.0 [14]. In this version they were accepted as an ISO standard and supported also by the European Commission. WCAG, although developed with specific reference to the accessibility of Web pages contents, have a sufficient general form as to be applicable also in different application environments.

Concerning with the interaction with the system and API, there are guidelines for the creation and implementation of *browsers* [15]. Current operating systems make also available, directly or through third parties, the support and functionalities to access the system and to manipulate it in appropriate ways for different types of users.

In the case of access to information, the use of the guidelines, although designed to provide the usability of information, is often not completely followed. An additional constraint is related to the fact that the guidelines require computer skills and are therefore directed mainly to professionals. In the Web 2.0 era, it is assumed that the production of information and publishing on the network is no longer just an asset in the hands of experts, but to all connected individuals who typically do not know and are not able to apply these guidelines. Thus, the use of guidelines such as those WAI can be limiting.

3.2 Learning Models Mediated by ICT

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. The educational and training potential of using technologies as information transmission systems are a vast field of research and widely debated. For this reason, it was considered necessary to revise the theoretical foundations that have addressed the issue of cognitive development related to the use of technology, especially computer. Through the analysis of learning theories (behaviorism, cognitivism, and constructivism) and their respective models, which are transmission model, learner-centered model and the participatory model, specific hardware and software technologies (see LOGO-MicroWorlds, V2: E-learning platform for primary schools, Vle Platform, Tabula Fabula) have been individuated.

Briefly, the computer systems CAI (Computer Assisted Instruction) and CBT (Computer Based Training) refer to the transmission model, while the ICAI (Intelligent Computer Assisted Instruction), ITS (Intelligent Tutoring System), MCL (Multimedia Computer Assisted Learning) and CACT (Computer Assisted Cognitive Training), defined as "Intelligent Software" exploiting the capacity of systems to formulate hypotheses and propose routes, to the learner-centered models. To the third model belong CSCL (Computer Supported Collaborative Learning) environments and the so-called web 2.0 tools including e-learning and mobile-learning.

It is precisely to the latter systems, based on the participatory models, which are attributed the ability to generate inclusive condition through the collaborative learning (Activy Theory, Situated action models, Distributed knowledge).

The latter has the potential to provide added value compared to the process of learning developed individually, especially for people with disabilities who are often disadvantaged and excluded in the individual learning practices [2]. In fact, with respect to specific disabilities, within educational contexts are traditionally used compensatory and dispensatory technologies that result in part ineffective, since they generate conditions of inequality.

The learning and development of each individual originates in everyday social practices, where the mediation of cultural artifacts plays a decisive role. On the other hand, it was demonstrated that the learning process stimulates the zone of proximal development (ZPD),[3] by activating a variety of evolutionary pathways which can only operate when the subject interacts and cooperates with his peers and with others present in the environment [16].

Systems that are based on the participatory model, typically turn their attention to learning processes involving scaffolding and tutoring. The learner is motivated through participatory practices to produce something on his own, sharing the project and making practice in problem solving [17, 18]. In this model, the computer is seen both as mean and learning environment where the learner may develop knowledge in an open and cooperative way. In doing so, the knowledge results well distributed and shared with other peers, thus stimulating different ways of thinking and supporting different learning modes. Within this framework, hypertext and multimedia play a very important role, as they allow to rethink and reorganize knowledge and the learner, throughout them, is able to produce new meanings [19].

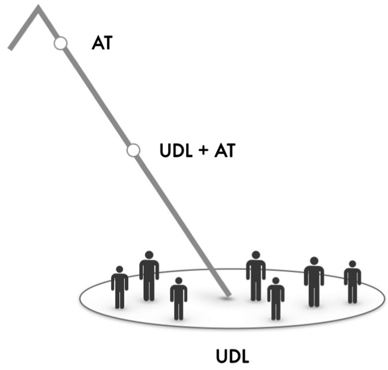
3.3 UD and Access to Knowledge

Considering the participatory model and web 2.0 tools as able to generate and foster inclusive learning processes, the work was focused at this stage to assess what can be the contribution of Universal Design (UD) in education.

As known, the Universal Design philosophy is based on the idea of a design oriented to satisfy the widest possible range of end user requirements (abilities, disabilities, and other characteristics-such as age, reading ability, learning style, language, culture, and others) during the entire development cycle of a product or service. The UD approach has been adopted in different sectors with the common goal of making fair the access and the fruition towards products, environments and services [20]. In the field of instructional design and related areas (educational sciences, neuroscience, cognitive psychology), UD was applied using the same approach. In particular, within the teaching-learning contexts, where UD is used for the development of teaching practices mediated by technology, it is properly called

[3]ZPD has been defined as: "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" [17].

Fig. 1 Pyramid-based approach of universal design for learning



Universal Design for Learning (UDL). This educational framework was born in the United States around the years two thousand thanks to the Center for Applied Special Technology (CAST), a research and development center which since 1984 operates in the field of assistive technologies for learning. The researchers' work of CAST has focused from the beginning on the accessibility of the text and reading books holders, realizing in advance that the instruments made available by IT companies (i.e. GUI text-to-speech systems, management media), would be useful to make transversal the use of teaching materials. Since that time, it was demonstrated that the technology could meet the needs of all, and that the difficulties of each individual should be read as access barriers to learning. Accordingly, AT are not replaced, but exploited as a means to reduce the barriers to learning. To express the coexistence between UDL and AT a pyramid-based sketch is shown in Fig. 1.

Starting from the base are respectively shown UDL interventions involving a larger number of subjects, UDL intervention supported by AT when needed, and in the top level, interventions with the exclusive use of AT [21].

The UDL by unifying the principles of inclusive design derived from UD along with research in neuroscience about learning sector outlines the following principles:

- To support learning recognition, provide multiple, flexible methods of presentation;
- To support strategic learning, provide multiple, flexible methods of expression and apprenticeship;
- To support affective learning, provide multiple, flexible options for engagement.

Specifically, flexible curriculum, shows how the inclusive universal design provides accessibility and flexibility of the learning paths. To enable effective use of the content, in line with the learning styles of each learner, means using tools (Multiple Means of Presentation) that support different languages and communication methods (Simple and Intuitive Instruction). Main objective of these principles is to break down the barriers of access to learning through the use of diversified and flexible teaching strategies. This is not to offer special educational solutions, but teaching practices employing diversified ways and media to represent the contents, in order to make them accessible and usable to all students. The main features that technologies have (thanks to binary encoding), and which are best suited to the application of UDL principles are[4]: variability, transcoding, convergence, multimedia and hypertext. These are shown below:

- Variability: the information on digital media are treated to never stand as definitive, they are changeable over time. At educational level, they allow customization of modes of presentation and use of materials;
- Transcoding: ability to convert one format to another (e.g. to translate the analog to digital etc.), to have the ability to manage and transmit information through diversified codes;
- Convergence: the digital allows you to transfer on a single support, information from different media. For us, to make convergent more media, it means having in hand different languages, integrated so as to involve the largest number of recipients;
- Multimedia: using different channels and media can enhance learning and diversify ways of content delivery;
- Hypertext. in addition to offering non-sequential reading experiences, it allows to organize the content to levels of depth and, therefore, of difficulty.

In conclusion, significant examples of web platforms (platforms UDL Editions, Learning Landscape and UDIO: The Universal Literacy Network) adopting the UDL principles for defining the design and procedural requirements useful for the development of inclusive solutions were evaluated. The main features are displayed in the Fig. 2.

Within this initiative, prototypes of online environments for making easy reading and the information more accessible to a wider number of users as possible were developed. The platform is structured as a series of functions to guide learning (Fig. 3) through a support function to build reading strategies and help readers understand the content of a “Texthelp” toolbar to promote accessibility and the search for language functions in the text, multimedia glossaries and enrichment activities of the specific context and multimedia resources.

Numerous scientific studies have shown that this model can also be transferred to higher levels of education and applied to any information environment (on-line newspapers, Wiki, etc.). An example, it is represented by the research presented in 2010 at the 71ST IDA Annual Conference.[5] Later, it was developed a digital version of the article “2020s Learning Landscape: A Retrospective on Dyslexia”, where they were incorporated inside the supports of the UDL for learning developed by CAST.

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[4]To make more solid the UDL approach, CAST developed, according to the three above described principles, further indications articulated in guidelines and operating checkpoints UDL Guidelines (http://www.udlcenter.org/aboutudl/udlguidelines).

[5]It refers to the following publication: Rose, David, Ge Vue, “2020s Learning landscape: a retrospective on dyslexia,” (http://www.cast.org/w/page/2020learning/l3).

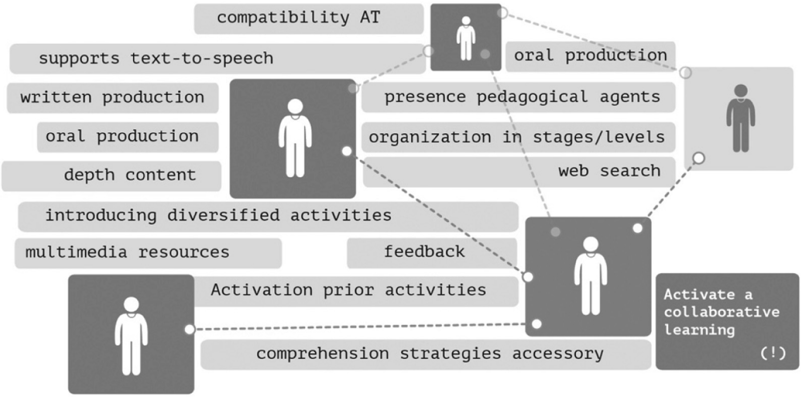

Fig. 2 Synthesis of requirements for the definition of an UDL platform

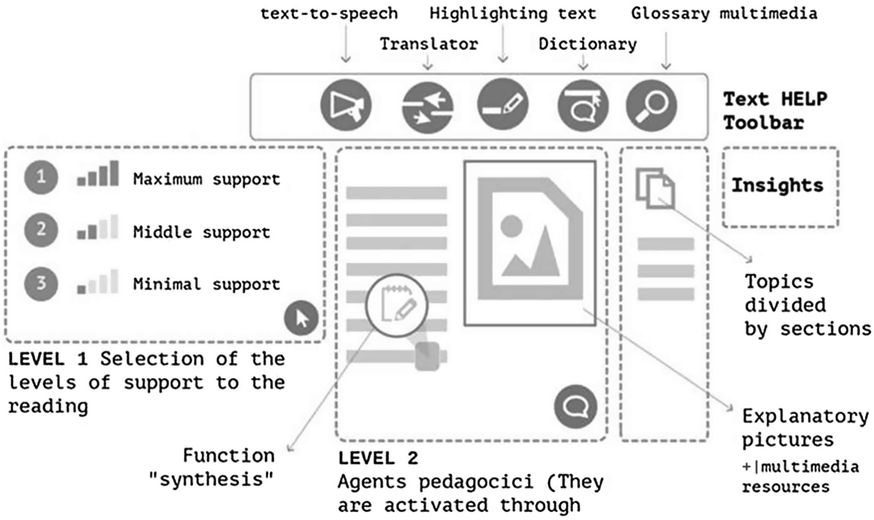

Fig. 3 Schematic representation of an UDL web platform

It should be noted in conclusion that the UDL guidelines do not enter into the merits of the design of online activities, nor are intended as standards for the design of systems. They have to be understood rather as guidelines to make inclusive learning practices in specific contexts, through the diversified use of multimedia languages thanks to the digital medium. Ultimately, they provide 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.

Table 1 Comparative assessment between accessibility standards and UD-UDL guidelines

Quality attributes of usability[a]	UD principles[b]	UDL principles[c]	WCAG 2.0[d]
Effective	Principle 3: simple and intuitive use	Multiple means of presentation	Perceivable
	Principle 4: perceptible information	Multiple means of presentation	
Efficiency	Principle 2: flexibility in use	Flexible curriculum	Understandable
Satisfaction	Principle 1: equitable use	Equitable curriculum	Robust
	Principle 6: low physical effort	Appropriate level of student effort	
Learnability	Principle 3: simple and intuitive use	Simple and intuitive instruction	
Memorability	Principle 3: simple and intuitive use	Simple and intuitive instruction	
Errors	Principle 5: tolerance for error	Success oriented curriculum	Operable

[a]Ref. [22], [b]Ref. [23], [c]Ref. [24], [d]Ref. [14]

Identified in the UDL a viable base of operations to define strategies for planning and structuring learning in accessible way, the similarities and potential synergies between UD, UDL, WCAG 2.0 and the quality attributes of Usability (ISO 9241-11) are listed herein in Table 1.

Although in Table 1 are evidenced similarities between the different approaches and standards of accessibility, their integration looks like as an interesting future perspective but not easy to apply. It is noteworthy that WCAG 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.

4 Conclusion

In this work, an overview on the inclusive potential of current ICT and related standards of web accessibility, platforms and content format is reported. Within the frame-work of ICT for learning, the UDL approach, if supported by human-centered design philosophy and the use of accessible ICTs, provides an interesting perspective and a solid basis, either theoretical and practical, to valorize individual differences.

In addition, the parameters and standards for accessibility provide valuable indications, but it is necessary to adopt a broader perspective and consider the standards as a starting point and not an end one. Finally, it is noteworthy that the research conducted in recent years related to the Educational Technology sector can significantly contribute to implement the existing standards, in terms of accessibility and usability, thus enhancing design practices.

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Part II
Designing for Inclusion in the Public Sector and Cultural Heritage

Making Voting by Mail Usable, Accessible and Inclusive

Kathryn Summers, Whitney Quesenbery and Amy Pointer

Abstract Two groups of voters have historically faced challenges in voting by mail: first, voters who are blind, have low vision, or low dexterity; and second, the many adult Americans who read at Basic or Below Basic levels as defined by the National Adult Literacy Survey. Although for different reasons, both groups can find it challenging to navigate the complicated process of receiving, marking, and mailing a paper ballot privately, independently, and successfully. This paper describes a two-pronged effort to increase the accessibility and inclusivity of the vote by mail process: (1) helping Maryland make their online ballot marking tool significantly more usable and accessible through iterative usability testing and evaluation in 2013; and (2) using iterative usability testing and evaluation to revise paper instructions and envelopes in vote-by-mail packages—identifying and applying best practices of plain language and plain interaction in order to forestall common mistakes and increase trust.

Keywords Voting · Absentee voting · Low literacy · Accessibility · Online ballot marking · Voting by mail

1 Introduction

Although 28 states in the United States allow voting by mail with "no excuse," and increasing access to voting by mail is frequently seen as one way to increase voter turnout [1, 2], access to voting by mail has historically not been equally available to

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all groups of voters. People with disabilities may be unable to use a traditional paper ballot privately and independently. People with low literacy or age-related impairments may struggle with the complexity of requesting the ballot, understanding the materials that come with the ballot, and putting the ballot package back together successfully for submission. Every year a percentage of absentee ballots that are submitted cannot be counted because the instructions have not been followed properly.[1]

Yet voters who are older or who have disabilities are often those who would most desire the convenience of voting by mail [2, 4]. In addition, allowing voters with disabilities to use their own assistive technology increases access to private and independent voting [5]. Therefore, in 2013 the Maryland State Board of Elections funded a major effort to increase the usability and accessibility of their online ballot marking tool—a tool that allows voters to mark their ballots at home, then print them and mail them in—as part of their effort to make voting by mail available to people with disabilities. The focus of that effort was to maximize the increase in usability and accessibility through rapid, iterative testing and evaluation [6]. This research led to the successful deployment of the online ballot marking tool in the Maryland General Election in November 2014.

After the online ballot marking tool was successfully deployed, additional funding was provided by the Center for Civic Design (using a grant from the MacArthur Foundation) to explore possible improvements to paper-based absentee voting packages, to see if these packages could be made more usable for voters with low literacy skills and mild cognitive impairment. Low literacy has been shown to correlate with lower voting rates [7–9], and adults with low literacy identify voting as a challenging task where they need support [10]. This research built on previous efforts to support voting activities for voters with low literacy skills [11–14].

Since ballot designs are usually constrained by law and inevitably vary across jurisdictions, the scope of the paper-based ballot research included only the design of the mailing package materials, the design of the voter's certificate, and the package instructions. A key goal was to make the voting package more secure and private (no more signatures going through the open mail on the outside of the envelope, and a separation of the voter's name and signature from the voter's ballot, to preserve anonymity of the ballot), while maintaining straightforwardness, ease of use, and trust in the process for low literacy voters comparable to the standard existing procedure of putting the ballot in a regular envelope, signing it, and mailing it.

[1]In 2003, nearly 30 % of all voters used "absentee" ballots [3]. In 2008, the Election Assistance Commission reported on nationwide voting practices, recording that 16.6 % of voters used absentee ballots—in comparison to 13.0 % who used various forms of early voting. Of these absentee ballots, 1.7 % were rejected nationwide, but two states, Indiana and North Carolina, rejected more than 10 % of their absentee ballots. Reasons included missing the deadline, lack of a valid signature, using an unsealed envelope, using an unofficial envelope, and not including a proper address [15].

Thus, this research consisted of two major efforts: (1) to refine an accessible online ballot marking system that would be broadly accessible to voters with disabilities who want to use their own assistive technology to mark, print, and mail their ballot; and (2) to develop a set of instructions and mailing envelope that would allow the voter's identity to be confirmed while still maintaining the privacy and confidentiality of their ballot, and simultaneously providing ease of use for voters with low literacy.

2 Online Ballot Marking Tool Research

The primary purpose of the online ballot marking tool usability project was to ensure that the online ballot marking system, developed by the Maryland State Board of Elections and previously used in the 2012 General Election, was revised to become usable and accessible for a broad spectrum of voters, particularly voters with accessibility needs, lower literacy skills, mild cognitive impairment, and age-related impairments.

Research questions for the project included:

- Are voters able to access the ballot independently?
- Are voters able to mark and print their ballots independently?
- Can voters verify that the printed ballot matches the voter's intent?
- Can voters successfully follow instructions to mail the ballot?

2.1 Methods for Online Ballot Marking Tool Research

To refine the online ballot marking tool, we performed two rounds of iterative, qualitative testing—one round (17 participants) of in-person testing at the University of Baltimore User Research Lab, and one round (17 participants) of remote testing with voters located in their own homes. Both rounds of testing were observed and recorded.

Interaction with the Ballot Marking Tool. During testing, voters were asked to fill out a ballot from a Maryland 2012 general election. Voters filled out most of the ballot without overt direction from the moderator. However, at the end of the ballot, voters were prompted to complete any of the following tasks that had not yet occurred naturally:

- filling in a write-in candidate
- attempting to overvote
- identifying and revising an undervote
- changing a vote in one or more contests
- printing the ballot.

If voters paused, looked uncertain, showed evidence of confusion or surprise, made a comment, or did anything unexpected, the moderator asked follow-up questions. During the remote sessions, voters were also asked to “think aloud” during the voting process.

Round One Procedure. During the first round, conducted at the University of Baltimore in October 2012, 17 participants interacted with the online ballot marking tool using a Windows computer. A Tobii T60 eye tracker was used for all sessions except those with participants who had low vision or who were blind. Blind participants had the option to use Window-Eyes or Jaws, although none of the test participants opted to use Window-Eyes. Those who needed only screen magnification used Zoom Text or used the browser’s own zoom feature.

During Round One, improvements to the prototype were generally made as problems were identified—sometimes between sessions. Making iterative changes as soon as possible has several important benefits. First, sometimes smaller problems can be obscured by larger issues, so fixing issues as they are identified can allow smaller issues to surface. Thus, fixing issues as they are identified allows more issues to be identified overall. Second, some issues that are identified during testing are complex, and the solutions are not obvious. By implementing possible solutions immediately, the value of these solutions can be evaluated, and the solutions can be refined or alternative solutions tried.

Round Two Procedure. The second round of testing included 17 participants, and was conducted remotely in November 2012. Because the online ballot marking system will be used by voters in their homes or other locations, it was essential to test the usability of the ballot marking system using participants’ own systems. Sessions were observed using GoToMeeting, allowing observers to see and hear what participants did on their own computers while performing the following tasks:

- interacting with an email that provided a link to the ballot marking tool
- using the ballot marking tool
- attempting to print their resulting ballot
- Preparing the ballot for mailing.

In order to allow observation and recording of each session, participants for the second round of testing were included only if they had a high-speed internet connection and were able to install and run GoToMeeting. Even with this prerequisite, the remote testing allowed us to observe voters with a range of computer setups and a range of computer expertise. However, some potential participants were screened out due to these technical constraints. It is possible that more issues remain to be discovered during launch, when voters with older equipment and perhaps with less internet experience attempt to use the online ballot marking tool.[2]

[2]The online ballot marking tool was successfully deployed in the Maryland 2014 General Election.

Table 1 Participant demographics for online ballot marking tool development

	Low vision	Blind	Hearing impaired	Limited dexterity/mobility	Low literacy	Mild cognitive impairment	Senior	Total participants[a]
Round one	3	3	3	7	3	3	2	17
Round two	5	3	3	6	0	0	5	17

[a]Some participants fit into multiple categories, so that the total number of participants is lower than the sum of the rows

Subjects. Participants for the online ballot tool testing included participants with low vision, blindness, hearing impairment, low literacy, and mild cognitive impairment (Table 1).

2.2 *Results from Online Ballot Marking Tool Research*

Many usability challenges were identified and resolved during the two rounds of testing. In particular, many opportunities for simplified language, visual interface, and process were identified and implemented. These simplifications will benefit nearly all voters, not just voters with disabilities or other challenges.[3]

Round One Improvements. In the first round of testing, participants experienced difficulties in logging in. Some participants failed to understand the key message that they would need to print and mail their ballot in order to cast their vote. Some users had trouble navigating the ballot and getting into the review screen. Voters using screen readers had trouble writing in candidates. When voters —particularly voters relying on screen readers—tried to leave the review screen in order to revisit contests or change a vote, they got lost and were sometimes unable to get back to the review screen in order to complete the process.

The most substantive change to the online ballot marking tool that resulted from the testing in Round One was to create a more focused, guided interaction for two key processes: (1) writing in a candidate name on the ballot, and (2) leaving the review screen in order to revisit a ballot choice.

Other improvements included interface improvements such as eliminating dropdowns, minimizing and simplifying text, clarifying button text and error messages, adding clearer progress indicators, adding navigational support for voters who rely on screen magnifiers, and making some revisions to the code to improve the screen-reader experience.

Round Two Improvements. During the second round of testing, the ballot marking interaction itself worked well. Thus, the focus of the second round of testing

[3]Detailed findings from this research are available in a report to the Maryland State Board of Elections that has been posted at the Maryland State Board of Elections website.

was on how successfully voters could access the online ballot marking tool using the email and instructions they received from the State Board of Elections, and on how successfully voters could print their marked ballot at the end of the process.

Based on observed challenges experienced by voters during the second round of testing, the email was simplified, its language was made more consistent with the ballot marking tool, and it was made easier for voters to succeed in “passing in” their ballot access code without manual entry.

The printing process presented the most challenges, and some issues remain in this area. Improvements included revising the print process to start with the ballot rather than the envelope and providing a simple checklist. Instructions on the print pages in the ballot marking tool were refined to be more clear, and a link was provided to allow voters to download a PDF of their marked ballot if they had trouble printing. The flow of the printing process was also refined to encourage voters to log out of the ballot marking tool successfully—an important consideration for security.

3 Paper Ballot Mailing Process Research

The second major project was to examine and suggest improvements to the experience of receiving a paper ballot in the mail and preparing the return package with the ballot and voter’s certificate to be mailed back to the election office. Anecdotal evidence has suggested that this process can be confusing for voters who are older or who have low literacy skills or mild cognitive impairment, yet who may not be eligible to use a tool such as the online ballot marking tool (currently available in Maryland only to voters with disabilities).

3.1 Methods for Paper Ballot Mailing Process Research

The exploration of voting by mail using paper ballots consisted of three rounds of testing, each with a different focus. All rounds of testing occurred at the University of Baltimore User Research Lab, in October 2015, January 2016, and February 2016. Sessions were recorded, and data collected by two independent observers.

Subjects. All participants for the paper ballot marking project scored 60 or less on the REALM and some had also been diagnosed with mild cognitive impairment. Two participants in Round Three had low vision, but not to the point where they needed any assistive technology other than glasses and occasionally a magnifying glass.

Round One Procedure. In Round One, researchers observed while nine voters were asked to choose among six different ballot mailing packages that are currently in use, and then to use two of them. The six options were selected to showcase a broad range of styles and approaches, and included ballot mailing packages from Maryland, Florida, California, New Jersey, Utah, and Minnesota. These sessions were used to observe areas of difficulty experienced by these voters and to get a broad sense of what worked and what didn’t in terms of layout, process, and instructions.

Based on the researchers' observations from Round One, two prototypes were developed for additional testing. Each was designed to increase voter privacy and security by ensuring that voter signatures were not sent through the open mail and were separated from a sealed ballot.

Round Two Procedure. In Round Two, researchers observed while twelve participants each voted twice, using both of the prototypes, in alternating order. One prototype used three envelopes: a ballot secrecy envelope, a signature envelope, and a mailing envelope. The second prototype used a single (but more complicated) envelope with a sealed section for the ballot and a removable flap for the voter's certificate that folded down to protect the voter's signature during mailing. Improvements to the prototypes and to their accompanying instructions were made between sessions as needed (Fig. 1).

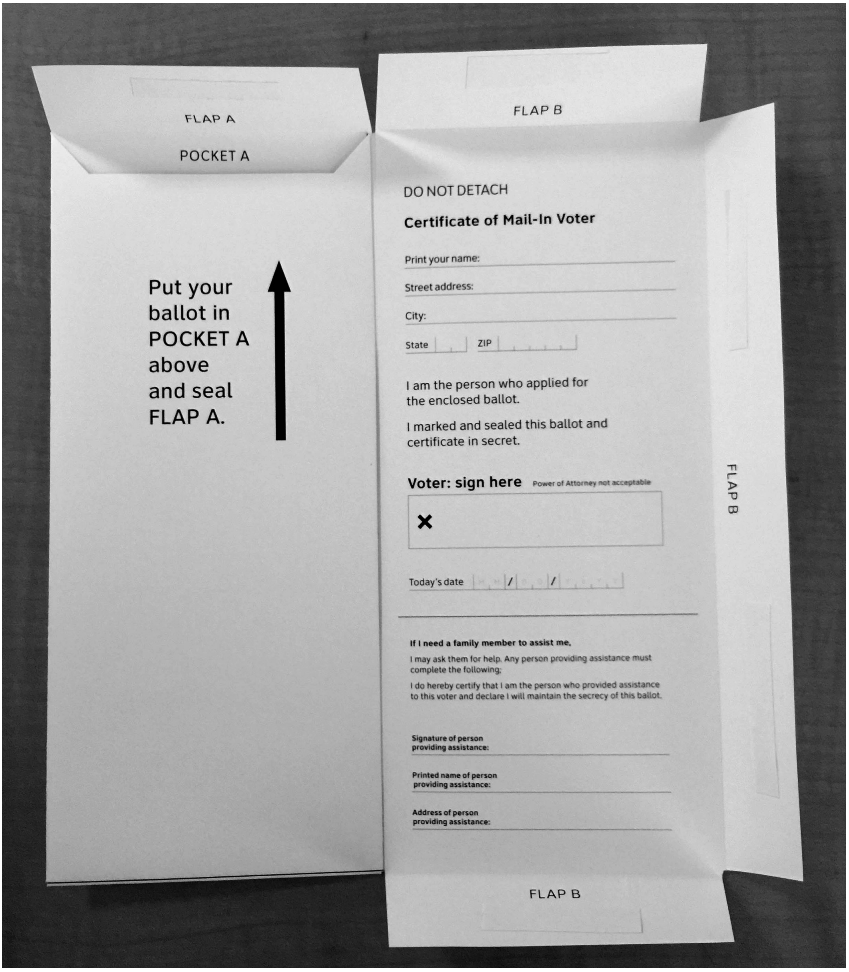

Fig. 1 The prototype mailing package is a single envelope with a pocket for the ballot that can be sealed separately, and a flap for the voter's certificate, which can then be sealed for mailing

Round Three Procedure. In Round Three, researchers observed while 20 participants each voted twice, using (a) the current vote-by-mail package from the state of Maryland, and (b) the single-envelope solution developed in Round Two. Round Three focused on the single-envelope prototype, for two reasons. First, it is likely to be more economical for voting districts, and is thus more likely to be adopted. Second, it was more challenging for the participants, so we wanted to make sure that we had in fact succeeded in making it sufficiently clear and usable. The Maryland voting package uses only one envelope, with the voter's signature contained on the outside of the envelope.

The participants used the two packages in alternating order. After completing their use of each package, participants answered rating questions about usability (based on the System Usability Scale, or SUS) and trust [14]. The number of errors in procedure and the number of times voters would have asked for assistance (either from family members or by calling the phone number provided for the Board of Elections) were also recorded.

3.2 Results for Paper Ballot Mailing Process Research

Round One Findings. Four of the eighteen ballots prepared by voters during Round One would have been rejected—suggesting a substantial level of difficulty for voters with low literacy and/or mild cognitive impairment in using existing ballot mailing packages. Rejected ballots generally lacked a signed voter certificate, or were put into an unsealed envelope.

Observation of difficulties experienced by voters during Round One led to articulation of the following design principles for the prototype development:

Make the instructions complete.

- Provide a simple instruction sheet that walks voters through the entire process.
- Let voters know at the start what they will need in order to complete the process.
- Include the final step of telling voters to mail or deliver their ballot.

Use visual design to make instructions and other text easy for voters to interpret.

- Instructions for all voters should be larger and more prominently displayed than instructions for "special case" instances (e.g., on the front vs. on the back). If this is not done, low-literacy voters are likely to follow all instructions, not just those that pertain to them.
- Provide as many nonverbal cues as possible to help voters know what they need to do. These can include size, positioning, and sequence of text; size and positioning of objects (e.g., envelopes, instructions sheets); use of arrows, highlighted arrows, etc.; and illustrations.
- Present instructions in a single-column format, with sequence clearly indicated through positioning and use of numbers.

- Provide a checklist to help voters track their progress through multiple required actions.
- Provide an accurate illustration for each action voters must take, whenever possible.
- Provide white space between and around instructions to make them easier to follow and less intimidating.
- Make text and line spacing large enough that voters can follow with their finger.
- Make sure that voters can refer to instructions easily while completing the associated action.

Use clear language that is easy to understand.

- Use simple, consistent terminology, without jargon.
- Use imperative voice for instructions, make them as simple as possible, and do not over-explain.

Design the envelope to make it easy to use.

- Make directive text on the envelope simple and large.
- Avoid putting directive text in the postage area, as voters will often interpret this as meaning that postage is prepaid (regardless of the actual text).
- Keep in mind that the size of envelopes will be interpreted by voters as a clue to what goes inside the envelope.

Round Two Findings. In Round Two, with twelve participants, the three-envelope prototype (and its instructions) went through five versions, and the single-envelope prototype (with its instructions) went through eight versions. During this round, no voters would have had their ballots rejected.

The final three participants had no problems, questions, or hesitations in using either prototype, and the prototypes were judged to be ready for comparative testing.

Round Three Findings. After using both the prototype and the state of Maryland voting packages, and answering all rating questions, participants were asked which package they would prefer to use in an election. Twelve participants chose the prototype, six participants chose the state of Maryland package, and two participants expressed no preference. Four of the 40 mailing packages prepared would have resulted in a rejected ballot: three packages lacked a signature and one envelope was not sealed.

The average SUS score for the prototype was 79.1, with a standard deviation of 12.88; for the Maryland package, it was 76.9, with a standard deviation of 15.13. Despite the additional complications involved in using the single-envelope prototype in comparison to the standard Maryland envelope, which one might expect to cause some reduction in user preference and additional time on task, in fact participants rated the prototype as slightly more usable than the Maryland voting package by 2.2 points and took 46 fewer seconds to complete on average, although these improvements were not statistically significant.

Table 2 Average requests for assistance, error counts, and time on task

	Avg requests for assistance	Standard deviation	Avg error counts	Standard deviation	Avg time on task	Standard deviation
Single-envelope prototype	0.25	0.55	0.8[a]	0.77	11:27	5.02
State of Maryland package	0.5	1.79	1.75	0.22	11:47	6.92

[a]The difference between average error counts is significant at $p = 1.35 \times 10^{-5}$

The average trust rating for the prototype was 4.08 (on a five point scale with 1 = strongly disagree and 5 = strongly agree), with a standard deviation of 0.76; for the Maryland voting package the average trust rating was 4.03, with a standard deviation of 0.63.

After the ratings had been completed and final preference gathered, participants were asked about the security of having their signature on the outside of a mailing envelope. None of the participants expressed concern over this security issue. When asked about separating the sealed ballot from their identity, they approved of this separation but had not thought about it during their experience of voting. Thus, the increased security and ballot confidentiality of the prototype did not affect their perception of usability or trust.

The number of requests for assistance, the number of errors, and the time on task associated with each voting package are detailed in Table 2.

4 Conclusion

These separate but related efforts contributed to the accessibility and inclusivity of the vote by mail process by helping to develop an online ballot marking tool that is fully accessible, and by developing a vote-by-mail package that is both usable for those with low literacy skills and protects the confidentiality of the voter's ballot. At the same time, the research generated helpful guidance for boards of election wrestling with these issues.

An overarching message of both research efforts, and of research in general into usability for users with challenges, is that simple solutions are typically preferable to complex solutions. However, it may only be possible to arrive at simple solutions through an iterative that involves testing out more complex solutions and then simplifying. For example, it was only as a result of an iterative process that our design team realized that a single-envelope solution was able to accomplish, simply and clearly, all of the functions that we had thought might require multiple envelopes. It is to be expected that continued research will lead to additional refinements and alternative options.

Acknowledgments Funding for this research was provided in part by the Maryland State Board of Elections and in part by the Center for Civic Design.

Appendix

These are the questions about trust used in the paper ballot mailing process research, Round Three. Questions were rated from 1—strongly disagree to 5—strongly agree.

- I felt like my information was safe with this voting process.
- I felt confident that I did it the right way when I put the mailing package together.
- I feel confident that my vote would arrive safely with this voting process.
- I would like to vote by mail in an election using this process.
- I feel confident that my vote would count in an election if I use this voting process.

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Bringing Universal Usability to All Users: A Case Study on Public Realm Locations of Tourist Interest in Bhopal, India

Shweta Vardia, Rachna Khare and Poonam Khan

Abstract Tourism sector in India is one of the significant parts of lifestyle of various societies and is growing rapidly. Thus the rapidly increasing tourism industry faces several challenges too. One of the challenges is that there is a segment of society who is not yet able to equally enjoy tourism attractions, facilities and services. Major parts of population constitute of persons with disability and are an increasingly main sector of tourism demand. A few of the tourist cities around the world have developed guidelines and few innovative solutions to overcome the problem. This paper aims to study the experience and develop understanding regarding the public realm spaces approached and interacted by diverse users. The study is an outcome of a hands on workshop conducted at the institute with diverse users at various public realm locations of tourist interest in the city of Bhopal.

Keywords Accessible tourism · Universal accessibility · Diverse users · Simulation · Public realm

1 Introduction

Tourism sector in India is one of the significant parts of lifestyle of various societies and is growing rapidly. It is the major source of income to the nation and is one of the leading elements of international trade. Today, it also plays an important role in communication and knowledge exchange. Thus the rapidly increasing tourism industry faces several challenges too. One of the challenges is that there is a

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segment of society who is not yet able to equally enjoy tourism attractions, facilities and services. Major parts of population constitute of persons with disability and are an increasingly main sector of tourism demand. Cities around the world have problems associated with visitor accessibility and connecting the transportation locations, places of stay and other facilities to the places of interest. A few of the tourist cities around the world have developed guidelines and few innovative solutions to overcome the problem. The overall growth rate of persons with disabilities or with special need is higher than population growth.

The study is an outcome of a hands on workshop conducted at the institute with diverse users at various public realm locations of tourist interest in the city of Bhopal. This study will facilitate to generate tourism for all so that the people with disability or with special needs may enjoy in a self-reliant manner, tourist products, services and resources designed for everyone.

2 Aim and Objective of the Study

The main aim of the study is to experience and develop understanding regarding the public realm spaces approached and interacted by diverse users.

The objectives of the study are:

1. To understand the difficulties faced by diverse users in various different public realm locations in Bhopal, India.
2. Pedagogical strategies linking education with practice are used to generate multiple solutions for the identified set of existing problems, after sensitization about universal accessibility.
3. The solutions are leading towards social, environmental and economic sustenance.

The proposed study is focused to investigate, identify and an attempt to find solutions and recommendations for making the spaces more user friendly for all in the public realm locations.

3 Methodology Adopted for Study

The methodology of the study involved mainly five stages including simulation, documentation, problem identification and generation of multiple solutions for the same. Three important tourist public realm locations were selected viz., the transportation locations: Kushabhau Thakre Inter-State Bus Terminal, place of interest: Indira Gandhi Rashtriya Manav Sanghralaya Museum (IGRMS) and place of shopping: DB mall in the city of Bhopal.

Table 1 Stages explaining the methodology

Stage	Intention	Activity
1.	To create awareness and sensitivity among students	Input given to participants/students about principles of universal accessibility, universal accessibility checklists, different types of disabilities, simulation exercises, tourism, etc.
2.	Shaping perception	Conducting and documenting the simulation exercise at various tourist and public realm locations of Bhopal city The use of auditing checklists for conducting accessible auditing
3.	Identification of problems faced by the specially able	While the simulation exercise and through the auditing process, various problems faced by the users is understood and listed in the existing premises
4.	Proposing design solutions	Possible design interventions to make the premises more accessible for the diverse users
5.	Evaluation process	Evaluation through various criteria

Critical examination of the space led to identification of problems faced by all types of diverse users. Tools were designed in the form of an audit checklist to map and review various spaces with their respective circulation pattern and functional aspects. In order to gather information of the difficulties and problems faced by users and visitors, simulation exercises were conducted. Documentation of the same led to a list of problems faced by persons with disability. The participatory approach of learning was pursued. Finally, an attempt was made to find solutions for making the spaces more user friendly for all including the elderly and persons with disability in the specified locations. The results can be implemented on site and the process can be used as an exemplary method for similar tourist locations (Table 1).

4 Stage 1—Creating Awareness

To make the built environment more accessible, it is essential to be aware of people's different needs and how these needs can be met in a variety of ways. It is important to remember that often the best and most appropriate way to make public realm locations more accessible is through management solutions and creating awareness among all [1].

The participants were trained on the principles of universal design which are equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, size and space. The participants were also made aware about all the different type of disabilities and also people with special need. The target groups are listed in the Fig. 1.

The participants were made sensitized with the universal accessibility checklists: viz Access Audit to learn about the existing Indian accessibility standards and

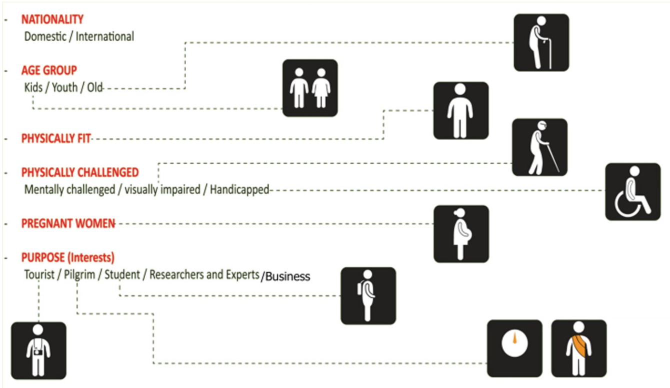

Fig. 1 The target groups

Universal Design Audit to learn about the International Universal design standards. The participants were asked to apply any one of the tools to assess the universal usability of their proposal.

5 Stage 2—Shaping Perception

Applying universal design principles to ensure that built environments are accessible and inclusive involves understanding the vast range of human abilities and frailties at all stages of life from childhood to old age [1]. In seeking solutions the general aim is to find one that is usable by everyone. To arrive at an acceptable solution, user consultation can be a key factor. By involving people with disabilities, older people and user groups in the process, it may be possible to ensure that solutions are practical and priorities are accurately identified [1].

The participants were instructed for conducting and documenting the simulation exercise at selected tourist and public realm locations of Bhopal city. The students had hands on experience by playing the role of differently able users or people with special needs. Accessible auditing was conducted with the help of given checklist to understand the physical barriers existing at the locations.

The state of Madhya Pradesh in India has many important tourist destinations of which one is the culturally rich city of Bhopal. The city of Bhopal is located on the Malwa Plateau in the Vindhyachal Range in the central India and a very important tourist city of the state of Madhya Pradesh, India. The city has a hilly terrain as it is surrounded with hills on all sides. The prominent hills in Bhopal are Idgah hills and Shyamala hills in the northern region, Katara hills in southern region. City's geography has in it two lakes namely upper lake and lower lake [2]. Bhopal, being the capital city of the state, is also important due to its well connectivity to other cities and places of tourist, commercial and religious interest. Bhopal in itself has many areas of tourist interests. As a part of the workshop, several places were identified but for the purpose of this paper, three important public realms have been identified and documented as case studies.

5.1 Case Study I: Indira Gandhi Rashtriya Manav Sanghralaya Museum (IGRMS)

The Indira Gandhi Rashtriya Manav Sangrahalaya(National Museum of Mankind) is dedicated to the depiction of humankind in time and space. It is one of the largest anthropological museums in India which is spread in 200 acres of undulating terrain near the bank of a seven miles long upper lake. It offers opportunity to explore the most subtle but artistic sensibilities of the rich Indian culture and heritage through its appealing exhibitions [3]. The museum has 8 open air exhibitions and 12 indoor galleries. The images of certain areas in the museum is seen in Fig. 2.

Participants of the workshop conducted the simulation exercise at the premises. Three disabilities were considered for the simulation exercise—wheelchair bound, visually impaired, old age people and lower limb disability as given in the Fig. 3. The participants went about the entire premises and assessed the human conditions and ergonometric setting. With the help of measurements and checklists they mapped the entire area right from parking and entrance to the indoor exhibits and outdoor exhibits via ticket counters and other provisions. The simulation exercise led to understanding the difficulties faced by the disabled users. This led to the identification of contextual problems by the participants.

Fig. 2 The Museum of Mankind (IGRMS)

Fig. 3 Simulation exercise

5.2 *Case Study II: Kushabhau Thakre Inter-state Bus Terminal (ISBT)*

Kashubhau Inter State Bus Terminus in Bhopal is an important bus terminus which provides services to destinations in the state and to other states of the country. The services are availed by a number of people daily with space to park 80 buses at a time. The Bus terminus has around 70 buses which arrive and leave daily. The platform and view of ISBT, Bhopal is given in Fig. 4.

Participants of the workshop conducted the simulation exercise at the premises. Three disabilities were considered for the simulation exercise—wheelchair bound, visually impaired and lower limb disability as given in the Fig. 5. The participants went about the entire premises and assessed the human conditions and ergonometric setting. With the help of measurements and checklists they mapped the entire area right from parking and entrance to the bus station via ticket counters and other provisions.

The simulation exercise led to understanding the difficulties faced by the disabled users. This led to the identification of contextual problems by the participants.

Fig. 4 Kushabhau Thakre inter-state bus terminal (ISBT)

Fig. 5 Simulation exercise

5.3 Case Study III: DB Mall

DB Mall, the largest Mall in central India belongs to the Dianik Bhaskar Group and its ventures. It spans across 125,000 m^2 (1,350,000 ft^2) in area. The mall is responsible for the entry of many international brands in the city. It is also an important place for the promotion of several important events in the city [4]. Images of certain areas of the mall can be seen in Fig. 6.

The Simulation Exercise of this public place was carried out by enacting six members of a family. A couple where the husband is visually impaired and two hyperactive kids go to the mall. They are accompanied with their parents, where the mother is wheelchair bound and the father has Spondlytis and also has a linguistic problem. The simulation helps them to realize the problems faced by different diverse disabilities and the consequent limitations in the built environment (Fig. 7).

Fig. 6 Some important spaces of DB Mall, Bhopal

Fig. 7 Simulation exercises at DB Mall, Bhopal

6 Stage 3—Identification of Problems Faced by the Specially Abled

The Simulation exercises led to the understanding of the various problems faced by the disabled users caused due to ergonometric disproportions and existing human conditions. The problems found in the case studies are enlisted below.

6.1 Case Study I: Indira Gandhi Rashtriya Manav Sanghralaya Museum (IGRMS)

The Indira Gandhi Rashtriya Manav Sanghralaya Museum is located on a hilly terrain and is spread in 200 acres of land. The whole area is contour site with outdoor and indoor exhibits at different levels of the site. The ticket counters are at the entrance gate of the museum and are inaccessible for the specially abled users. The site being located on a rocky terrain and is vast thus the outdoor exhibits are spread all over the site. There are no designated pathways or paved areas for the movement of wheel chairs around the outdoor exhibits. Thus the outdoor exhibits are mostly inaccessible. There is no designated accessible parking while entering the premise. Lack of proper signage's causes confusion for first time visitors. This proportion of the number of risers in one flight is difficult even for children, elderly and pregnant women. The staircases have disconnected or no railings. The ramps provided in the outdoor areas are not of the required gradient leading to compulsory assistance required by wheel chair bound person. The pathways provided are uneven and are prone to accidents for the usual users also. The canteen provided in the premises is on a steep slope and becomes inaccessible. The indoor exhibit areas have been refurbish with ramps, low risers, railings, lifts, escalators, non-slippery flooring and signages. But still there are still certain problems which need to be addressed like, provision for drinking water fountains and accessible toilets, the gradient of ramps are steep, missing railings, tactile pavers and missing signages for specially abled users. The entire premises lacks in the availability of tactile pavers, signage's and designated pathway for wheelchairbound persons. Refer Fig. 8.

6.2 Case Study II: Kushabhau Thakre Inter-state Bus Terminal (ISBT)

The Kashubhau Thakre ISBT, campus is a contour site with the bus terminus at 3.5 m below the ground level. There is no designated accessible parking while entering the premise. Lack of proper signages causes confusion for first time visitors. This leads to levels in the building. The central core with the services is divided in two levels with a huge staircase. The staircase comprises of 30 steps with

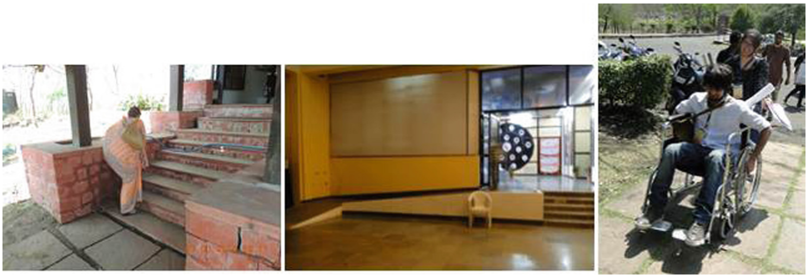

Fig. 8 Identification of problems at IGRMS, Bhopal

Fig. 9 Identification of problems at Kashubhau Thakre ISBT, Bhopal

2 mid-landings. This proportion of the number of risers in one flight is difficult even for a normal person. The staircases have disconnected railings The ramps provided at the entrance are not of the required gradient leading to compulsory assistance required by wheel chair bound person. The entire premises lacks in the availability of tactile pavers, signage's and designated pathway for wheelchair bound persons. Two principal ramps catering to wheelchair bound persons were found to be of the gradient 1:8. The ticketing counter, the drinking water taps were all found to be inaccessible. A toilet for handicapped is present but has inadequate facilities like lack of grab bars and disproportionate counter top heights. Refer Fig. 9.

6.3 Case Study III: DB Mall

In the simulation exercise, a family of six members with different types of disabilities was considered. Hence, problems were identified from the perspective of each member of the family. From the perspective of the visually impaired person, the site being an important public realm location was found to be lacking in the provision of tactile pavers and signage's in Braille. The railings of the escalators were disconnected due to the placement of the flower pots. There were also no provisions for people with linguistic disability. The ramps in the premises though they existed, were not in the proper gradient. A wheel chair bound person could not move about without assistance. The flooring texture was also not appropriate for the

Fig. 10 Identification of problems at DB Mall

movement of a wheelchair. There were also no railings available for the ramps. In the food court area, there was no space or designated table for the wheelchair bound person. Again the flooring in the mall was very slippery and accident prone for children, elderly and pregnant women. The toilet for the handicapped is generally closed and the height of the counter top wash basins was also found inaccessible for the disabled users. Refer Fig. 10.

7 Stage 4—Results and Findings in the Form of Design Solutions

After the conduction of simulation exercise and access audit the participants identified various problems regarding accessibility at all the three chosen public realm locations. The participants also identified the different expectations and requirements of the users depending on the purpose of their visit. Most of the results and findings were common for all the three locations with a few site specific ones. The proposed design solutions are an attempt to make these public realm locations users friendly to all types of specially abled people. There were several design solutions proposed collectively for all the locations which are as follows:

Pre visit Information: there could be a provision of information in advance of, any visit to all the three choosen public realm locations which were Museum, Bus terminal and shopping mall. The pre visit information will be helpful to visitors to decide and plan in advance and to know which all areas are accessible, or no access or limited access. The online websites are useful aid to provide previsit information.

Interpretive information: helps in informing the visitor about the place itself or its contents, its architecture or its services. Information should be designed to be accessible to as many people as possible both in terms of sensory and intellectual access. These methods may include: pictorial symbols, annotated maps and models, tactile guides, haptic models: these are 3D models of objects which communicate information about the object through touch to people with vision impairment, audio guides and easytoread leaflets [1].

Facilities: There are some of the key facilities which are required to be provided at all the public realm locations mentioned in the study. These is a need of **reception facilities** at all the three locations. Reception should be located near the

Fig. 11 Proposed design solutions for reception, sanitary facilities and signage

entrance with a clear evenly lit unobstrucive route. The reception desk should have lower level counter top which could be used either by someone in wheel chair or by people of short stature. **Sanitary facilities**: all the three locations require proper accessible toilets with grab bars, easy wheel chair movements, clear signage and clear access route. Refer Fig. 11.

Arrival and Parking: The arrival to all the three locations were easy and was access by everyone through the principal entrance. A provision for designated accessible car parking and set down areas are required at all the locations. The parking area must be close to the building or site entrance. At the museum where the parking area was not possible to be close to the entrance, provision need to made for minimum travel distance or some form of shuttle service. Refer Fig. 12.

Accessible routes and surfaces: A designated routes required to be provided for the outdoor exhibits and locations in the Museum and to approach the bus parking in the Bus terminal locations. The routes need to be wide enough to cater to all users viz wheelchair users, people with buggies, people who cannot walk very far or people who are blind or have vision impairment. The surfaces should be even and slip resistant. In the area where the ground is uneven or wet, as in case of the Museum, timber broadways or other alternative anti slip materials can be used to create the routes. **Tactile paving** are provided at few locations and missing at few. There is need for tactile paving to be provided along the routes and should be well designed and harmonise with the adjoining surface and also providing tonal contrast for people with vision impairment. **Steps, Ramps and Mechanical Lifts** The level changes exist in the study locations are either as a result of the natural topography or as part of the original design and layout. These level difference need to be

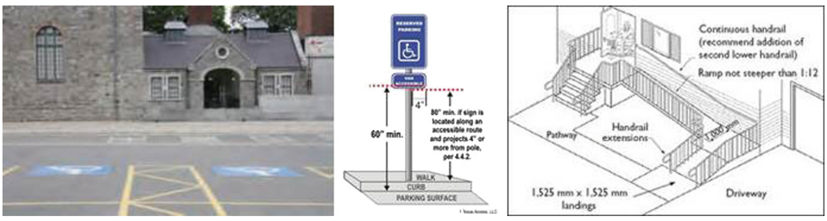

Fig. 12 Proposed design solutions: designated accessible parking, ramps, handrails

addresses. Ramps are generally preferable to mechanical solutions, such as lifts, particularly where level changes are small or where there is sufficient space to integrate a ramp. However, ramps are not suitable for everyone and steps may be required also as an alternative for some users with mobility difficulties [1]. Ramps can be permanent, semi-permanent (or demountable) or temporary (or portable). Handrails are required either on both sides or on one side depending upon the location to facilitate a person going both up and down. **Resting places and Signange** The study locations require rest areas along the accessible routes, waiting areas and exhibit areas for all types of users. Proper, well designed and clear signage at the strategic locations without obstructing the views are required all along the three public realm locations of the study. Refer Figs. 11 and 12.

8 Stage 5—Evaluation Process

The criteria for evaluation of the outcome of the different teams working on the different case studies are given in Table 2. The evaluation criteria are given as per the stages and the activities related to the respective stage. The stages are also related to Bloom's Taxonomy of Learning Domains.

Benjamin Bloom and his associates identified the three domains of educational activities in 1956. He gave the taxonomy of holistic education in three domains—Cognitive—mental skills or knowledge, Psychomotor—manual or physical skills and Affective—growth in feelings or emotional area leading to development of attitude and values. This is relevant in architecture education also [5].

In the current process, we can see that in Stage 1, students gain knowledge—the application of the cognitive domain, they visit the site and conduct the simulation exercise—the Psychomotor Domain and finally the sensitization towards universal accessibility leads to a change in their attitude—the affective domain. Hence, we say that a holistic and positive methodology has been achieved.

Table 2 Criteria for evaluation

Stage	Domain of education	Activity	Expected outcome
1.	Cognitive	Understanding the issue	Queries and interaction at the input stage
2.	Psychomotor	Simulation, observation and interviews	Identification of issues
3.	Psychomotor	Addressing the identified limitations by design	Design solutions
4.	Affective	Assessment of the universal usability of their proposals	
5.	Affective	Explanation of design intentions	Ppt presentation

Table 3 Evaluation of the three case studies

Stage	Activity	Grades obtained		
		Case study 1	Case study 2	Case study 3
1.	Understanding the issue	B	B	A
2.	Simulation, observation and interviews	B	B	A
3.	Addressing the identified limitations by design	B	C	A
4.	Assessment of the universal usability of their proposals	B	B	A
5.	Explanation of design intentions	B	B	A

For the purpose of this paper, the outcome of three groups who studied the three case studies is being rated. We have used the relative grading system where A stands for outstanding, B stands for good performance, C stands for fair performance, D stands for poor performance and E stands for unsatisfactory performance. Refer Table 3.

9 Conclusions

The entire methodology adopted here is an effective hands—on exercise for the teaching—learning process. This exercise led to the development of an understanding of the difficulties faced by the disabled users. Due to unawareness and lack of incorporation of the right ergonomic factors at the design stage itself, inconvenience is caused to diverse users. Hence creating awareness and shaping the perception of young architects towards universal accessibility through such simulation exercises proves beneficial pedagogical strategies which can be incorporated to develop multiple design solutions which are practical and universally accessible.

During the learning process, students are acquainted with the principles of universal accessibility and with tools like the accessible audit checklists. With the help of such tools and techniques incorporated in the methodology, solutions generated, are leading towards social, environmental and economic sustenance.

We further emphasize that such a methodology of learning should be incorporated with its application in particular design situations for sustainable and accessible spaces for all in the public realm locations.

Acknowledgments We express our gratitude to the Faculty Team members at SPA, Bhopal and all students who were the participants of the workshop. We are thankful to the staff of IGRMS, Bhopal, Kashubhau Thakre ISBT, Bhopal and DB Mall, Bhopal for their co-operation and support before and while the simulation exercise.

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Part III
Design for Disability and Social Inclusion

Design for People Affected by Duchenne Muscular Dystrophy. Proposal of a New Type of Ankle Foot Orthosis [AFO] Based on 3D Indirect Survey and 3D Printing

Alessandra Tursi and Giuseppe Mincolelli

Abstract Duchenne is a rare form of muscular dystrophy affecting 1 on 3.500 male children that, at about 8–12 years old progressively become wheelchair bounded, with an expectation of life on the late 20 or 30 years old. Due to muscles' weakening, Achilles tendon takes over on muscle tissue and starts to thicken and shrink in length, causing plantar flexion and retractions, while the function of AFOs is for applying a stretching force that can delay equine deformation of the feet. It is scientifically demonstrated that a constant use of night Ankle Foot Orthosis, together with physiotherapy, can extend the independent ambulation by up to two years and delay the occurrence of other complications. Moreover even once the child is wheelchair bounded, a further delay in retraction prevents contractures, complications and pains. Night Ankle Foot Orthoses are not a cure for DMD patients and Achille tendons' retractions at the end will in any case take over muscular strength. The research started from these premises to understand margin of improvements of current products and design an innovative type of static AFO. The obtained results at this stage prove that an innovative process is possible, it demonstrates with the case studies its great potential of application an improvement compared to current products, but it has to be further tested and developed in order to become a usable orthoses.

Keywords Duchenne · Ankle foot orthosis · Laser scanner survey · Parametric design · 3D printing

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1 Introduction

This study was developed during the PhD of the author, from 2012 to 2014. It was born thanks to a partnership between the Department of Architecture of Ferrara and the Italian Onlus Parent Project for Duchenne and Becker. It investigates night Ankle Foot Orthoses [AFO], commonly prescribed to Duchenne Muscular Dystrophy [DMD] patients, to understand if there are margins to increase their comfort, aesthetic customization and psychological acceptance, but also to improve their manufacturing process and to reduce costs.

Firstly, a market analysis on the lower limb orthoses available on Italian, European and North American market conducted to an interactive database that scheduled more than 700 different types of AFOs. This phase was essential to understand the state of art, the Italian picture and the most advanced innovations.

Then the research focused on methodological approaches in the design of the AFO. After an overview on theories as User Centered Design, Universal Design and Design for disabilities, a Quality Function Deployment process translated theories into design directives, relating user needs, technical requirements and comparison with the competitors.

The scheme provided the guidelines for the design of an innovative dorsal night AFO for DMD patients, which takes advantage of the most innovative technologies of indirect surveys, parametric design and 3D printing. The adopted solutions proves to achieve interesting results thanks to an automated technique of production that reflects in a reduction of time of manufacturing and in an enlarged possibility of customization on demand.

2 Paper Preparation

The design of a new type of AFO had to be capable of grasping margins for improvements of existing products in terms of clinical efficacy, comfort, personalization, aesthetic and psychological acceptance by the users, while optimizing the process of production and marketing with a plausible cost reduction.

Nowadays medical frontier research is experimenting several new trials to extend the life of children affected by Duchenne Muscular Dystrophy, but many things have still to be done in order to improve their **quality of life**.
Current AFOs present several problems:

Technique of acquisition of the shape of users' lower limbs for the customization of the AFO. In most of the cases, children's lower limbs are surveyed in a very "handcrafted way", with plaster cast as a mold for plastic casting, with an inaccurate result that could be easily improved thanks to modern technologies;

Technique of manufacturing. The handcraft manufacturing requires long time of production and, since its poor accuracy in the survey, it requires several reviews and handmade modifications;

Costs. Current AFOs' price is by consent considered excessively high for a pair of children' shoes that needs to be changed at least every six months. It is not motivated by materials, since plastic is extremely cheap, but from the labour, manual skills and long time required to be produced.

Comfort. Children and their families complain about AFO's discomforts. They proved to be really hot especially in summer season, bulky in natural night movements, the frontal straps are harmful and sometimes cause redness, callus and even ulcerations.

Aesthetics. The possibility of an aesthetic personalization that manufacturers usually offers, especially in Italy, is generally limited to the choice of 5–6 patterns that are stitched or printed on the orthoses. A wider possibility of choice could be extremely important in the process of psychological acceptance of the orthoses by the child, who will feel himself as part of the decision of buying a new pair of AFOs.

Clinical efficacy. This aspect could be achieved improving the phase of acquisition of the shape of the foot. Moreover, more comfortable and appreciated orthoses will be worn more continuously having an indirect effect on clinical efficacy.

Psychological acceptation. The prescription of wearing night AFOs since the first childhood of the children is not justified by a clinical urgency but more by a necessity to make the child get used to orthoses. As soon as he grows up, he tends to consider them an enforcement and he usually starts to refuse wearing them, but an irregular donning of the orthoses decrease drastically their efficacy.

Concluding, problems related with AFOs are not merely technical or biomedical. Especially since AFOs are addressed to children, the main concern of this object is the approach to the design. The AFO is a silent friend of Duchenne children for their entire life and therefore the design had to be aimed at creating something that would be not considered as an "intruder".

3 Applied Methodologies

This research started from a question formulated by Parent Project Onlus for Duchenne and Backer. They turned to a Design Faculty to deal with this problem: "*Are the designs of our children's orthoses the bests we can offer them? Is it possible to do* ***something better to improve the quality of their lives****?*"

"*To find anything better*" and "*to improve the quality of life*" were the two milestones on which to build on the methodological approach of the thesis. In order to answer the first task, two questions needed to be answered: what exists now and what are users' requirements and aspiration related to AFOs. These goals highlighted the opportunity of recurring to product design methods that consider the user as the fulcrum of the entire design process, as **Customer Centered** and **User Centered Design** theories. Most of contemporary orthoses are already customized on user's feet and progressively adapted by doctors and technicians in order to improve their clinical efficacy. However, this seems to be insufficient, since still forms of dissatisfaction towards this product persist. The main change was to aim at designing an orthosis that didn't only respond to "*how the user IS*", but attempted to give persuasive answers to "***what users WANT***".

On this concern, a little clarification is required on the acceptance of the term 'user' that included not only children affected by Duchenne Muscular Dystrophy. The survey of their *expressed*, implicit and latent needs was a crucial step of the design process. Nevertheless, main users have to be considered parents as well, who, especially when children are very young, perform the main role in the process of commissioning, choosing and taking care of the orthoses. Only in a later stage, they will be backed up by their children, who will predictably be more interested in the aesthetic aspects of the orthoses than in their clinical efficacy. Primary and secondary users' requirements were considered as a whole system, including even doctor prescriptions, trying to attribute the appropriate relative weight to each need and evaluating which of these needs existing products already satisfied and which margins of improvement could be identified.

Only at this stage, technology comes to the aid.

A User Centered design approach at this stage was translated in the criterion of **selection of the best technology possible for the user**. Even at a first sight, it was perceivable that adopting modern techniques in all the phases of the manufacturing could produce immediate advantages. But technology couldn't be considered a response by itself. The key point wasn't wondering if the adoption of a technology brought the best possible result but if the solution brought the best possible advantage to the user. For example, the adoption of the best vanguard laser scanner for an ultra-high resolution in the survey on child's lower limb is definitely the best technological choice, but it would reflect in a dramatically high increment of AFOs' cost, without a real consistent advantage for the user.

Nevertheless, AFOs were considered as something different from a simple medical device, since they are a companion of every day's life of a child affected by Duchenne. Almost everyone in our life proved at least once, the pleasure of choosing and buying personal accessories. It isn't a consumer consequence, neither a narcissist feeling, but it is the natural human instinct of owning something that belongs to us, that improves the image we have of ourselves. This is particularly true during adolescence when, the construction of the psychological and physical-aesthetical self-image, passes from these aspects too. Duchenne child, during his adolescence lives his hardest period since all the most dramatic changes and consequences of the disease appear in a strong way.

These reflections were framed in the internationally renowned theories of **Universal Design, Inclusive Design** and **Design for all**, with a particular attention to the fundamentals of **Design for disability**. Among all different design process methods, **Quality Function Deployment** process was considered the one that suited best with the goals of the research. It suited perfectly with the attention devoted on user needs by User Centered Design. Moreover the research proved that the QFD matrix, putting in relation user needs, technical requirements and an analysis of the response of the best competitor products to user needs, was in this case one of the best instruments to obtain innovative design suggestions.

The relation between what is desired by users, what already existed and what needed to be done, clearly evidenced what could be done and which were the margins of improvement in order to create "*something better to improve the Quality of Life of Duchenne people.*"

4 Results

The innovative product designed cannot be described in details, since it is in the process of being patented. However in general we can affirm that, even if the prototype needs future development to obtain the required certification in order to enter the market, it is characterized by:

- **Improvement in clinical efficacy**. This goal was reached in several way;
- **Improving wearability**, customization on the exact shape of the foot;
- **Improving strength resistance**, adding material and resistance only when required, thanks to a deep analysis of the optimized forces flow inside the orthosis;
- **Improving comfort**. Thanks to a new morphology, currently unavailable for critical diseases as Duchenne Muscular Dystrophy, and to an increment in the percentage of open surfaces—to drastically improve the breathability of the orthosis;
- **Monitoring of the progression of the disease**—since an indirect survey allows to easily collect and monitor over time the progression of plantarflexions and to have measurable data dated in time and scientifically comparable;
- **Lower cost and time of production** compared with handicraft products. These reduction of time and costs is pursued and obtained in any phase of the process:
- **Survey**, made with an indirect technique;
- **Parametric Design**, thanks to an algorithm that customize the AFO on the shape of the leg and can be customized on user tastes.
- **3D printing**—Additive manufacturing isn't affected by advantages of scale of mass production and it's the perfect answer to the need of a unique customized product in a short time and with low human efforts. The idea of a 3D printed customized static orthoses was related to the choice of a parametric design and in view of the best optimization of the process in terms of quality, time and costs.
- **Improving aesthetic qualities of the product and customization on users' tastes**—Improving the correspondence of the aesthetic of the AFO to users' expectations would incredibly help in the process of psychological acceptation of the orthosis and it is particularly true if we're talking about children or young consumers. A "fashion" orthosis, whatever it means depending on the age and tastes of the user, could drastically influence the decision of wearing it or not.

5 Conclusions and Future Developments

The PhD was successfully concluded on April 2015 evaluated with "*Excellent and the recognition of the dignity of publication of the thesis and of patent of the prototype*". Soon after, the process of deposit of the patent started and on June the author won the "*Business Exchange and Student Training*" scholarship, offered by the Fulbright commission. The grant consist of a period of six months in Silicon Valley to develop the project with the support of most renewed experts in technology and high technology start up.

This research will consciously not be able to solve all the criticalities encountered and no result will have to be considered definitive and unchangeable. Especially if we draw upon technology to improve some processes we have to consider that each solution is extremely temporary. This considered, it is clear how the research developed an optimized process and approach to the design of a new innovative type of night AFOs for DMD. Such result is more durable to the passage of time and more adaptive to contemplate technical and technological progresses.

At the moment the research results has not be published yet, until the process of deposit of the patent will not be concluded. However, the development of the project is continuing as on the scientific and technical side as on the commercial aspects, and a trial test on a small group of volunteers is expected to start soon.

Design for Duchenne. Guidelines for Dwellings' Construction or Renovation for Muscular Dystrophy—Affected Families

Michele Marchi and Giuseppe Mincolelli

Abstract Duchenne is a rare form of muscular dystrophy (DMD) that affects 1 boy out of 3500. The first symptoms appear around 2–5 years of age and result in a total muscles paralysis. The Italian legislation on accessibility of spaces and services is rather outdated and not entirely relevant for the specific needs of DMD-affected children. This research aims to offer a practical guide to renovation or new-construction projects that can be useful for parents of DMD-affected children, designers and experts. The covered aspects include the design of residential buildings' spatial and functional architectonic elements and the connected design of furniture. Both aspects are conceived having in mind key accessibility requirements by users with limited mobility. The purpose is to improve users' quality of life, with a specific focus on DMD-affected children and their families. The research follows the approach of Design for All, developed through the application of a User-Centered design methodology based on QFD (Quality Function Deployment).

Keywords Disability · Accessibility · Design for all · Architectural barriers · User centered design · QFD

1 Introduction

The objective of the doctoral research whose results are described in this paper was to create a tool that supports families and technical professionals to get information and advice around house accessibility. The research was co-funded by the University of Ferrara's Department of Architecture and the Parent Project Onlus—

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an association created by parents of children suffering from Duchenne and Becker muscular dystrophy (DMD/BMD).

Since 1996 the organization works to improve treatment, quality of life and long-term prospects of people with DMD through research, education, training and awareness campaigns. Initially their scientific research focused on finding a genetic treatment leading to the complete and full recovery for people affected by this syndrome.

Unfortunately, given the complexity of the disease and its recent discovery, a definitive treatment has not been found yet. However, many national and international research trials are currently ongoing, and they have contributed to extending the lives of people with DMD. By consequence a new focus emerged around the quality of life of the affected people.

The research was aimed to analyse the way families use their house according to the progression of the disease and to focus on the causes of the reduction of the quality of life depending by the characteristics of the domestic environment.

Through the application of a User-Centered-Design method, and after having identified the families' needs, the purpose was to select best available solutions and provide an instrument to increase awareness and knowledge about it, that could be usable both by the families and the professionals.

2 The Duchenne Muscular Dystrophy

DMD is one of the many existing dystrophies, all having in common the deficiency and/or defect of dystrophin,[1] which is a protein contained in the muscle fibre's membrane.

The DMD and BMD are the most common forms of dystrophinopathies. In the form of Duchenne, dystrophin is absent or greatly reduced in muscles, while in the form of Becker dystrophin is reduced or altered, therefore not functioning as

[1]Dystrophin is a protein formed by 3685 amino acids which is present in muscle tissue. It is synthesized by a gene discovered in 1986 in the X chromosome. Dystrophin is an essential protein that stabilizes the muscle fibre's cell membrane and it is assumed that its absence in individuals with progressive muscular dystrophy causes a failure of the membrane due to its own weakening. This leads to a ripple effect that ends with the muscle fibre's death. The University of Ferrara's Laboratory of Molecular Genetics within the Section of Medical Genetics, has been engaged for years in diagnostics and research around dystrophinopathies which are a group of inherited genetic diseases linked to chromosome X (thus affecting mainly males) that are due to heterogeneous mutations in the dystrophin gene. The latter is a very large and complex gene and its alterations are the basis of different clinical cases, spacing from Duchenne or Becker and the chromosome X-linked dilated cardiomyopathy, to some very mild or asymptomatic situations, often characterized by increased CK serum. The dystrophin gene contains the information necessary for the production of the dystrophin protein which is a fundamental component of the structure of skeletal and cardiac muscle fibres.

See Health Dictionary, University of Ferrara.

normal. However, there are other rare forms of dystrophinopathies, for example one that only gives cramps and muscle pain, and another that starts at around 30–40 years of age.

DMD is a rare disease[2] that affects 1 in 3500 live male births. It is estimated that in Italy there are 5000 people affected by the disease, but there are no official data since protocols, reference centres, diagnosis, management of care and a dedicated database are still absent. DMD is the most common type of muscular dystrophy that affects children and it affects almost exclusively males, with very few exceptions, as the cause of the syndrome is an alteration of a gene located on the X chromosome that contains the information for the production of a protein: the dystrophin.

The lack of this protein induces a certain permeability of the cell that can now be penetrated by some substances, causing the explosion of the cell and its death. As result, the contents of the dead cell pours outside, calling the immune system to clean a wider area of the muscle than necessary. The process causes a bigger damage than the initial one and the "vacuum" created by this process is replaced with connective tissue. With the reiteration of the phenomenon the muscle is increasingly damaged and the healthy cells get "strangulated". The constant repetition of this pattern leads to the complete death of all muscle's cells.

The first DMD symptoms appear between 2 and 5 years of age: at first, the child shows difficulty to walk or climb stairs, then his/her upper and lower limbs come to a complete paralysis and finally death intervenes due to heart or lungs' failure.

Therefore, on top of being a debilitating and complex disorder, it forces affected people to a continuous change of their physical, motorial and psychological functions. As a result both personal daily habits and family dynamics are constantly evolving and changing.

Given that throughout the years the degenerative condition will limit first and then deprive the individual of his/her independence and autonomy, important psychological aspects on the side of the affected person must also be considered. To be able to plan clearly for the years ahead, it is recommended that families of a DMD patient receive clear explanations around medical implications, architectural possibilities, physiotherapy treatments, psychological effects and technical devices that could be considered to obtain a quality daily life.

Unfortunately, given that the disease has been recently discovered, there is little knowledge around the most appropriate behaviours and actions. A lot has been done in the medical and psychological fields, and there are several new research

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[2]A disease is considered "rare" when it affects no more than 5 in 10,000 people. However, the low prevalence in the population does not mean low numbers in the affected population; indeed in Italy millions of people are affected by "rare" diseases while numbers spike up to tens of millions across Europe. The number of rare diseases known and diagnosed oscillates between 7000 and 8000.

Speaking of rare diseases as a whole and not as individual pathologies, allows to highlight and recognize common welfare issues and to plan for public health interventions that are targeted and yet not fragmented so as to serve groups with similar needs, all accounting for peculiarities and differences. When it comes to rare diseases, one must speak of the so-called "orphan drugs". Drugs that, precisely because of the fragmentation of individual diseases, are struggling to meet the economic interests of pharmaceutical companies. See the Superior Institute for Rare Diseases.

trials to find a cure or a therapy that could relieve pain and prolong the lives of MDM-affected patients. Specific treatments, cycles of therapy and an inclusive social context resulted in an increase in quality and length of life expectancy, to the point that a DMD-patient can live up to 40/50 year. However, in the architectural field there has been limited research around the relation between living space and DMD, which remains little explored and known.

3 The Accessibility Issues for DMD Affected People

It is in this context that the Parent Project Onlus has asked help and support to the University of Ferrara's Department of Architecture to try to find design solutions to improve the homely daily life of DMD-affected persons and their families.

The research stems from very complex yet stimulating premises since on top of the complex medical condition, the Italian legislation around accessibility is quite cumbersome and obsolete.

For many years, motorial (para and tetraplegia) and visual impairments (hypo visibility and blindness) were the main research focus—up to the point that the most important legislation in Italy (Law no. 13 of 1989 and the subsequent Ministerial Decree 286/1989) can be considered almost exclusively intended for their protection.

In Italy, for more than 20 years—and beyond the intentions of the legislator—a building was considered accessible if in line with these regulations—which contributed to a partial and incomplete accessibility culture. Today we know that this is false and incorrect. Each person has variable requirements depending on different conditions and different phases of their life. Today we know that a person's disability is determined not only by its physiological functionality, but also, and especially, from the different degree of enabling environment in which they live.

This work is rooted in the acknowledgment that the main causes of lack of accessibility and inadequacy of the houses of DMD-affected families are due to cultural aspects and lack of information. Once families are given the diagnosis and they become aware of the diseases affecting their child, they have to take—or at least be informed of—very difficult actions around their child's psychological and practical wellbeing.

In a scenario of this type, a family asks to a professional technician for advice on effective accessibility measures, considering that the syndrome is very complex. Unfortunately not many professionals are aware of this disease and, as stated earlier, there is little knowledge and information tools to receive clarification or advice. Moreover, it is essential not only to meet the present needs, but also to be able to foresee and fill the future gaps. Each person has their own course and degeneration due to the disease and therefore it is impossible to elaborate rules that can "fit all". However, it is possible to highlight common patterns that should be considered to guarantee a broad accessibility within the home.

Due to the progress of the disease, the body of a DMD-affected person changes and by consequence their needs, requirements and expectations. A dwelling must ensure a degree of flexibility and adaptability to be able to interface in a holistic way with these changes of physicality and needs. Moreover, more information and a cultural shift from the "building habit" are necessary. Professionals have to know the final recipient of their project and be aware that strictly following the current legislation (Law 13/1989 and Ministerial Decree 236/89) on accessibility does not necessarily support the persons that receive their services.

For instance, while designing a bathroom according to the Italian law on accessibility a handrail should be placed next to each piece of furniture. However for a DMD-affected person this is not only useless but it also hampers their transfers. While the disease progresses, the DMD-patient loses strength and tone in their upper limbs and therefore these tools become a dangerous obstacle.

Since the very offset of this research, it became clear that it was necessary to tackle firstly information and cultural barriers. The recipients of this work are meant to be all people that at any point could improve awareness and knowledge of the real needs of these families. For this reason the two main targets of users for the present research are parents and designers. Therefore we have decided to shape our tool as a manual. Specifically, we created a two-sided manual that tackles the same topic using specific language, vocabulary and references that are suitable for the two different audiences. The final goal is to enrich the information available to families and technicians allowing them to open a dialogue to find feasible solutions that otherwise would be hard to foresee, visualize and define.

4 The Method; A Guide to Design Houses for DMD Families

Design for All (DfA) has been used as research method and it has accompanied all aspects of the study—from getting acquainted with the syndrome to setting-up the table of content, getting in contact with competent specialists and considerably diversified sectors. This process was essential to get to know the universe revolving around DMD, including the medical indications, growth-related issues, relations around surrounding space and many other elements. Regarding the project on the manual, it is important to highlight that the DfA approach has been adopted in a complete and structured way for the graphic interface. The research involves a complex and variable arrays of users and aims to design inclusive products that can also look at social integration.

The main design tool adopted for the development of an effective and comprehensive guide has been that of the Quality Function Deployment (QFD). The great merit of this instrument is to put in the correct and comprehensive communication all users, stakeholders and technicians involved in the life cycle of the product that you want to design.

Considering it from a philosophical point of view, QFD has the ambitious goal of translating certain intangible instances (the desires, needs and fears of the final users and those of the operators that make the product or service available) into measurable quantities (the technical features that describe and measure the performance of a product or of a service), through a multidisciplinary approach, so that these are translatable into viable processes.

Though this description shows many similarities with the processes of User Centered Design, traditionally applied in Inclusive Design, it should be noted that the QFD stands by them for some specifics, such as:

- A strong focus on quantitative parameters that can measure the quality expectations in terms of performance.
- A careful comparative evaluation of the solutions already available.
- The application of an algorithm for the determination of the importance of the performance characteristics.

The main tasks of the design process that has been reached through the application of QFD method can be resumed as follows:

1. Definition of the characteristics of the information contents required by families and technicians, that could grant the higher level of precision, effectiveness and adequacy in the description of accessibility issues and solutions.
2. Definition of the characteristics of the design of the graphic and physical interface of the handbook that could grant the higher level of usability and accessibility, according to skills and needs of the different users.

4.1 Information Contents

The quality and reliability of the information provided by the guidelines are two essential and indispensable parameters. This has also been confirmed by the two major users (households and technical professionals), during the interviews conducted in the early stages of the project.

The choice of direct and indirect sources was a very important moment in the development of the manual. Indirect sources have been identified in the Italian and international scientific literature. A significant number of publications related to the accessibility of the dwelling spaces and the removal of architectural barriers in buildings has been analysed, and some application of general principles were derived from this analysis. However, not many studies related to the specific disability of dystrophic persons are available and hence it was necessary to make a work of re-interpretation of the collected information in relation to the users needs analysis conducted on the field. The direct sources instead derive from participation in National and International Conferences, interviews with experts, interviews with families.

4.2 Graphic Layout

It has been paid much attention to the identification of the factors that could determine the pleasantness or the readability of the handbook layout. After having conducted a careful and thorough analysis of the needs facing the two major users regarding the readability and clarity of the information provided by scientific or technical manuals, we decided to design a prototype and to involve users in all phases of its design process to verify that the analysis previously carried out was really apt to produce a qualitative and innovative work.

Considering the vast range of actors involved, this approach is the most reliable and appropriate for the type of required outcome.

For these reasons it was decided to design an online questionnaire with the possibility to process text and images in a simple way yet capable of generating a high number of data.

The questionnaire was used to understand the end users' degree of satisfaction around the manual and it highlighted some dissatisfactions and gaps that were corrected and revised according to the feedback of families and technicians.

Therefore, thanks to the needs expressed by the different people involved in the project, it was possible to finalize the updated manual. Once the research phase was over, we started the publishing work to enable families and technicians to access and consult it.

5 Results

The results obtained in the survey show us that the graphic layout of the proposed prototype meets the identified usability requirements. The needs analysis was conducted effectively, allowing us to identify the real needs of both families and technicians. The market research conducted on magazines and technical manuals showed the critical points and the positive factors of the Italian and international publications that have similar aims. More specifically, for the part of the handbook aimed to families, 103 questionnaires have been compiled; this number represents approximately 21.65 % of all sent questionnaires. In fact, the questionnaire was sent repeatedly through social networks or personal email from Parent Project Onlus Italy to its members (about 800). The opinion expressed on the handbook quality is positive, as the average is always higher than 4.12/4.15 out of 5 and variance ranges from 0.27 to 0.72. For a media survey, an acknowledgment of 21.65 % on the totality of interested or involved people, is not a high value. The objective was to reach at least the 25 %. The low feedback from the families is not motivated by any predictable reason, since the theme is relevant to them and the questionnaire is short and intuitive.

As for the media questionnaire addressed to technical professionals, there has been a greater level of participation; it should be noted that the calls were in greater numbers. The catchment area of the survey has embraced the Professional Order of Architects of the Province of Ferrara and Bologna and Emilia Romagna Architects

Federation. The completed forms amounted to a number of 202 and, therefore, represent a satisfactory number for statistical analysis. Unlike families, engineers have been profiled, always anonymously, to understand their level of competence and experience. The questionnaire showed that most of the respondents (69 %) were enrolled in a Professional Order from a period ranging from 2 to 20 years and that 71 % have already designed for special or vulnerable users (elderly, people with disabilities, users with special needs…) and that 43 % of them had problems or impediments due to a lack of competence or lack of availability of specific informations. The results obtained, however, denote a high perceived quality for the prototype of the handbook, since the average satisfaction regarding the graphical interface oscillates from 3.92 to 4.51 and the variance goes from 0.28 to 0.54.

The judgment by families and technicians has reached very high levels of satisfaction, achieving percentages ranging from 92 to 96 %. If we compare the level of acceptance between the "expected quality", and the final project, we observe an increase in the partial and overall satisfaction. The levels of "expected quality" had been defined prior to the design of the graphic layout, according to average quality of the analyzed textbooks.

6 Conclusions

We created a user-friendly product that is rooted in the results of a rigorous scientific trial. In this sense, the manual should be considered as a design object, both in its form and content, as well as in the layout and in the selection of sources and information. It is about a kind of design that does not want to amaze or persuade the buyer but that rather listens to, analyses and interprets new ways of living. It takes upon the hardships that come along with DMD and, starting from them, it suggests innovative solutions that could improve the quality of life of DMD-affected families, respecting everyone's needs (Fig. 1).

All book's medical or architectural contents, both in the form of new design or existing solutions on the market, have been conceived and designed according to the real needs of people affected by Duchenne muscular dystrophy. We have tried to convey a method rather than already-established solutions. We wanted to highlight that on the market there are many types of accessible bathroom appliances, kitchens, and closets and it is only necessary to know and understand what the present and future needs are to be able to buy the most suitable product.

Moreover, DMD is a diseases that implies continuous modifications around needs in all the areas of daily life of a DMD-affected family. This determines considerable complex interpersonal and contextual dynamics, to the point that it can be considered as one of the most challenging and hardest fields of design.

It should be considered that because of the extreme complexity of the needs resulting from a severe degenerative syndrome such as the one analysed, the identified solutions can be considered as transferrable to many other ambulatory conditions (Fig. 2).

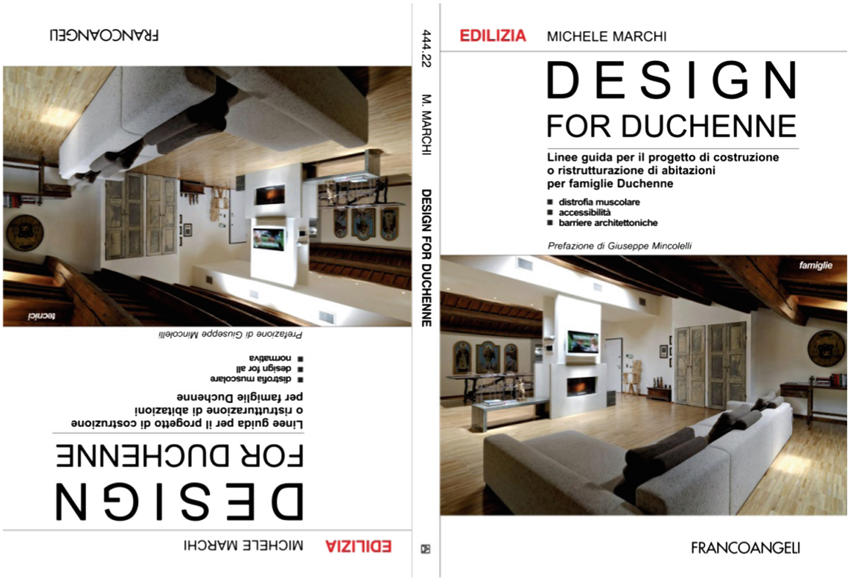

Fig. 1 Cover of the editorial product

Fig. 2 Manual layout example

For example they can be applied to persons on wheelchairs, with limited mobility in their upper limbs, people affected by temporary lower or upper limbs disability, and elderly that need specific support to ease their daily activities within their houses.

The only diseases not covered in the manual are those associated with cognitive disabilities and low vision as people with DMD do not experience this kind of damage. The results of the research can benefit greatly to all researchers and practitioners interested in the study and development of solutions related to the issue of accessibility.

IESAMI: An Intelligent Environment to Support the Academic Monitoring and Inclusion of Students with Disabilities in University

Paola Ingavélez-Guerra, Fernando Pesántez-Avilés, Vladimir Robles-Bykbaev, Jennifer Yépez-Alulema, Cristian Timbi-Sisalima and José Ramón Hilera

Abstract According to the latest estimates of The United Nations, currently, between 180 and 220 millions of youth (15–24 years) around the world live with some form of disability and approximately 80 % of them are from developing countries. Consequently, it is fundamental that youth with disabilities have the same opportunities to access to Higher Education and develop their full potential. However, most of universities (especially in South America) do not have programmes that can guarantee a suitable inclusion for these people. Therefore, this paper describes a proposal of an intelligent ecosystem to support inclusion of students with disabilities in higher education. This ecosystem has the aim of integrating several sides related with humanistic level, academia, research, and technology. Some parts of this ecosystem have arisen after a practical experience of 3 years in development of assistive technologies to support education for people with disabilities (children and youth). The aforementioned experience has raised awareness in higher education students about disabilities (through their participation in social projects) and has favoured to approximately 200 children and youth

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through carrying out of research projects with social purposes in the city of Cuenca (Ecuador).

Keywords Disabilities · Assistive technologies · Inclusion · Children · Youth · Intelligent systems

1 Introduction

According to Convention on the Rights of Persons with Disabilities and its Optional Protocol, disability is a concept that changes due to existing interaction among people with disabilities, attitudinal barriers and an adverse and discriminatory environment. In this situation, people with disabilities cannot be fully and effectively part of the society as a result of unequal conditions. Ecuador, in complying with law, "deems that a person with disabilities is who, as consequence of one or more physical, mental and/or sensory disabilities that can be congenital or acquired; has less than 30 % of his/her ability to do a normal activity while he/she is doing his/her usual functions".

Current situation in Ecuador demands a higher awareness about the role that each citizen should perform inside the society. Now, there is not a comprehensive and inclusive social educational proposal to allowing students and general population raising awareness about national situation. Therefore, people cannot easily generate changes and propose appropriate solutions to placate economic, political and social problems. Accordingly, the Ecuadorian Constitution considers that an analysis of situation of people with disabilities is vital to help them to be part of the society (articles: 5, 47, 48, 49, 66 and 81) [1].

Generally, there are not minimal physical or sensory requirements to get access to the University. There are usually one or two academic requirements: having a high school degree and some universities also ask for doing a selectivity test. Some countries, like Spain, as part of inclusion projects, make adjustments according to students' requirements (furniture, teaching materials, exams, etc.). These adjustments are made after an application; thus, a student with disabilities should first apply for a "Certificate of degree disability" to Chancellorship of Social Affairs (IMSERSO). This certificate empowers to its owner to access to free higher education and also benefits like: tax reduction, bus free-pay, financial support for housing and more. When a person with disabilities applies for this credential, an equipment of professionals assesses to the person according to standards of the World Health Organization (WHO) [2]. On the other hand, some Mexican universities provide a developed skills certificate to the student if he/she does not meet with all the academic process required for the degree final certification [3].

This initial scene provides a short illustration of the challenges that people with disabilities have to deal. Hence, the following sections of this paper will head to present the work done and its importance in this environment. In this manner, Sect. 2 describes how Ecuadorian law and Universities look for enforcing the right of education to people with disabilities. Section 3 presents a brief description of researches in the area of inclusive higher education. The general architecture of the suggested approach is illustrated in Sect. 4. The pilot experience that was carried out during the last 3 years and that was used to create the proposed ecosystem is depicted in Sect. 5. Finally, Sect. 6 presents conclusions and ideas for future work.

2 Disabilities and Education: The Ecuadorian Reality

Ecuador is following a path towards progress and equality for its population. Hence, various actions have been taken in order to promote an active participation of marginalized population as people with disabilities. According to data collected by National Institute of Statistics and Census in Ecuador (INEC), population census establishes that population with disabilities has grown in about 5.6 % between 2001 and 2010 [4]. The research entitled “Ecuador: disability with figures” sets that 12.14 % of Ecuadorian population has any kind of disability; and, a bio-psycho-social research made by Manuela Espejo Solidarity Mission points out that there are 294,803 cases of people with disabilities [5]. Having in account Ecuadorian law, Constitution of the Republic of Ecuador 2008, in its 47th article, cites: “The State will guarantee policies for prevention of disabilities (…) People with disabilities have rights to: (…) 7. An education that develops their skills and potential in order to achieve their integration and participation on equal footing” [6]. Here, it is essential to point out that disabilities can be typified in different ways and their origin can be diverse. For example, disabilities can be physical, hearing, visual, intellectual, etc. On the other hand, disabilities can be classified as mild, moderate or severe disabilities. Thereby, it is necessary to keep a record about students with disabilities in order to assess their situation and accomplish their inclusion with support of law.

The Chancellorship of Education, through The National Office of Analysis and Educational Information, points out that in 2015 it was identified 22,196 students with any kind of disability. These students are part of the educational system according to the following groups: 4110 students are in educational institutions for people with disabilities; 17,367 students are part of the regular education system and 719 students are part of permanent popular education [7]. It is important to highlight that 78 % of students with disabilities are part of the regular education system; in such manner, they have a high likelihood to continue with their higher education. By the end of 2015, there were 844 youth with disabilities doing their last grade of high school and this is summarized in Table 1.

Previous data show that inclusion of youth with disabilities in higher education is not only based on good intention of Universities having policies to avoid any kind of student discrimination. However, in spite of inclusion of students with disabilities in Universities has grown during the last years, there are not global statistics related with this topic until now. For example, according to an analysis carried out by Politécnica Salesiana University, the largest private University in

Table 1 Students with disabilities that were doing in their last grade of high school [8]

Kind of disability	Female	Male	Total
Hearing disability	50	52	102
Autism	1	5	6
Intellectual disability	96	107	203
Motor impairment	69	81	105
Disabilities caused by syndromes	11	8	19
Multi-disabilities	18	23	41
Down syndrome	4	2	6
Visual disability	198	119	317
Total	447	397	844

Ecuador (more than 20,000 students), there are 267 students with disabilities that are looking for an opportunity to be part of the population with a higher education level. Seventeen percent of these students have hearing disability, 31 % has physical disability, 32 % has visual disability and 17 % belongs to another disability [9].

Finally, it is essential to have in mind that a real inclusion of students with disabilities depends of a continuous monitoring and universal learning in pursuance of accomplishing that students keep doing their degree and achieve to finish it. Thus, the current project proposes to provide to Higher Education with an intelligent ecosystem to support academic monitoring and inclusion of students; taking in account good practices used along Ecuador and also standards and regulations recommended along Latin America.

3 Related Work

Developed and growing countries have to face to the continual increasing of academic and social exclusion. This exclusion implies lack of access to basic services causing that more people cannot obtain levels of dignity and equality to which each person has right. Access to employments in the actual knowledge society is determined by the amount of academic years. This situation excludes many people from the benefits of development and therefore it is important to give to population a suitable, adequate and updated level of education. Thus and according to UNESCO, inclusive education is a process that should increment participation of different students and reduce their exclusion with and from education [10].

As many countries are now conscious of inclusive education, they are doing researches to evaluate the inclusion level of students in Higher Education. Thus, Gross Martínez cites how inclusive University requires participation of each person who is part of it: lecturers, students and administrative staff. Hence, taking in account that Universities have a dynamic reality, it is necessary to have institutional doings to allow strengthening the right to a timely and excellent education [11]. Moreover, Alias, Alias and Ibrahim exhibit how Universities in Malaysia are moving towards an inclusive education after they have perceived that students with special needs in education have to overcome barriers and challenges in their learning phase, their field work, their evaluations and even when they have to communicate with university staff. In addition, these students have problems like physical access, lack of awareness, deprivation of appropriate technology for them and lack of support from university staff and from other students [12].

Getzel cites that amount of new students with disabilities in University is growing and therefore University is still dealing with problems and challenges to help these students to finish successfully their academic programme. With this background, Virginia Commonwealth University has developed and implemented a support model that integrates existing services in their campus with new approaches or strategies that allow attending to students with disabilities. Getzel describes that this model encompasses three axes being the first one of them the development of self-determination skills by students with disabilities through mentorship or organizing support groups. Another axis that is included in this proposed model is technology applied to students with disabilities requirements. So, if software to organize reading materials, to create papers, to convert voice to text conversion and more is used in a proper manner, it decreases the likelihood of students leave their academic programme. The last axis of the analysed model is formed by internships or other kind of experiences related with professional practice. These experiences allow to students with disabilities creating a liaison among their knowledge and acquired skills in academia with their duties in labour sphere [13].

Peña with his analysis of the monograph “Allies for Inclusion: Disability and Equity in Higher Education” highlights that faculty and administrative staff should be allies of inclusive process in Higher Education. This proposal, goes one step forward, pointing out that academic success of students with disabilities depends of a shared model between campus ownership and responsiveness toward students. Finally, it stands that inclusion models in Higher Education should challenge traditional beliefs, taking in account individual differences to deepen in attitudes toward disability as well as services that are provided in campuses for these students [14].

4 General System Design

This section shows a proposal about an entire supporting ecosystem aimed at facilitating inclusion of students with different kind of disabilities inside educational level with emphasis in Higher Education. This project looks for merging, in an effective manner, all aspects of human area (students, lecturers, family/environment, classmates and research groups on educational and technological inclusion), technological area (expert systems, intelligent supporting ICTs) and academic area (general curriculum, personalized curriculum and more). As Fig. 1 exhibits, this

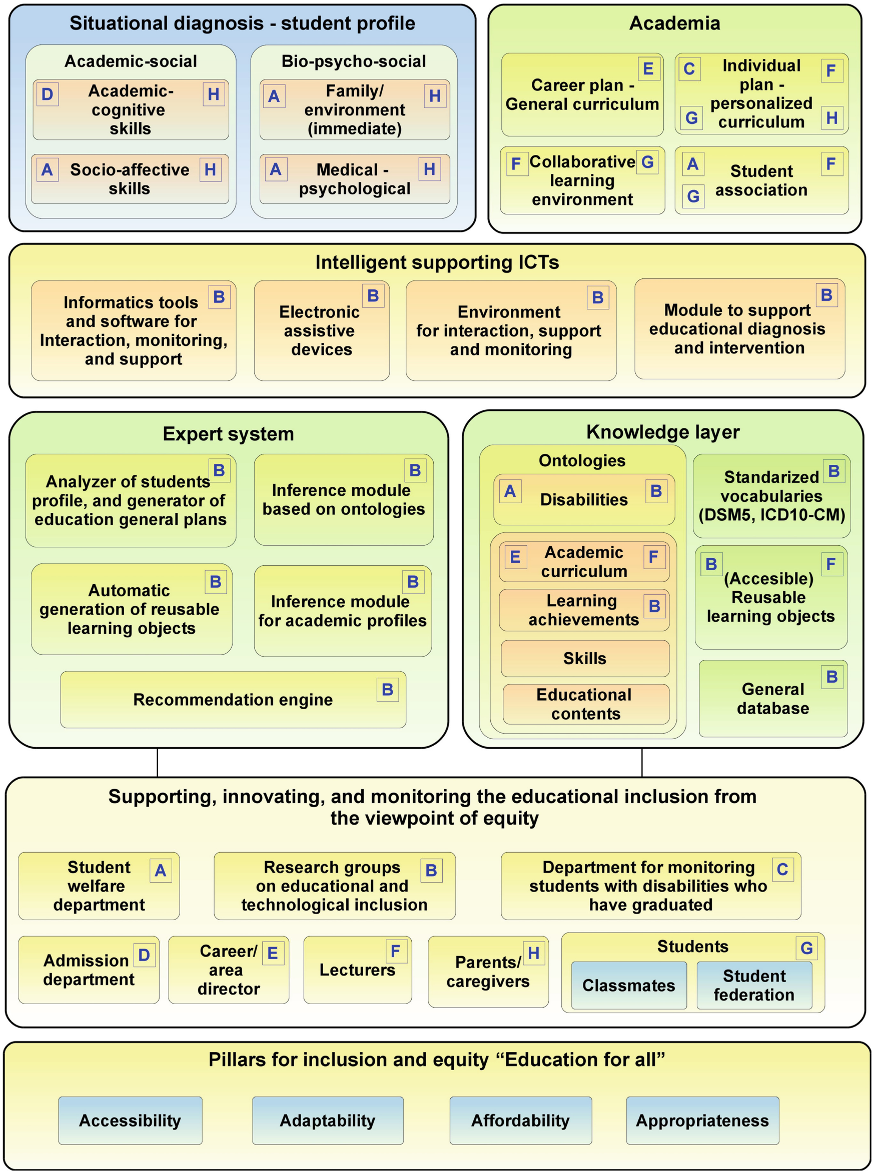

Fig. 1 General design of the proposed ecosystem

system is organized in layers with interconnected elements that make it more flexible (allowing incorporation and elimination of actors and elements easily), robust (behaviour of elements in each layer can change without altering services provided by these layers) and properly specified (each letter defines which actors or elements from a same layer or other layers have interaction among them). A general description of each layer and elements that are part of the proposed ecosystem is explained below.

- When students begin their studies in an educational centre, it is essential to have a **situational diagnosis** to clearly know which abilities each student has in **academia**, **social** and **bio-psycho-social** fields. In order to evaluate **academic-cognitive skills** of one student, **admission department** (psychologists, educational psychologists, speech therapists, etc.) and **parents/caregivers** will be fundamental pillars to help to establish and estimate these skills effectively. **Socio-affective skills** and **bio-psycho-social environment** will be analysed by the department that is in charge of **student welfare** with collaboration of **parents/caregivers**.
- Once parameters and variables, to describe precisely at one student, have been identified, it is crucial to have an **individual plan** (**personalized curriculum** coordinated with the **Career/Area Director**). This plan will take in account skills, disorders, developmental abilities and each feature related with the student. This **personalized curriculum** will be schemed in accordance with the previous information and it will be based on the **career plan (general curriculum)**. In the same manner, it is important that activities for one student with disabilities can be developed in an environment characterized by cooperative learning and sustained on the structure of **student association (classmates, student federation)**.
- Tools that allow removing barriers to access information (like Information and Communication Technologies) are a key aspect in inclusion process. In this case, it is important that these tools be **Intelligent Supporting ICTs** due to there should be the likelihood to adapt themselves to **student profiles** (according to their skills and disabilities). As part of this group of tools, it can be cited: **informatics tools and software for interaction, electronic assistive devices, environments for interaction and module to support educational diagnosis and intervention**. Development of each of these tools should be done inside research groups related with inclusion area; this will allow incorporating entire processes for technological innovation
- In many cases, knowledge depends largely of people that are expert and work for educational institutions. Thus, it is essential that this knowledge be available to be used in any moment, even if people that own it are still working or not for the educational institution. As an answer to this requirement, the proposed ecosystem includes an **expert system** capable of providing support to decision making (inter alia, automatic generation of learning objects adjusted to students requirements, automatic analysis of profiles and generation of educational plans). This knowledge should be saved not only in a common database but rather it should be used for a real knowledge model based on **ontologies and reusable learning objects**. All elements in this layer (**expert system**) should be designed, kept and developed by research groups together with experts in each area.

– Each layer and elements of the ecosystem should be sustained on pillars for education and inclusion that are: **accessibility, affordability, adaptability and appropriateness**. These crucial concepts are along the whole model and they define guidelines in order to have an effective process of educational inclusion in all levels.

5 Disability, Social Awareness, and Related Research: 3 Years of Experience in Cuenca, Ecuador

This proposal has been implemented over the past 3 years in the city of Cuenca, Ecuador and it has allowed participation over 100 university students, 15 experts of special education and rehabilitation, 20 lecturers, 5 institutions of special education and 2 universities. Similarly, more than 200 children and youth with disabilities have been benefited through the improvement of their academic processes.

As Fig. 2 shows, all this process corresponds to 3 elements that are characteristic of University tasks and that are closely related: research, entailment and lecturing. Based on this, it has been possible to develop interrelationships that have allowed strengthening the following axes:

– Lecturing activity: emphasis on training, counselling and supporting for use of assistive technologies and disability.
– Knowledge production activity: disability topics are promoted in academia, both undergraduate and postgraduate programmes, through the development and accompaniment of technological projects for assistance. It favours generation of disability awareness not only among students and lecturers, but also among university authorities and community in general.
– Intra and inter-institutional relationships: comprehensive tools have been developed in order to simplify access to information, monitor processes and student assessment. Thus, some strategies have been set up in order to achieve that internships respond to requirements of community with disabilities.

All of the tools and developed systems thus far have provided very positive and encouraging results. Benefits achieved by the projects that have been carried out embrace diverse areas like the following: improvement in rehabilitation processes (time reduction in diagnosis and intervention of speech therapy, generation of reports to support decision-making), better access to certain educational processes, universal access (web accessibility) among others.

A brief description of the 5 most important projects, selected among 50 that were developed during the last 3 years, is shown in the following list:

- **Ecuadorian Web Accessibility Analyzer**. *Binding Courses*: Expert Systems, Hypermedia Programming, Distributed Application. *Results*: Development of the first web accessibility observatory to monitor and report accomplishment of

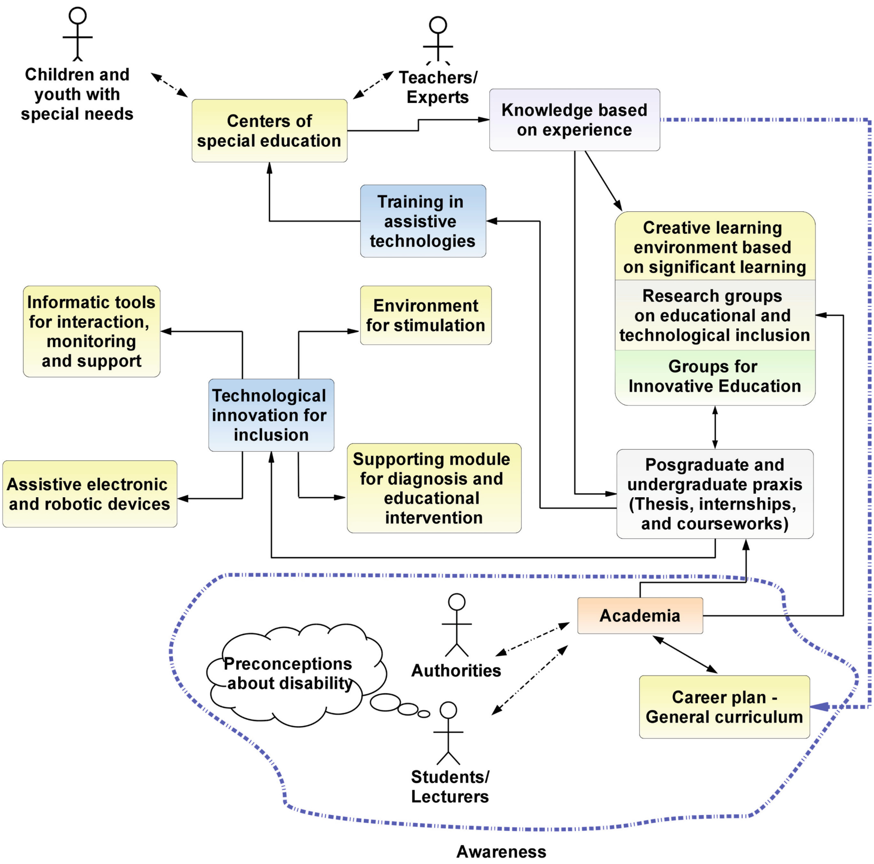

Fig. 2 The process carried out to conduct a partially implementation of the proposed model

ISO/IEC 40500. *Target Population*: 20 % of people with disabilities economically active of Ecuador. *Participants*: 6 lecturers, 5 professionals with disabilities, 2 state institutions, 10 university students.

- **Environments for stimulation**. *Binding Courses*: Computer Architecture, Electronics, Software Projects. *Results*: 5 rooms of stimulation given across the country. *Target Population*: 170 children and youth that attend to the educational centers and are benefited with the use of these rooms. *Participants*: 10 special education professionals, 4 lecturers, 15 university students, 4 special education centers.
- **Intelligent System to support speech therapy**. *Binding Courses*: Artificial Intelligence, Expert Systems, Software Projects. *Results*: 1 expert system to creation of speech therapy plans, 1 support tool for speech therapy, 3 robotic systems to support speech therapy. *Target Population*: 170 children and youth

that receive speech therapy supported by these tools. *Participants*: 10 special education professionals, 5 lecturers, 10 university students, 4 special education centers.

- **Monitoring and stimulating system for attention, memory, visual and hearing discrimination**. *Binding Courses*: Artificial Intelligence, Expert Systems, Software Projects, Electronics, Programming, Database. *Results*: 1 monitoring system for children and youth with intellectual disabilities. *Target Population*: 20 children and youth that receive therapy and special education. *Participants*: 5 special education professionals, 3 lecturers, 5 university students, 1 special education center.
- **Registration system for university students with disabilities**. *Binding Courses*: Artificial Intelligence, Expert Systems, Software Projects, Electronics, Programming, Database. *Results*: 1 support system for registering, monitoring and supporting of students with disabilities in university. *Target Population*: University students with disabilities (number of students not determined yet). *Participants*: 5 special education professionals, 7 lecturers, 10 university students, 10 university students with disabilities, 2 universities.

6 Conclusions and Future Work

Comprehension of problems that students with disabilities have to face in higher education comprises more than awareness of university community (faculty, university staff, classmates and more). Inclusion is not only related with access to students with disabilities to classrooms, it requires a global process to create suitable institutional conditions. It is also related with development of individual skills and abilities in the interest of accessing to higher education that also requires a technology that be free, accurate, flexible and adaptable to different requirements. Students with disabilities should be an active part of scientific researches to get trans disciplinary research. So, these students can contribute to Science and creation of useful technology from their own experiences.

Development of an intelligent ecosystem requires many phases that look for the joining of modules that will be strengthened with data from different cases. This characteristic allows getting timely and proper information to support inclusion process and therefore coexistence inside University environment.

As lines of future work, we propose the following ones:

- To develop ontologies for representing inherent existing relations among different actors of the ecosystem.
- To evaluate accessible learning objects according to international standards.
- To plan and implement virtual courses of training to learn about how to handle the ecosystem.

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Communication Support with the COMUOON Communication Support System

Shinichiro Nakaishi

Abstract The Comuoon is a device that makes a speaker's voice easier to hear, thus providing needed support for all types of hearing deficiencies—congenital, spontaneous, noise-induced (sensorineural), and age-related impairments. The high-performance microphone flawlessly picks up voices and delivers them with minimal distortion via an independently developed, egg-shaped speaker and high-clarity aluminum honeycomb speaker unit—a process that makes sound more intelligible for the hard-of-hearing and dramatically improves communication between the hearing impaired and unimpaired. The increase in hearing loss due to aging is a global concern, but it is believed that improvements in communication with people with age-related hearing loss lead to improvements in quality of life as well. Also, improvements based on feedback from communication with hearing impaired children at educational institutions have resulted in enhanced speech capabilities. The Comuoon helps reduce the stress related to hampered communication and, while working together with medical institutions, we continue to develop technology that makes life easier.

Keywords Hearing loss · Hearing impaired · Communication support · Hearing aid device

1 Introduction

In this paper, we consider a way to provide support on the side of the speaker when communicating with a hearing impaired person. Hearing aids and cochlear implants are the most common devices used to help the hearing impaired, and are useful for a range of hearing impairments, from mild to severe. Nevertheless, not all people with hearing difficulties wear hearing aids, citing issues with usage difficulty and a

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stigma about being seen wearing one. Japan has a usage rate of only 14.1 %, which is lower than the US and Europe [1].

Even if everyone used hearing aids, that would not necessarily mean that no additional help is necessary. When communicating with a person with a hearing impairment, the ability to communicate can be affected by environmental acoustics and the speaker's vocal characteristics, leading to frequent difficulties in communication even when the listener is wearing a hearing aid or has a cochlear implant. In addition to hearing aids and cochlear implants, many other devices for helping the hearing impaired exist, such as FM listening systems and audio induction loops, but they frequently are difficult to set up and may not benefit all hearing impaired persons.

Hospitals are reported by people with hearing impairments as locations where a "auditory barriers" are felt, meaning patients and medical service providers have difficulty communicating with each other. This can create problems regarding informed consent, etc., with potential for issues that may put the patient's life in danger [2]. People with hearing impairments require different kinds of support depending on the environment where communication is occurring, as well as their own hearing abilities. This paper takes a look at the Comuoon Table-Top Communication Support System, a device that provides an innovative support method via compromise by the speaker, without need for extra effort on the part of the listener, such as wearing a hearing aid, etc.

2 Background Behind Research and Development of the Comuoon

While working at my previous job at EMI Music Japan, a main reason why I decided to devote myself to researching the possibilities of using a speaker system for the hearing impaired via a non-profit was that both my grandmother and father were hard of hearing. As the years progressed, it became harder to speak with my grandmother. Attempts at communication would go unnoticed, and as a result, she would often feel disconnected and discouraged. As we continued our research, I heard from my grandmother that while she wished to speak with her family, she feared her hearing impairment made it too much trouble for her family members, leading to a marked drop in communication.

At that time, I increasingly realized the importance of studying about listening, and through the NPO, I worked to understand hearing impairment and to enlighten normal listeners regarding hearing impairments. While researching speakers for use in helping with hearing impairments, I thought about how we, as people doing the talking, can work to help people with hearing impairments—something contrary to the thinking behind hearing aids—and that's how we came to research the Comuoon Communication Support System.

2.1 Optimal Support System for Voice Listening

The Comuoon features a megaphone-like speaker enclosure to increase loudness at the speaker front and improve directionality, thereby preventing reflections of sound off of walls, etc., and reducing mic feedback, to provide an easy listening experience (Fig. 1).

In addition, by using our proprietary aluminum honeycomb speaker, high quality circuitry design technology, and a high quality operational amplifier, there are dramatic improvements to distortion, making for increased intelligibility even for people with sensorineural hearing impairments. Even at higher volumes, where hearing impaired people often find distortion inhibits intelligibility, we have made significant advances in clarity.

As a result, we've accomplished high levels of hearing improvements without a hearing aid, even at advanced levels of hearing impairment equivalent to 70 dB.

Usefulness was reported at the 115th Annual Meeting of ORL Society of Japan by the Otorhinolaryngology Team of the Faculty of Medical Sciences at Kyushu University [3].

We have also found that people with severe hearing impairment can also see improvements in intelligibility through combined use with a hearing aid or cochlear implant (Fig. 2).

In Japan, following the passing of the Act to End Discrimination Against Disabilities in April 2016, communication speaker systems for the hearing impaired (Comuoon®) are being utilized in medical facilities out of consideration for patients with hearing disabilities (especially elderly patients). With regard to medicines, the number of generic drugs is increasing, medicine names are becoming more complicated, and the number of drug types is growing, making adequate explanation more important than ever. We are currently testing the effectiveness of the Comuoon® in establishing a better communication environment for both normal

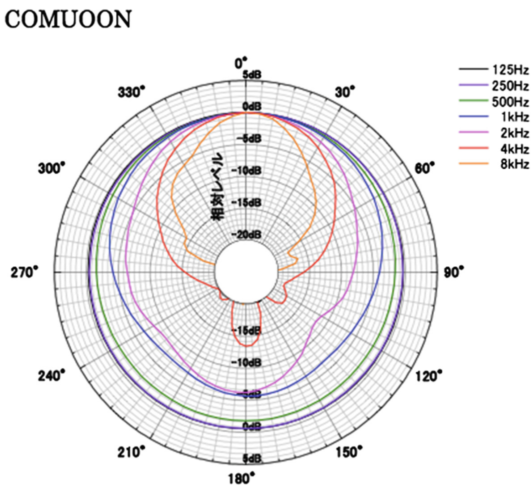

Fig. 1 Comuoon features a megaphone-like speaker

Fig. 2 In use at the Department of Otorhinolaryngology, Kyushu University Hospital

listeners and hearing impaired persons at the pharmacy counter of the JA Kagoshima Kouseiren Hospital.

The survey involved a subjective assessment of 15 staff members being read a list of 11 items from a medicine information sheet to test the listening change when the Comuoon® was turned off and when it was turned on. The results were that 6 members indicated improved intelligibility, 4 had slightly improved intelligibility, and 3 showed no change. There were especially marked differences for drugs with long names and “p” sounds. In addition, a subjective survey of listening improvement was given to 86 patients actually receiving prescriptions (mean age: 65.3 years). Of these, 42 patients (48.8 %) experienced improved intelligibility, 42 (48.8 %) showed no change, and 2 (2.3 %) experienced decreased intelligibility. Additionally, 35 of the 86 patients had been waiting behind someone, and only 2 of these people (5.7 %) responded that they could hear the explanation the person in front of them was receiving, while the remaining 33 patients (94.3 %) could not.

The above resulted in a report in the Japan Society for Health Care Management stating that the Comuoon® is useful in improving the listening environment at pharmacies when providing complicated medicine explanations or giving medicine guidance [4] (Fig. 3).

Fig. 3 In use at the Department of Otorhinolaryngology, Kyushu University Hospital

3 Conclusion

The Innovative Proposal of Universal Sound Design. Up until now, I've discussed the importance of not only having hearing assistance devices that require the cooperation of the listener—the person with the hearing disability—but also ways the speaker can also provide support. The Act to End Discrimination Against Disabilities enacted on April 1st, 2016, outlines "prohibition of discrimination" and "obligation for accommodation." As an example, imagine a patient visits a medical facility and, regardless of whether he or she is wearing a hearing aid, the patient receives a one-sided, inadequate explanation because a staff member assumes they can't hear much anyway, and the visit ends without confirming whether the patient understood what was explained. Such a case where a person with a disability doesn't receive the same consideration as someone else could be considered a "lack of reasonable accommodation."

Deaf and hard of hearing patients who pretend to understand what they hear because they do not want to bother the doctor or nurse are not uncommon. For elderly patients with hearing difficulties, many doctors are aware of the extreme frequency of situations at reception or outpatient care where communication is difficult even when speaking loudly.

Changes such as these shouldn't be considered mere adjustments made to abide by the Act to End Discrimination Against Disabilities; they should also be considered as part of the common hospitality offered to patients. When patients visit a medical facility, they already feel anxiety. When patients feel difficulty communicating with doctors or nurses, their anxiety increases. This is one reason I feel that Sound Field Clarity Improvement Systems for use by the speaker, like that used by the Comuoon, are going to gain attention in the future from a variety of fields.

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Part IV
Designing for Inclusion: Methodology and Future Trends

Building Bridges Between User and Designer: Co-creation, Immersion and Perspective Taking

Santiago Martinez, John Isaacs, Fabiola Fernandez-Gutierrez, Daniel Gilmour and Ken Scott-Brown

Abstract Designing *for* users rather than *with* users is still a common practice in technology design and innovation as opposed to taking them on board in the process. Design for inclusion aims to define and understand end-users, their needs, context of use, and, by doing so, ensure that end-users are catered for and included, while the results are geared towards universality of use. We describe the central role of end-user and designer participation, immersion and perspective to build user-driven solutions. These approaches provided a critical understanding of the counterpart role. Designer(s) could understand what the user's needs were, experience physical impairments, and see from other's perspective the interaction with the environment. Users could understand challenges of designing for physical impairments, build a sense of ownership with technology and explore it from a creative perspective. The understanding of the peer's role (user and designer), needs and perspective enhanced user participation and inclusion.

Keywords Design for inclusion · Co-design · Immersion · Perspective taking

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1 Introduction

There are generally two distinctive roles when designing, developing, evaluating or deploying technology: 'user' and 'designer'. The former is the operator of machinery or artefact [1, 2]. The latter is the planner of the purpose, form and working of technology [1, 2]. Historically, the designer has been the central part of the process of technology design, due to the complexity and demands that the process requires. However, there are standards [3, 4] and methodologies [5–7] that work towards the understanding of user needs, context of use and participation of user in the design process. These methodologies and techniques open new possibilities for both parties: the user becomes a key contributor of the design process, realizing of the possibilities and limitations of the designer; the designer includes new perspectives in their design, experiencing as the user does.

2 Research Background and Methodology

The work described here employed methodologies in technology design and innovation that take users on board in the design/evaluation process, as opposed to those that design in isolation from users. Examples of the former (research methodologies that take *do take* users on board in the design process) are user-centred design [5], participatory design [6] or co-design [7]. This paper describes three practical approaches used across different research projects to build user-driven solutions with the collaborative work of end-user and designer: *co-design*, *perspective taking* and *immersion*. Co-design is a cooperative design process carried out by designers and users. Users become active contributors of the process of designing. Perspective taking consists of viewing a situation or becoming aware of something from a specific alternate point-of-view. Thus, a perspective of a given situation may be taken from a first- or third person, differing in the perception, attitude or experience of each of the perspectives. Immersion is defined as the technique to use a foreign element (e.g., language, costume) as an instrument to learn and/or experience something new.

2.1 Co-design

The co-design methodology was used for two different projects: an environmental web portal for Scottish citizens and a mobile game for age-related macular degeneration patients.

Scotland's Environment Web (**LIFE**) **project** (**SEWeb**). The project was funded by Scottish Environment Protection Agency (SEPA) and it was part of the LIFE + programme (the European Union's funding instrument for the environment).

Fig. 1 *Left* co-designed result of the map page of the SEWeb. *Right* current version of the map webpage of the SEWeb

Abertay University (UK) provided the research, co-design and development expertise. The project consisted of re-designing an environmental web portal with the participation in the process of target users (academic community, policy makers, educationalists, industrialists, public authorities and citizens) all participating in the design process. The project comprised a survey of the SEWeb site and a 5 stakeholder workshops (see Fig. 1) to identify how users access and interact with the environmental information retrieved on SEWeb and other online sources. The outcome of the project was an effective and usable SEWeb site accessible to clearly defined groups of target users. It provided a unique yet viable mechanism to deliver the objectives of the SEWeb (LIFE) project: namely to bring together information on Scotland's environment in an easily available and usable form.

Tapology. The project was initially funded by a Scottish Crucible 'Project for Scotland' grant. Follow on funding for co-design and public engagement was provided by the Carnegie Corporation of New York and dissemination supported via the EU NorthSea Region IVB 'iAge: e-inclusion in ageing Europe'. The Tapology project aim was to co-design and implement a mobile game platform to foster e-inclusion and create a future eHealth platform for people with age-related macular degeneration in the UK [0]. A group of 5 mini-games (see Fig. 2 for an example) were co-desgined to assess and exploit different parts of visual function. This was achieved through a series of Co-Design sessions, conference calls, user feedback and 'road map' planning meetings. The resulting 'app' was launched at the national DareProtoplay Indiefest Computer Games Festival and gathered data

Fig. 2 Screen shot from co-designed mini-game 'Pouring'. The task is for the player to drag the bucket left and right to capture as many falling drops from the cloud as possible. As a twist on the 'space invaders' game concept, this game involves gardening as its narrative inspiration, and the task is based on the difficulties experienced in pouring for people with low vision. This aligns the game with the player demographic

from a range of users to inform the development of the gameplay. Further user trials have been conducted with clients from the Fife Society for the Blind with members of the public. Results reinforced the viability of an assistive suite of apps with the capacity to monitor and perhaps rehabilitate visual function in a group of users with impaired vision and no prior experience of ICT [8].

2.2 Perspective Taking

Retrospective analysis of user experience through first-person perspective. The research project entitled The Integrated Interventional Imaging Operating System (I^3OS) of the EU Seventh Framework Programme (FP7) 2007–2013; funded by Marie Curie Initial Training Networks (Grant Agreement 238802) included a retrospective analysis of user experience (UX) of professional radiologists in a clinical operation theatre using first person perspective viewing. The analysis of the UX comprised ergonomic workflows and visualisation layouts for multimodal imaging and Magnetic Resonance Imaging (MRI) techniques, at the Institute for Medical Science and Technology (IMSaT, University of Dundee, Dundee, UK), coordinator of the I^3OS project. The methodology employed life-like experiments to evaluate the impact that clinicians' UX had in simulation of vascular MRI-guided procedures [9].

Participant Profile: 3 clinicians with different levels of expertise participated in the experiments: a senior interventional radiologist with more than 20 years of experience in vascular procedures; a trainee interventional radiologist with 3 years of experience in vascular procedures; and a trainee physician without experience in clinical interventional radiology. A research nurse with training in imaging environments assisted the clinicians during all experiments.

Interventions: The interventions were performed at IMSaT imaging facilities. The installations included an angiography suite and an adjacent MRI scanner room, both connected through sliding shielded doors (see Fig. 3). The interventions were scheduled in two slots of sessions, with the participation of 3 and 2 clinicians respectively. Participants wore spectacles with built-in microphone and high definition (HD) video camera that allowed record the intervention viewed from the

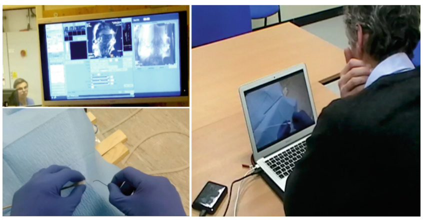

Fig. 3 *Top-left* MRI screenshot of an angiography. *Bottom-left* radiologist's hands from his first-person perspective dealing with a catheter. *Right* radiologist observing his own first-person perspective video while his running commentary explaining what he does is recorded

first-person perspective of the clinician. Two additional external, wall-mounted, cameras recorded the sessions from different angles in third-person perspective.

Data analysis: The post-intervention data analysis was based on a retrospective protocol analysis [10] with semi-structured interviews with the clinicians participating in the experiments. The interviews consisted in letting participants watched and listened their own intervention in first-person. Participants' comments describing the situations observed in the video were audio recorded. Participants answered questions made by the interviewees during and after the video visualization. Their answers were also recorded.

2.3 Immersion

Instant Ageing workshop. A workshop designed to immerse participants in the physical limitations of ageing. Participants were users and designers of technology, generally unaware of such limitations. Participants comprised policy makers, academics, educationalists, health professionals, formal and informal health carers, politicians and members of the general public. Ages ranged 18- to 70-year-old. The workshop has been carried out across four EU countries, UK, Spain, Netherlands and Norway, with more than a 100 participants. The 'Instant Ageing Lab' is an active enquiry approach to learning where students literally see and feel the experience of slight loss related to ageing. Central to the practical, is a managed introduction of sight loss simulation spectacles to participants; followed by further age related sensory losses such as hearing and touch sensitivity reduction using ear-plugs and gloves respectively. Using simple role-play and day-to-day tasks, the participants gradually experience the ageing process first-hand, through 5 different stages. In "Your most precious Sense", participants are invited to freely choose the sense they would least like to lose and say why. In "Instant Ageing—Vision", participants wear a pair of spectacles that recreates a clinical eye condition (e.g., glaucoma, diabetic retinopathy, cataracts). In "Instant Ageing—Touch", participants wear gloves and surround their fingers with elastic bands to simulate the restriction in manual dexterity created by arthritis. In "Instant Ageing—Hearing", participants wear earplugs to simulate hearing loss. In "Challenges of Daily Life", participants perform daily routines such as using a phone to make a call, send a text message or paying an exact amount of cash that requires the use of coins and notes. Participants perform these tasks wearing the spectacles, gloves with elastic bands and earplugs (see Fig. 4).

Tapology. (see above for a complete description): The designers of the mobile application used a special pair of spectacles that recreated the macular degeneration; the also recruited members of the public played games and learned about Age-Related Macular Degeneration (AMD) and wider issues of ageing. Participants wore low-vision sight simulation spectacles and were invited to consider the implications of this view point on the interactions required with smartphone and tablet technology.

Fig. 4 Example of experiences generated when participating in the Instant Ageing Lab. Low Vision Sim Specs induce characteristic close up viewing of display screens (*Top*) and keyboards (*Bottom Left*). Arthritis Gloves induce labored manual handling and reduced dexterity (*Top Right* and *Bottom Right*)

3 Results

The results are divided into the 3 methodologies/techniques for ease of reading. Results are subsequently separated by role, user and designer, inside each category.

3.1 Co-design

The following results refer to the three research projects that used co-design as part of their methodology: *Scottish Environment Web* and *Tapology*.

User

1. Simultaneous exploration: Co-design allowed exploring use in context simultaneously with other users. This helped to address the problem when the technology is designed with one user group (e.g., patient) in mind but later is used by additional user groups (e.g., relatives) not included in the design.
2. Technology-free environment: Co-design promoted users thinking of their needs without the constraint of current or known technology. Users did not have to be familiar with the technology available in the market to be able to express their preferences and needs.
3. User Creative Innovation: Co-design encouraged users using imagination to create new possibilities, which may open out into innovation coming from users.
4. Problem-solving scenario to stimulate participation: Co-design may make use of current problems to compel users to explore new ways of using technology. The SEWeb project was particularly useful in this respect making a diverse spectrum of users realise the problem of finding environmental information in the Internet. This problem-solving scenario made users aware of the potential benefit of a solution to the problem, which stimulated their participation in the later co-design session.

5. User ownership: Co-design may lead to an intangible benefit for the user-designer tandem: user ownership. It was observed in numerous occasions that error tolerance and overall satisfaction was higher than expected among the end-users who participated in the co-design sessions. This was due to their feeling of ownership [0] towards such solution, that in many cases led to word-by-mouth communication and spread of the work, literally described by participants as "theirs".

Designer

6. Voicing end-user needs: Designers had the chance to directly listen from users the description of their needs; this saved the difficulty to designers of having to imagine by themselves.
7. Requirements elicitation against multiple user groups: Co-design exposed user requirements to the open scrutiny to designers and to more than one user group simultaneously. The designer could ascertain how the requirements of one group can benefit, intersect or interfere with other user groups.
8. User needs selection and prioritisation: Designers are a privileged observer of how users select their most important needs. Time limitation (45–60 min) for the preparation of groups' presentations encourages careful selection and prioritisation of needs.
9. Users as designers: Designers are replaced of creating first non-functional prototypes, resulting in a more accurate version of addressing user needs that was made by users through co-design session.
10. Reference material for design: There are tangible material (props) and meaningful information (audio-video recordings) as result of the co-design. This material and information is valuable for developers when implementing the ensuing functional prototype.
11. User ownership eases design: User ownership became an incentive that ease designers' prospective technology refinements and user test recruitment.

3.2 Perspective Taking

The following results refer to the perspective taking technique used in the project "First-person perspective retrospective analysis through user experience" [11], made in collaboration with professional radiologists in a clinical operation theatre.

User

1. Own error detection: Watching a video in first-person perspective of their own actions allowed radiologists realised their own errors, unknown until then.
2. Learning from errors: The visualisation of errors made it easier to learn from them, thus improving the intervention.

3. Tacit knowledge explained: When asked for specific actions related to their tacit knowledge, radiologists were able to explain with the aid of showing them on the video and explaining why they were performed in that way and/or at that moment.
4. Perspective change on user interface design (UID): Radiologists found out that being a user for one day and seeing themselves afterwards changed their perspective of the impact that UID can have in clinical environments.
5. "Games are not for me": Age-related patients initially thought that games were not for them. When they were asked whether they played 'Scrabble' (a game to create words by individually joining letters on a board), many of them replied positively and then started to become more open about the possibility of playing games on a mobile device.

Designer

6. Access to user visual perspective: The first-person perspective allowed designers to have a privileged viewpoint of how the user performed actions and interacted within the environment. In addition, user oral explanations that accompanied the videos gave an understanding of the importance of sequence of actions, errors and time.
7. Learning tool for novices: The material collected through the experiment sessions were considered by the radiologists a primary source for learning tools for radiology students. The video explanations would allow a new student firstly to observe in first person the behaviour of an expert and second learn why, how and when the actions should be performed in a clinical theatre during an intervention.

3.3 Immersion

The following results refer to the immersion technique used in the *Instant Ageing* workshops and the development of a mobile game for macular degeneration patients called *Tapology* [12]. In this case, 'user' refers to the participants of the workshops who did not have any age-related impairment neither designed technology. In the case of the mobile game development, the term referred to participants who had AMD, or to a patient's relative or carer. The term 'designer' referred to the participants of the workshops that designed technology. In the case of the mobile game, the term referred to the technology designers in charge of its development.

User:

1. Raise awareness: The workshops raised awareness among participants of what were the barriers faced by age-related impaired users when using technology. For instance, rheumatoid arthritis in the fingers could make gestures difficult;

lack of contrast and a too-small font size could make the interface unreadable by visually impaired; audio feedback should be distinguishable for hearing impaired users.
2. Speech processing: The rate of presentation of information needs to be regulated to account for differential abilities to process and respond to information. This can be achieved by responsive software that responds dynamically to reductions in response rate. It can also become a user selected item.
3. Empathic Design: In game-play designed for conventional video games, it is quite common for players to 'die' (i.e., a game sequence ends) if they fail a task enough times. For example, if three items in a row are missed, the level might end and play restarted at the beginning. This level of gameplay can be quite demoralising for older users, who are inclined to give up. Accordingly, the game can continue for a pre-set time instead and the player can continue to accumulate hits. The misses can accrue but not have severe penalties attached to them like cessation of play.

Designer:

4. Redefining UID: Designers were able to experience in first-person the impediments that age-related impaired users and AMD patients face when using technology. In particular, an adequate application of the concepts of contrast, size, user feedback and less cognitively demanding steps to help users in their way of achieving their goals.
5. Abilities of impaired and disabled users: Designers realised of the different coping strategies developed to be able to use technology. For instance, the importance of peripheral vision in how AMD patients developed the skill of seeing through their corner of their eye, instead of looking directly to elements on the screen.

4 Discussion

Three approaches to design applied throughout a number of research projects with tangible results have been presented. The results have shown the central role of 'user' and 'designer' in their participation, immersion and perspective taken to build user-driven solutions. These results are discussed in the following subsections.

4.1 Co-design

The facilitated co-design methodology served as an effective instrument of bringing user as key participants of the design process. Moreover, designers had the benefit of directly seeing and hearing how users expressed their needs, selected and presented them in a meaningful way, without the constraints of unfamiliarity with current technology. In addition, the outcome of co-design sessions led to a conceptual level prototype that served as a meaningful platform from which to start the full product design and implementation.

The role of the facilitator should not be underestimated, they are responsible for rapport building, establishing ground rules, defining scope and keeping the work to schedule. The format of their questioning methodology relies on a well-established technique in Cognitive Psychology [13] and Investigative Interviewing [9], namely the preference for open prompt questions or challenges rather than closed questions or leading questions. The avoidance of any method of priming the participant in one direction or the other, or giving the participant clues as to the preference or intention of the facilitator leads to better use of memory and internal process rather than tempting them to recognize options suggested by the facilitator.

A pilot of a co-design session is advised prior to the definitive session to adjust the right balance between times and tasks. To avoid incomplete tasks and unnecessary pressure on users, at least 45 min is advised, to challenge users to select the most important needs. Designers are privileged observers of the discussion between user groups about their needs (and the processes of sorting and filtering out the most important ones). Plentiful appropriate creative materials are essential; items such as papers, pens, Post It™pads, etc. are drivers of creativity. Users explain in their own words (audio) and hands (using props) what they want. The creation of these materials and the fact of having the opportunity to describe them develop a sense of ownership that positively influenced the design and dissemination processes, resulting in the evolution of quotes that expressed such benefit, from “Technology is not for us” to “This technology is ours”.

Co-design encouraged users’ imagination to create new possibilities, which may open out into innovation opportunities that come from users. The higher degree of user contribution in co-design may contribute to unfold new technology innovations invisible to designer’s eye accustomed to a slower and, at times, lack of user-driven innovations in the technology market.

4.2 *Perspective Taking*

Cued-retrospective [11] analysis using a first-person perspective was a useful technique for two reasons: firstly to directly visualise the field of action; secondly to meaningfully gather information through questions related to the actions that only the participant recorded could know and answer. Experts (i.e., radiologists) detected unknown errors. They recognised the source of error and learned from them to avoid repeating it in the future. Moreover, they were able to explain some actions related to their tacit knowledge in a more practical way than “in situ” while the action was in course. Importantly, the recorded material was designated as potential source for learning tool for radiology students. Finally, users (radiologists) realised the importance of UID, visualisation and technology inside the operation theatre, as well as the adequate introduction of the technology into existing clinical workflows in order to empower the knowledge of the physician with the advantages of technology.

4.3 Immersion

The immersion technique [0] allowed participants of the workshops to experience in first-person the physical impairments due to age. This immersion had an effective lasting effect of raising the awareness among participants, who usually changed their mind about the difficulties that a person faces when using technology. Moreover, these limitations were understood as impediments beyond technology use: existing in daily life and affecting routine actions, such as paying a bus fare with coins, or reading the pedestrian signs on the street. The technique also benefited designers, who were able to experience the visual reality that AMD patients face when using technology. They started to pay special attention to find the adequate contrast, size and user feedback mechanisms for these users. In addition, less cognitively demanding screens were designed to help users to make the right choice without difficulty and effort. Finally, the coping strategies used by these users guided designers in the implementation of UI elements that move across the screen, where users could practice their peripheral vision to perceive such elements.

5 Conclusion and Future Work

This paper has presented research aimed at solving the problems that occur: (1) when designers try to imagine what user needs while working in their studio (disconnected from the real scenarios of use); (2) while users are unaware of what are the possibilities and benefits of using technology solutions designed by end-users. The three distinctive approaches of *co-design*, *perspective taking* and *immersion* provided a critical understanding of the counterpart role: designers used and users designed. Designer(s) could understand what were the user needs explained by users, experienced what were their physical differences and how and when users look at the surroundings when interacting with the environment. In addition, users could understand the challenges associated with designing for people with diverse physical needs, how to look at technology from a creative perspective, and how to build a sense of ownership with the technological solution. All these findings would not have been possible without the active contribution of both, ‘user’ and ‘designer’, in the creative design and evaluation stages. It was the understanding of the peer’s role (user and designer), needs and perspective that enhanced the user’s participation and inclusion of their needs.

Future work should explore in depth and in different contexts the methodologies and techniques employed in this research. For instance, user innovation through co-design offers an incentive for user participation in the market of technology development. Regarding perspective taking, to explore the potential of using the material recorded to create learning tools where experts learn from novice's behaviours, which has been explored in other areas of Psychology [14]. Finally, study the immersion technique as an instrument to experience the different degrees of an impairment and disability, contributing to the inclusion and acceptance of impaired and disabled people in design, science and life.

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Conflict of Interest The authors declare no conflict of interests with the participants, companies and institutions mentioned in the paper.

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Ask Yourself the Right Question. To Know and Understand the Beauty of Human Diversity It Is the First Design Step: A Design for All Structured and Autopoietic Tool

Avril Accolla and Luigi Bandini Buti

Abstract The authors discuss the characteristics of a possible way of approaching the complexity of Human Diversity for the purpose of design, implementation and communication, within the cultural framework of inclusive and participatory design; a way which they have experimented and tested, during the European development of the theme "Active Aging", with a quite diverse cluster of actors which has been created to represent the abilities-necessities-aspirations of the elderly and the various parties involved in the construction and management of housing for the elderly. The authors, after years of practice, were also interested in understanding why some actors are not using the vast work produced worldwide in the field in the lasts decades nor are they familiar with it, and focused on building an easy multilevel approach, in which each level bears its own efficacy, in the attempt to engage those who might be interested but, for various reasons, are not on board yet.

Keywords Design for all · Holistic ergonomics · Co-design research · Human factors design · Human diversity · Participatory design · Inclusive design

1 Ask Yourself the Right Question

The Authors have focused on building an easy multilevel Design for All qualitative approach, in which each level bears its own efficacy, to start to navigate and to understand the complexity of Human Diversity for the design practice. Also in the attempt to engage those who might be interested in the participatory design but, for

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various reasons (such as sediment habits, inaccessibility, background work practices, etc.) are not yet experiencing it, they kept it as simple and easy to refer to as possible.

1.1 Asking as a First Design Step

Design for All, design for human diversity, social inclusion and equality, [EIDD Stockholm Declaration© 2004] is a way of addressing design processes. DfA highlights that ethics can work and be business-oriented and that Human Diversity creates a complexity in the societies worldwide which nature is continuously re-shaping. While attributing to design and designers a great social, environmental and economic responsibility, Design for All (DfA) goes through it with a positive, proactive and integrating approach.

In this context the authors introduced Design for All as a way to embrace the randomness generated by questioning, and suggest that the creative professional can benefit from acquiring the capability to navigate, rather than oppose, the uncertainty [1], being able of provoking change, observe the behaviours, consider which are usual stereotypes and try to anatomize them to be able to compose their elements in a different way to initiate a positively proactive effect.

This approach to change, behaviours and stereotypes, can be a game changer in areas with a strong inertia like, for example, the care and management of the elderly, were a consolidated approach to medical data and established answers can be reassuring and particularly comforting, so restraining future development and preventing innovative changes.

Therefore asking is a first creative design step, which needs a strategic overview and can lead, according to the different design process phases, to understand the theme in its globality, as well as to deepen the motives for the objective setting, to know the relevance for the project of specific actors in the value chain, and so on. Setting the questions is, within the design process, a multilevel activity: it is a way to approach strategically the design brief, as well as the concept creation and the implementation phases.

Some questions seems without a possible answer, dealing with inconsistent or contradictory themes (like a convenient tiny mobile with big comfortable buttons), but often these are the places to find relevant reasons for innovation. It is particularly relevant for understanding the importance of both the formulation of the questions and their quality, this discussion on the comparison between incremental and radical innovation: [2]

> …human-centered design, with its emphasis on iterated observation, ideation, and testing is ideally suited for incremental innovation and unlikely to lead to radical innovation. Radical innovation comes from changes in either technology or meaning. Technology-driven innovation often comes from inventors and tinkerers. Meaning-driven innovation, however, has the potential to be driven through design research, but only if the research addresses fundamental questions of new meanings and their interpretation.

1.2 The Right Question

Gathering relevant information it is both difficult and complex, and since insight and goodwill are not enough, the various actors, designers and non-designers, can benefit from a process' guide which is easy to use, intrinsically customizable, looks simple but bears the needed complexity without the complication.

"Ask yourself the right question" starts from the understanding that gathering relevant information on the Abilities, Necessities, Aspirations and dreams (A.N.A.s) of all the actors in the value chain is essential for satisfactory design solutions (Fig. 1), and that design thinking provides a holistic approach in meeting people's needs and desires in a technologically feasible and strategically viable way in the market [3].

In a design process speculative acts of knowledge serve as actions aimed at achieving objectives. When organized through simplicity, they can direct design activities in their goals and purposes. [4].

The authors suggest a process (Fig. 1) which distinguishes strongly between the wording of the questions and the acquisition of the answers: this helps simplifying and organizing, therefore managing creatively the complexity of the data gathering. Highlighting the questions helps also in structuring the strategy behind them and keeping the process consistent with the established objectives while allowing it to stay open to unexpected discoveries.

The complexity of societies and markets requests and expects a constantly increasing quality of processed data; for example the discussion on the individual

Fig. 1 The infographic illustrate the authors' vision of the 3 areas in which the designer operates and the critical relations between them

characteristics that influence design choices, have gone from the knowledge of the necessities, abilities and comfort of the body (physical ergonomics) to those of the body and mind as a whole (holistic ergonomics) to the necessities, abilities and aspirations of the human diversity and its satisfaction (Design for All). Both the single professional/researcher (impossibility to have deep knowledge on everything) and the multidisciplinary groups (risk for juxtaposition of deeply specialized knowledges with lack of holistic synergies) can benefit from a praxis that is quite simple, but can easily adapt to increasing complexity.

1.3 Finding a Satisfying Answer

The answers, drawn from the vastness of information, asking subjects, consulting the literature, and involving experts, will give a mass of knowledge, often contradictory and inconsistent, whose critical reading will lead the designers to make creative decisions, which are their contribution at this process' stage. There's no *right answer* per se in the structured and aware creative process of choosing: finding a balance between the beautiful simplicity expected from the design and the

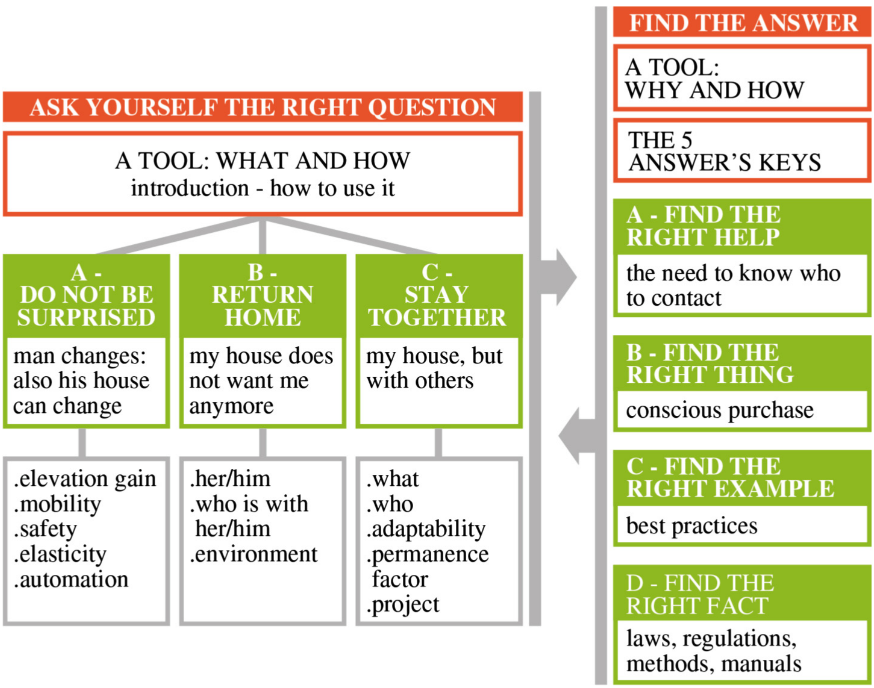

Fig. 2 The infographic illustrate the authors' implementation of the discussed approach in the field of housing for the elderly. Overall map of ask yourself the right question and find the answer

complexity of the functions it offers, is the creative contribution needed, because few elements can be much better then many elements [5].

The complexity of the diverse value chains which may be relevant for a specific project can heavily influence the design process and can be dealt with the awareness of the role of the network itself [6, 7].

Grouping the answers according to both the result to be obtained and the method to find them (Figs. 2 and 3) has proofed to reduce the perception of unmanageable complexity and amount of data and it made it easier to self-navigate and organize the data.

Another grouping that has been found helpful, especially during the pilot project "Fatto Apposta", is a classification of the answers according to the level of difficulty—specific cultural and scientific filters required—that their understanding requires, for example: directly implementable and non-specialized both quantitative and qualitative, conceptual which require trans-disciplinarily and critical elaboration, specialized/expert which require to have the knowledge/awareness to be able to recognize the need to acquire such answers.

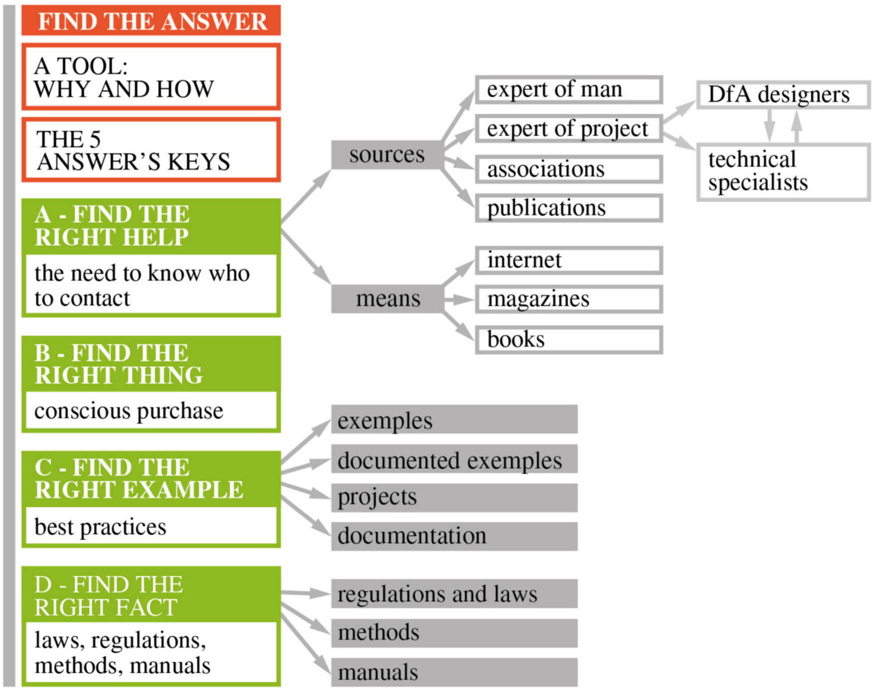

Fig. 3 The infographic illustrate the authors' implementation of the discussed approach in the field of housing for the elderly. Section: find the answer

2 Experimenting, Co-creating and Testing

During the European development of the theme “Active Aging”, the authors have experimented and tested “Ask yourself the right question” to manage the complexity of teaching a holistic approach to and sharing information with decision makers, elders represented by associations supporting them, designers (engineers, architects and surveyors), clinicians and other health care professionals, and makers (contractors, installers, maintainers), i.e. all parties involved in the construction and management of housing for the elderly.

2.1 The Pilot “Fatto Apposta”

Confartigianato Vicenza (the local Association of Artisan SMEs in the Italian town Vicenza), facing Italy as one of the oldest countries in the world when it comes to the progressive aging of population, and having evaluated the impact of that on the local community (housing, health facilities, care services, etc.), wanted to start a proactive plan for a positive change of the status quo of the management of the elderly. Three sections were involved: Home System, Young Entrepreneurs, Elderly and Retired.

Confartigianato Vicenza teamed up with Azienda ULSS 6 Vicenza (the local Public Corporation for Social and Health Services) which had similar concerns and goals.

The authors, invited to design a model of intervention for the actors of the local community, proposed to the decision makers to co-designed a co-learning experience for housing for All, expanding the concept of the old person in elderly’s family and friends, their social relations, and also the ones to be old in the future.

The projection in time holds a strong relevance in design as such, and maybe even more when there is a focus on the elderly and Human Diversity, where habits, culture and the unknown to come, play such an important role. For example a person lives differently the time that goes by if her future comes to her or she goes to the future [8].

and the perception of oneself in the life span drastically changes if to be faced in front of us is perceived to be the unknown future or on the contrary the near past with progressively fading far away memories [9].

The designed common goal was to help the local actors to have an innovative learning experience on aging that could also provide the participants with practical and effective tooling and knowledge which, applied, could enhance the quality and effectiveness of participants’ impact in the elderly housing area of activities with a for All holistic perspective. These tooling should incorporate also the experience with the elderly in the various professional fields of the local actors.

The Pilot Project was named “Fatto Apposta” (customized and on purpose) and it lasted one year and a half.

Various other decision makers, influencer and stake holders were involved with different roles in the project: Vicenza Chamber of Commerce, the association

Design for All Italia, local professional associations of Architects, Young Architects, Surveyors, the local association for the Assistance to the Elderly.

All sessions/meetings welcomed a strong group which had quite diverse backgrounds, experiences, praxis and opinions. The people in the group were invited to participate, learn, share their professional experience and understanding on the housing for the elderly and eventually to co-design with the authors the further development and the very specific implementation of "Ask yourself the right question" into the Pilot for "Fatto Apposta".

The participants were grouped differently during the sessions according to the activities: no groups, cross-disciplinary groups, professional cluster groups.

Seeing and comparing the quite specific and technical visions of each profession on a given subject has helped the participants to get out from their own daily work routine and to be able to relate to the other actors in the housing for the elderly field. Working together cross-disciplinary has shown them the effectiveness of the synergy. For example in Fig. 4 is recorded an activity on how do the different professional clusters perceive the Abilities—Necessities—Aspirations of the elderly and who's around them.

The actors in the group were:

- Confartigianato Vicenza Officials, from the three sections involved Home System, Young Entrepreneurs, Elderly and Retired.
- elderly representatives and health care professionals (physicians, geriatricians, occupational therapists, health-social workers, health facilities managers)
- designers (architects, surveyors, interior designers, engineers)
- builders, contractors, installers, maintainers

2.2 *The Feedbacks and Results*

From the experience of decades of practice, rooted in the inclusive design culture, the authors take the opportunity of the pilot project "Fatto Apposta" also to investigate the reasons why, though separately the different actors and stakeholders

Fig. 4 Professional cluster group activity: how do the different professional clusters perceive the abilities—necessities—aspirations of the elderly and who's around them?

held, if not an holistic approach, a sound knowledge in their specific field, the set of actions done for the elderly both in the private and public sector (buildings, renovations, services, healthcare, products), regardless of the amount of money invested, often was not answering to the needs, abilities and aspirations of the elderly, their families and their social relations.

Among the collected feedbacks, stood out the necessity for the makers (contractors, installers, maintainers) to have a new way to communicate and convey the effectiveness and advantages of the holistic approach to their clients, so that to be able to do a better job and selling its competitive advantage.

The longed need for the elderly to have their dreams and aspirations tackled as well as the enabling management of their social relations (family, friends, work related relations) came out in the private rejuvenating projects as strongly as in the public/shared housing ones.

The lack of a multidisciplinary group/platform for discussion, comparisons, work sharing, getting to know other actors and professionals with similar goals, has been enucleated as one relevant obstacle to an effective holistic implementation.

Recognizing the competitive advantage of the Design for All approach on the market, Confartigianato Vicenza accredited, at the end of the experience, the participants as "innovators and socially responsible" creating a business group of actors for a positive change.

The participants themselves, with the support of the decision makers, created a common platform for the above-mentioned purposes.

Some of the participants, as a result of the interactions in the meetings, teamed up in their professional daily life as cross-discipline groups.

2.3 Communication and Diffusion

At Lanificio Conte, Schio was held an event "Prove Tecniche di Futuro" (Future Technical Tests) to: (Fig. 5)

Fig. 5 *At left* the presentation event of Fatto Apposta. *At right* "Quaderno 1—Fatto Apposta—Guida allápproccio di Design for All" edited by Confartigiananto Vicenza, 2014

- communicate the whole project in its motives, participants, process and results;
- distribute the two “Quaderni Fatto Apposta”. (1) Guida all’approccio Design for All. (2) Progetto per l’abitare del futuro” (Customized and On Purpose. (1) Guide to Design for All approach. (2) Design for future living.) a publication about the Design for All approach, the project Fatto Apposta, the method “Ask Yourself the Right Question” and the co-designed tools for it.

The publication has been distributed for communication and diffusion purposes.

Also it has given to the participants as a co-designed guide to the new approach experienced during the project for their daily practice.

3 Conclusions

Within the design research and practice in the areas of participatory approaches and methods for design, the authors propose a model for the convergence and dialogue of many very different knowledges and work praxis, a tool for communication with both the business partners and the receivers of the service, a structured guide for acquiring data and processing them through interviews in qualitative research which brings awareness of the holistic approach to both parties.

The methodology allowed to include in the design briefing lifestyles and dreams with the same relevance of necessities and abilities.

Also the feedback from the participants in their daily practice shows a positive change in action, ranging from “I’ve changed the way I conceive my profession”, “I’ve changed the way I look at people/clients/patients”, “I see the potential impact of my role and I can manage it more cunningly now”, “I’ve got a better idea of how to communicate with my clients now and what to tell them, but still I’m not sure they are really listening to me nor believing me”, “Asking has become an aware action and, even though I do not use all the levels in the guide, it became kind of natural the distinction between designing the question and trying to listen to the answer”.

Among the extremely motivated and participative health care professionals, all the clinicians were satisfied of the other participants’ development and they gladly share their knowledge, but some didn’t perceive a motive to evaluate their perspective.

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User Knowledge Creation in Universal Design Processes

Elke Ielegems, Jasmien Herssens and Jan Vanrie

Abstract Besides the need for designers to build a strong body of user knowledge within the domain of Universal Design (UD), linking knowledge about user needs and design practice is fundamental for increasing its uptake. Designers often experience difficulties when transferring user needs into inclusive design solutions. The tacit nature of user needs considerably complicates this transfer. Therefore, this paper examines how designers may create and apply knowledge on UD. Concepts from Knowledge Management are used to shed new light on designers' knowledge creation process about user needs. By relating UD processes to Nonaka's SECI model, an analytic framework is proposed in which four modes of developing knowledge enable us to analyse the continuous dialogue between tacit and explicit knowledge from user to designer. As such, this paper explores to which extent the SECI model offers interesting insights into designers' knowledge creation process on user needs.

Keywords Communication · Tacit and explicit knowledge · SECI model · Knowledge creation · Architecture · Design process · Universal design · Inclusive design · Design for all

1 Introduction

Theoretical and empirical research on Universal Design (UD) is exponentially growing. Demographic changes and design innovation require an increasing amount of knowledge about user needs. According to Dong and colleagues [1],

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understanding end-users from different perspectives is one of two research areas within the user knowledge base of UD. The other area aims at understanding the information needs of knowledge users promoting or creating UD solutions, such as designers, policy makers, etc. However, in design practice there is still a gap between these two areas: when translating user needs into design solutions throughout a UD process, in many cases designers' existing design knowledge does not sufficiently include the aspect of user needs [2]. In other words, there is a gap between designers' knowledge about user needs and their design knowledge. This paper therefore reflects on different modes of creating knowledge about user needs in a UD process.

Various scholars have already suggested that concepts on knowledge creation in business can provide interesting links with creative disciplines, such as design or art [e.g. 3–6]. By introducing concepts from Knowledge Management (KM), we want to propose an analytical framework to investigate designers' actual knowledge creation in the context of UD. Inspired by Nonaka's knowledge creation theory [7], this paper adapts the SECI model to study how designers' knowledge creation process on user needs may affect UD processes. Although the concepts discussed in this paper are applicable and relevant to various design domains, we focus on the built environment.

The first section of this paper defines the concept of user needs and knowledge creation in the context of UD. Both sections two and three elaborate on Nonaka's SECI model in order to link user knowledge to design practice as a continuous dialogue between tacit and explicit knowledge.

2 User Needs and Knowledge in a Universal Design Context

2.1 *Translating User Needs into Design Solutions Throughout Universal Design*ing

Universal Design (UD), Inclusive Design (ID) and Design for All (DfA) are synonyms all aiming "*at elegant, usable and sustainable design solutions for products, services and environments, so that users are supported in their actions and experiences and that the design can be used to the greatest extent possible by everyone*" [8]. UD is considered as a design strategy throughout the design stages rather than an objective or end-result [9, 10]. This way, the process of Universal Design*ing* is emphasised as a non-stop design and building process with continuous user feedback [11]. Importantly, when applying UD as a design strategy, it is generally considered fundamental that user needs are taken into account in the design process from the earliest stages of designing [e.g. 10, 12, 13]. Choices made at the beginning may have significant consequences on possibilities later on in the process [12, 14].

Thus, how do architects acquire knowledge about user needs? Kirkeby [12] specifies that architects generally use a rich variety of different sources throughout the design process, ranging from rule-based knowledge and facts to good examples and concepts. User needs can be transferred to designers through direct user involvement, such as focus groups and workshops, or through indirect involvement utilising, for example, academic papers and checklists. Each of these approaches has advantages and as well as limitations and it is important that designers select methods fitting their own design approach. Moreover, the chosen methods need to provide designers with the expected knowledge outcome in order to be usable throughout the design process [15]. First, however, we need to address the epistemological and ontological foundations of this question: how do we define knowledge and how do we interpret the concept of user needs?

2.2 Defining User Knowledge Creation for UD

In this paper, the term *knowledge* is deliberately used in contrast to *information* or *data*. Although the terms information and knowledge are often intertwined, a clear distinction is visible [7]. Bender and Fish [16] schematically visualised knowledge in relation to data, information and expertise in a hierarchical structure. *Data* are raw numbers or facts with no context or judgement attached to it. For example, minimum sizes for a toilet usable by all can be considered as raw user data. This raw material becomes *information* when it is given meaning and purpose [16]. In contrast to data, information may convince, describe, challenge, move, etc. If the minimum sizes of the toilet would be illustrated in a sketch showing a possible toilet setting (such as in an educational flyer), this may be considered as information about user needs. Next, information can turn into 'knowledge' when it is interpreted and related to a context by its holder [7]. Knowledge will be created when integrating information with what we already know, or in other words: "*It is information interpreted by the individual and applied to the purpose for which it is needed*" [17]. For example, when a spatial expert and a layperson are reading the same book, different knowledge may be generated. Although the original information is similar, their background, experience and interpretation would be different [18].

Knowledge is understood in a broad sense of the word, including not only facts and rule-based knowledge, but also intuitive and experience-based kinds of knowledge that can generate true understanding of user needs. Finally, gaining 'expertise' is placed on top of the hierarchy. The difference between knowledge and expertise can be found in the depth of knowledge: Knowledge becomes expertise in a specific field when it is enriched by long-time experience, education and training [19].

In general, when relating these concepts to the field of UD, merely collecting data on user needs is not enough to cope with the challenges of designing inclusive environments. It does not give sufficient meaning to truly understand the lives of real people [20]. Designers need to be able to actively interpret this user data or information in order to gain *personal knowledge* that can be integrated in specific design situations [21]. We can illustrate this with our example of the toilet: When designers have sufficient expertise and truly understand why some users need extra space and how they make use of the toilet settings, they are able to effectively transfer this knowledge into other toilet designs suited for all. However, when designers do not fully comprehend the underlying principles, they might design a toilet, which is still useless for some users despite having applied the right minimum measurements.

Thus, in addition to user data and information, designers require *knowledge* to appropriately address user needs in UD. This way, they can understand the underlying reasoning and qualitatively embed the acquired user information in a descriptive way in daily design practice [22]: "*Knowledge on people is essential in order to come up with informed and inspired design interventions*" [23].

2.3 The Tacit Nature of User Needs

Having discussed the concept of user knowledge creation, we now focus on the concept of *user needs*. In this paper, the term user needs is to be interpreted in its broadest sense. It concerns all aspects that are potentially required for users to fully develop themselves in the built environment. These needs do not only address primary physical needs (e.g. accessibility), but also other needs, such as social needs or needs to enable personal growth [24]. User needs are not perceived as the needs of one person, but as those of the widest diversity of people, with and without disabilities.

Having identified user needs, it should be noted that only a relatively small percentage of user needs exists out of explicit knowledge that is easily articulated and written down in checklists, guidelines or regulations. The main body of user needs is tacit by nature. Whereas explicit knowledge is easy to verbalise, tacit knowledge is much more difficult to capture or communicate [7]. For example, you can easily describe how your bicycle looks like, but it is much more difficult to explain how to ride that bicycle. The former is defined as explicit knowledge, whereas the latter is tacit knowledge. Tacit knowledge is more intuitive, unarticulated by nature [25] and deeply rooted in our actions, crafts and skills [7]. Polanyi [25] accurately phrases tacit knowledge as follows: "*We know more than we can tell*". The knowing is in the action itself by "*intelligently doing something in an intuitive manner*" [26].

O'Shea [27] confirms the difficulty within the domain of UD to express all tacit, hard to describe qualities of building experience, which are nevertheless of fundamental importance to designing inclusive environments. For example, describing sensory qualities, which are mainly tacit by nature, is usually very difficult, nevertheless, they are decisive to make buildings more usable and enjoyable for all users by allowing a more fully multisensory experience [28].

Thus, whereas stated earlier that designers need genuine *knowledge* about user needs in order to make well considered design decisions, we in fact need to go one step further. In order to create inclusive environments, it will be of utmost importance that designers are able to develop *tacit as well as explicit knowledge* about user needs. Indeed, architects face a huge challenge to capture tacit as well as explicit types of user needs, to genuinely understand them and, moreover, to adequately translate them into design. However, a different approach is generally necessary when eliciting tacit user needs in contrast to explicit user needs and it is not always clear for designers how to manage this throughout the design process [15]. It is precisely this complex process of creating user knowledge by designers that we want to clarify and facilitate. In order to gain more insight into this user knowledge creation process, we propose to apply a model developed in KM, which we will describe next.

3 SECI Model

3.1 Introducing the Model

A theory regarding knowledge creation and conversion, originally developed by Nonaka [7], is generally known as the SECI model. Although it is not a recent model, it still proves to be very influential in its field of research and beyond [17, 29]. It was developed within the domain of KM, but since then it has also been used in various research domains to empirically and theoretically gain more insight in the nature of knowledge flows [30]. Here, we explore its potential to shed new light on how designers may create knowledge about user needs throughout UD processes.

Originally developed to gain more insight in how organisations gain new knowledge and how this process may be managed more effectively, the model considers knowledge creation as a dynamic human process related to human action. This process is created through a "*continuous dialogue between tacit and explicit knowledge*" [7]. The interaction between tacit and explicit knowledge covers four different modes in which existing knowledge can be transformed into new knowledge [7]. They are identified in the SECI model as the modes socialisation (S), externalisation (E), combination (C) and internalisation (I).

Socialisation	→	tacit knowledge *to* tacit knowledge
Externalisation	→	tacit knowledge *to* explicit knowledge
Combination	→	explicit knowledge *to* explicit knowledge
Internalisation	→	explicit knowledge *to* tacit knowledge

Whereas the mode 'socialisation' focuses on converting tacit knowledge into tacit knowledge through shared experiences, 'externalisation' elicits explicit from tacit knowledge by creating a meaningful dialogue with users. The mode ‘combination’ exchanges and combines explicit knowledge and ‘internalisation’ converts explicit into tacit knowledge, which is addressed by Nonaka as a more traditional learning process. While each of the four modes can create knowledge independently, the model aims at visualising dynamic interaction between different modes of knowledge conversion [7]. Nonaka visualises this interaction as a linear process, more specifically as a spiral, involving all four modes subsequently. He differentiates multiple levels through which knowledge is created: from individual to inter-organisational level. All knowledge is first developed on an individual micro level in the minds of people before this knowledge can take form on a collective macro level. Clearly, it will be important for increasing the general uptake of UD that this knowledge is indeed becoming widespread throughout all these levels and it would be interesting to also take these levels into account. However, this paper will only focus on the individual, being the practicing architect, in the framework of a UD process.

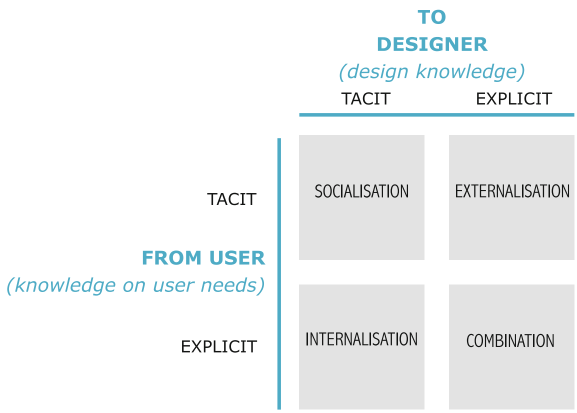
3.2 Knowledge Creation Theory Within Design

In the disciplines of art and design, the SECI model has already received some authors’ attention for its interesting commonalities [e.g. 3, 4, 31–33], although it has not been explicitly used as an analytical framework in the domain of UD. Niedderer and Imani [4] have explored concepts of KM to “*better understand and build research methodologies and to integrate individual methods with regard to managing different kinds of knowledge*”. They point out that the SECI model can indeed serve as an interesting framework to manage different kinds of knowledge in design research. Evenson and Dubberly [32] have also been inspired by the interesting link between KM and design and found similarities between models of design processes and the SECI model in terms of conceiving designing as a learning process. The SECI model is linked to, for example, IDEO models and Kumar’s innovation model [32]. Indeed, the four modes of the SECI model display similarities with the steps in some design models. However, none of the existing design models elaborate on specific learning processes of designers in terms of creating tacit and explicit knowledge. We agree with Evenson and Dubberly [32] that the lens of the SECI model can potentially enrich our insights regarding the design discipline in general, but we will now focus more specifically on linking Nonaka’s knowledge creation theory to a UD process.

4 SECI Model for Universal Design

In this section, we examine the SECI model more in detail from a UD perspective. When applying UD as a design strategy, it is fundamental to continuously consider user needs throughout the design process, as mentioned earlier. The SECI model

Fig. 1 SECI model for universal design



may enable us to link knowledge about user needs to design knowledge. Moreover, the model distinguishes the transfer of tacit and explicit knowledge between source and receiver, i.e., user and designer, which, as was described earlier, is an important aspect of user needs. Four different modes can be distinguished in which designers develop knowledge in the process of trying to translate user needs into design solutions. In every mode designers can develop knowledge about user needs, but the approach or knowledge outcome may considerably differ. It is worth mentioning that the model emphasizes that it is the interaction between different modes that ultimately provides a rich source of tacit as well as explicit knowledge (in this case for designers throughout a UD process).

First, however, we need to consider the four modes separately in order to investigate their potential to better understand how knowledge can be created and how it may influence UD processes. Each mode is first described in terms of how architects may acquire knowledge in this mode. Additionally, the possible characteristics of knowledge are explained. Finally, suggestions are made about how this knowledge may affect the design process. Different examples within an architectural design process are used to illustrate these aspects in more detail (Fig. 1).

4.1 Socialisation from a UD Viewpoint: User Experiences

The mode 'socialisation' represents the process of tacit knowledge (of users) converting into tacit knowledge (of the designer). *Shared experiences* are considered to be key when acquiring tacit knowledge [7]. For example, when designers need to design a new office building, they can develop knowledge by means of investigating time in open-ended observations of employees, their working habits, organisational culture, etc. Users are not always aware of their behaviour, actions or customs and this way, some user needs could be derived, even when not explicitly communicated beforehand or given a priori attention to by designers. These experiences on site may also give architects more insight in, for example, users' *abilities*. Instead of focussing on *disabilities*, as generally occurs, users' *abilities* may inspire designers when designing enabling environments [34]. These aspects are often easier to observe than verbally communicated. This knowledge does not only enable designers to get familiar with end-users and better understand their user needs, it may also generate empathy.

Apart from experiences on site, designers may also gain knowledge by means of their personal daily experiences or by, for example, participating in do-it-yourself workshops in which disabling situations are simulated. Although simulations do not serve as a complete substitute for users' experiences, they can give designers insights in how disabilities may affect people's daily lives. This way, understanding as well as empathy may be created among designers.

Based on the examples above, it is clear that these different experiences, whether or not linked to a specific project, may affect the design process in several ways.

Next to gaining insight in sometimes less apparent user needs, which designers may not been thinking of in the first place (e.g. observing people's abilities instead of focussing on their disabilities), 'socialisation' helps to gain empathy among designers. This may result in a more attentive design attitude towards user needs, positively influencing design decisions throughout the design process, without specifically articulating. Thus, 'socialisation' is not always intentionally created, neither is its origin always clear. Although the knowledge outcome for this mode may not always answer well-defined research questions, it may help designers to take well-founded design decisions throughout the design process.

4.2 Externalisation from a UD Viewpoint: Meaningful Dialogue with Users

A second mode called 'externalisation' focuses on the transformation of tacit knowledge to explicit knowledge. Interacting with users through meaningful dialogue, i.e., talking to users and genuinely listening to them, can reveal tacit user knowledge. For example, the architect of a school may have noticed that in the existing school one playground area is very popular, whereas another area remains unoccupied. When he or she confronts children with this observation, they cannot give a specific. In such a case, there might be underlying causes which nevertheless remain tacit: the organisation of the playground; its functionality; its atmosphere, etc. Still, it would be very interesting for the architect to have an insight in these underlying reasons in order to design a new playground. By asking questions in a more systematic way the designer might be able to find out *why* children like or dislike certain areas of the playground. This explicit knowledge may then be used to frame and create suited design solutions.

Nonaka and Konno [35] identify two key aspects to elicit tacit knowledge in the mode 'externalisation': (1) the use of specific techniques or methods to elicit this knowledge and (2) the translation of tacit knowledge into understandable forms. For example, highly specialised design language is not easy to understand by non-architects and therefore not interesting to employ when designers want to acquire knowledge from users. Similarly, design artefacts (e.g. sketches, models, CAD drawings, etc.) need to be adapted when they are to be employed in conversation with users: not everyone can 'read' or 'fully understand' two-dimensional plans for example. "*Architects probably design most frequently with the plan, which is a very poor representation of the experience of moving around in a building"* [36]. Thus, when designers want to gain information from other people, they need to make sure that the (design) language as well as the (design) artefact is adapted to the people they want information from. However, design artefacts, when chosen well, are often used to stimulate interaction [37].

Thus, by creating a meaningful dialogue with users and genuinely listening to them, designers may elicit tacit user needs. The outcome for the mode 'externalisation' is not supposed to be a list with requirements, but a deeper understanding of actions or underlying principles. This affects the design process in a way that it gives architects more insight in more complex *why*- or *how*-questions. In the example of the playground, users could not immediately answer the architect's questions. He or she needed to dig deeper and interact with people in a more systematic way in order to gain understanding in its underlying causes. Actively considering these *why*- and *how*-questions throughout the design process, understanding and adequately integrating them in design solutions, may improve the overall user experience of buildings.

4.3 Combination from a UD Viewpoint: Q&A About User Needs

A third mode focuses on converting "*explicit knowledge into more complex sets of explicit knowledge*" [35]. Nonaka defines this process as 'combination'. Two groups can be identified in this mode. In the first group, explicit knowledge is created when designers communicate with different stakeholders in order to gain specific answers on specific questions. Whereas it is much more difficult in the mode 'externalisation' to elicit knowledge, here the answers are more easy to articulate. For example, specific surfaces to comfortably circulate in corridors or user needs already described in the design brief are situated in this mode. The second group consists of indirect ways to acquire knowledge about user needs, such as using checklists, guidelines or regulations. These are very explicit, generally directly related to a design, which makes them on the one hand time efficient, but on the other hand also less flexible, leaving not much room for designers' interpretation.

In sum, knowledge from the mode 'combination' affects the design process in such a way that it is very specific knowledge directly related and/or transferable to a design. This outcome is very interesting to rapidly gain knowledge about, for example, physical user needs, such as basic accessibility rules. However, it is much more difficult to make less specific user needs explicit, such as user needs facilitating personal growth [27]. Therefore, next to the interesting characteristics of knowledge created in the mode 'combination', it may not be applicable to all user needs leading to UD qualities, which are nonetheless necessary to create enabling and meaningful spaces.

4.4 Internalisation from a UD Viewpoint: Learning-by-Doing

The final mode 'internalisation' implies the process where explicit knowledge becomes tacit. Nonaka compares this to a more traditional learning process in which designers can learn-by-doing. By processing explicit knowledge through action, practice and/or reflection, it may really become knowledge of one's own [38]. For example, architects may learn from reading various books on UD. They may also learn from their own realised projects. Conducting a POE may help them to gain insight in how end-users experience the final design result. This way, knowledge can be generated for future projects by looking back at the level of inclusion of their own practice. This is learning-by-doing in its most obvious sense. Reflection-on-action [39] is fundamental in order to generate new tacit design knowledge [36].

In contrast to the other modes, it seems less evident to which extent the mode 'internalisation' affects UD processes. Learning-by-doing becomes the base for designers' new routines [32]. These developed routines are visible in the designer's actions and his or her design approach throughout the design process. Although this knowledge considerably contributes to improve the designer's UD strategy throughout the design process, their effects may be less recognisable for researchers. Thus, although in-depth UD knowledge can be acquired by combining knowledge from all four modes, knowledge developed in 'internalisation' as reflection-on-action is indispensable to embed UD as a design strategy into design processes.

5 Discussion

Four modes within the SECI model are viewed from a UD perspective, focussing on different ways in which designers can acquire knowledge about user needs. The examples given above may help to understand how every mode may be used when analysing designers' knowledge flow, however, looking at the examples from a slightly different perspective may shift them from one mode to another; For instance, in the example of the architect trying to find out why some areas of the playground remained unoccupied: if the children would have answered that, for example, a lack of benches was the main reason -and it turned out when examining this that it was indeed the true reason- the example would shift from 'externalisation' to 'combination'. Thus, all examples are influenced by specific circumstances, design approach as well as the designer's knowledge outcome. Nevertheless, this flexibility makes the models also very interesting to examine designers' highly dynamic and influential knowledge flows throughout UD processes.

Nonaka [7] argues that although "*each of the four modes of knowledge conversion can create new knowledge independently, the central theme of the model […] hinges on a dynamic interaction between the different modes*." We agree that in-depth knowledge about user needs benefits from combining different modes. Although it has become clear that every mode has its specific positive characteristics, their strength lies in combining these modes. Creating knowledge by relying on one mode is not sufficient to capture tacit as well as explicit nature of user needs.

Nonaka visualises the interaction between the four modes as a spiral, involving each mode subsequently from socialisation to internalisation [7, 35]. When linking this spiral to different levels, from individual to organisational level, this structure may be applicable. However, when focussing on the individual knowledge creation process of the designer or design team, we assume that a more nuanced answer is necessary, tailored to the individual designer. The highly individual nature of the designer's knowledge creation process may not benefit from a specific order to follow when acquiring knowledge about user needs. The model's flexibility enables to use it in any direction without a prescribed route to follow.

Moreover, the model's abstract nature, i.e., dealing with communication flows, makes it possible to use it in different design situations as well as for different time periods. For example, it can be used to analyse small design projects of individual architects working for a single client as well as complex projects of a whole design team working with different stakeholders. When considering the time aspect, a specific design stage can be analysed as well as the whole design process. These levels are interchangeable using the same model, which makes it an interesting, dynamic tool for researchers to analyse UD processes.

In sum, the model shows potential in this context, but further research will of course be required to investigate the relevance of the model as an analytical framework, i.e., how useful it is to accurately and effectively describe daily UD design processes. For example, how do the four modes relate to each other within the designer's knowledge creation process in practice? Do designers follow all four modes of the model to create new knowledge or do they focus on some of them? Case studies where UD has been used as design strategy could enable researchers to gain more insight into these issues.

6 Conclusion

The challenging task of designers aiming at using UD as design strategy is to make appropriate translations of user needs into inclusive design solutions. As user needs are less tangible and most of its knowledge is tacit by nature, it is, however, very difficult to make them understandable to designers. Moreover, collecting information on user needs is not sufficient: Designers need to acquire knowledge by interpreting and genuinely understanding explicit as well as tacit user needs. Here, Nonaka's SECI model has been introduced as an interesting model to distinguish four ways for a designer to create knowledge about user needs. Every mode of the SECI model represents a different dialogue between tacit and explicit knowledge of user and designer. Whereas 'socialisation' focuses on understanding users through shared user experience, 'internalisation' learns-by-doing to create in-depth tacit knowledge about user needs. The mode 'externalisation' focuses on creating a meaningful dialogue with people and 'combination' gives specific answers on specific questions through direct as well as indirect user contact. From exploring how these processes might function in a UD context, we conclude that these different modes are indeed relevant and that every mode of the SECI model seems to affect the design process in a different way. From providing knowledge that is directly translatable into specific design parameters (combination) to creating empathy and providing insight in less apparent user needs that may not be articulated, but could be usable in different design decisions throughout the design process (socialisation). By introducing this model as an analytical framework to further investigate UD processes, we hope to achieve a better understanding of how designers create knowledge about user needs throughout the design process. This way, a more complete picture can allow us to optimise, stimulate and facilitate UD processes.

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Light: Towards an Inclusive Perspective

Kim Janssens, Jan Vanrie, Katelijn Quartier and Stefan Danschutter

Abstract Current research was conducted to gain more insight in how staircase design can contribute in creating a safe and pleasant home environment for older adults. Participants of varying ages (from students to older adults) took part in three studies that combined experimental designs with semi-structured interviews. Renderings of a staircase were created showing different light settings in a nightly situation, from a downward view as well as from an upward view. A mockup staircase with five steps, five different lighting settings and three possible cover materials was custom built. The following specific questions were addressed: (1) which light setting for which cover material can be considered as the most clearly visible and preferred option and (2) what type of additional lighting is best suited at what illuminance level to increase depth perception in stair descent. Guidelines regarding staircase design are formulated by and for (future) interior designers.

Keywords Staircase design · Universal design · Experimental studies

1 Introduction

In 2050, 4 million Belgians will be older than 60, of which 1.25 million will be over 80 years old [1]. The growing interest in active living and healthy aging [2] entails that older adults prefer to stay as long as possible in their own homes rather than residing in care or retirements facilities [3]. However, to this point housing is generally not well-fit to grow old in [4]. Thus, there is an increasing need for guidelines towards designers for creating age-friendly, safe home environments satisfying older adults' concerns and aspirations [5].

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The current research focuses on the staircase as part of the home environment and on rethinking lighting as an aspect defining staircase design [3]. Overall, younger people can better evaluate depth on a staircase and distinguish colors more easily, even in nighttime situations but for elderly people it is not that obvious. Descending a staircase can be a dangerous undertaking: injuries caused by falls on stairs are highly prevalent in the elderly population [6–8]. Moreover, in Belgium, 200 deaths per year occur as a consequence of older adults falling on stairs [9]. An adequate contrast between depth and color of the steps is needed in order to create an as safe as possible situation on a staircase. More specifically, it was found that improving lighting to create more visibility on the separate steps, installing (color) contrast on the steps and providing a handrail are home modifications that are particularly useful for older adults [10].

Previous research already indicated that contrast sensitivity is the element that first suffers from age-related changes in people's visual capacities [11, 12]. As from the age of 50, our sight weakens and as a result we have difficulty estimating depth. Correctly distinguishing between lighting levels is difficult as from 65 years old. Implementing specific lighting design in the home environment can be a very effective way to compensate for the deteriorating eye sight [13].

Hence, exploring options to improve safety on stairs in a home environment is a public health issue and thus highly relevant. Therefore, the aim of this research is contributing to elderly people's quality of life by studying lighting contrast on stairs in order to create a visually safe environment, especially in a nighttime situation. The ultimate purpose is to distill hands-on guidelines for staircase design.

Three user-focused experimental studies are set up to gain insight in light settings in a staircase design to create a safe and pleasant home environment for elderly.

2 Study 1

2.1 Participants

This explorative study was conducted as part of a student course of the educational program in Interior Architecture at a Flemish university. Ninety-six participants were recruited via snowball sampling (51 women and 45 men), equally divided over four pre-defined age categories (25–44 years old, 45–64 years old, 65–75 years old and 75+). Per age category 24 participants took part in this experiment.

2.2 Procedure

For this experiment, renderings (i.e. computer graphics) of staircases were created (see Fig. 1). That is, the renderings were drawn based on the broad variety of

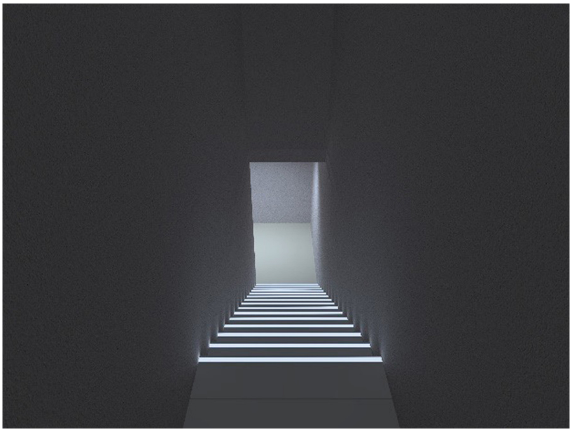


Fig. 1 Example of a rendering seen from the top with strong lighting above the stair nose in a *white matte* finish

possible designs taking into account different integrated light settings and different staircase coatings. The renderings were created in Dialux Evo.

The 40 renderings were chosen from a designer's perspective and selected in view of three covering materials—a light wood cover, a dark wood cover and white cover (with the two latter both in a matte and in a glossy finish) and eight light settings on the staircase—lighting above the stair nose; weak lighting under the stair nose; strong lighting under the stair nose; leading light across the steps; 1 spot light in the stair cheek per step; 1 spot light in the stair cheek per two steps; 1 spot light in the stair cheek per three steps; leading light in the handrail). Twenty renderings were made as from the top view and twenty as seen upward from the bottom of the stairs.

Of the 40 renderings each participant was asked to rate and evaluate 10 renderings. The 10 renderings to be assessed were allocated at random, but in such a way that every rendering occurred just as many times. After every rendering shown on the computer screen participants had to fill out a questionnaire with seven statements regarding overall lighting on the staircase, contrast on the steps and the pleasantness of the several lighting setups. The statements were to be rated on a 7-point Likert scale with possible answers ranging from 1 ('I do not agree at all') to 7 ('I totally agree') (e.g. "The staircase is adequately lit").

2.3 Data Analyses and Results

Factorability of the seven statements was examined: five of the seven statements correlated with a minimum of $r = 0.5$ with at least one other statement suggesting reasonable factorability. A principal components analysis with a direct oblimin rotation was conducted on all statements with two factors explaining 73 % of the variance.

Internal consistency of the two scales was examined using cronbach's alpha. For the five positively formulated statements cronbach's alpha was quite high, $\alpha = 0.89$.

No substantial increase in alpha was to be found by eliminating items. The two statements asking about hindering light spots and blinding lighting were, too, highly internally consistent with $\alpha = 0.69$ [14].

Composite scores were created for the two factors (one factor consisting of positively formulated items and the second factor consisting of negatively formulated items) based on the mean of the items. The rendering of the staircase that scored highest on the positive items ($M = 5.70$, $SD = 0.83$) was a rendering seen from the bottom view, with a white covering and strong lighting under the nose of the stairs. The rendering that received the highest score on the negative items ($M = 4.18$, $SD = 1.81$) was the rendering from the top view, with a white covering and lighting above the stair nose. Overall, the renderings from the bottom view were considered as more positive ($M = 4.53$, $SD = 1.61$) than the renderings from the top view ($M = 3.91$, $SD = 1.64$), with $t\ (958) = -5.95$, $p < 0.001$.

The staircase was considered least blinding when finished in a dark wood matte cover ($M = 2.16$, $SD = 1.74$). The light wood cover showed the least blinding spots ($M = 2.74$, $SD = 1.89$) whereas with white glossy finish the staircase was assessed as best lit ($M = 5.22$, $SD = 1.91$), the most clearly visible ($M = 4.58$, $SD = 2.05$) and the lighting was rated as the most agreeable ($M = 4.54$, $SD = 1.90$). The white matte finish ascertained that the steps of the staircase held sufficient contrast ($M = 4.25$, $SD = 2.00$). Overall, respondents rated the lighting of the stair nose as the most pleasant ($M = 2.26$, $SD = 1.36$) and the one spot light per three steps as the most unpleasant ($M = 2.29$, $SD = 1.43$).

When only taking into account respondents of the age categories 65–75 years old and 75+ the rendering that scored highest on being adequately lit, clearest visibility and ideal lighting is the rendering seen from the bottom in a light wood cover with a strong lighting under the stair nose. The rendering that scored the lowest had a dark wood cover in a glossy finish and a weak lighting under the stair nose. The rendering that caused blinding spots and was evaluated as most blinding had a white cover with glossy finish and had lighting of one spot light per step. This rendering was probably rated lowest by the elderly respondents because of insufficient contrast between the steps of the stairs. Renderings holding a leading light across the steps were, too, evaluated negatively and thus were not considered in following studies.

With these results in mind, a second experimental study was set up with a mockup staircase holding five different light settings. Study 2 was performed specifically with elderly participants given they are our main target group.

3 Study 2

3.1 Participants

Respondents for this study were recruited from the open course for seniors at a Flemish university. Over two days, seniors were asked to participate in the experiment. In total, 55 people participated, varying in age from 58 to 81 years old (M = 67.77 and SD = 6.16).

3.2 Procedure

The mockup staircase that was used in this experiment was custom built for the purpose of conducting research. However, it was never the goal to letting participants ascend or descend the stairs given its unstable structure but rather to allow for the possibility to use it as a sort of shell to be put on existing staircases. This demountable, wooden staircase consists of five steps, each with a rise of 15 cm and a going of 23 cm. A light wooden handrail (6 cm in diameter) was positioned on the right side of the steps (as seen from the top view) and led strips are adjusted at the nose of each step. The test model has five different light settings: a handrail lighting; lighting above the stair nose, lighting under the stair nose, two spot lights in the staircase wall and five spot lights in the staircase wall. In this study it was placed on an actual hallway staircase (see Fig. 2) and again a nightly situation was created.

We used a qualitative approach and planned semi-structured (individual) interviews. On the first day, participants (N = 20) were either asked to evaluate the light settings when looking from the bottom of the staircase upwards or from the top of the staircase downwards. The interviews were organized to elicit the perspectives of the elderly sample on *overall visibility*, on *visibility of the separate steps*, on *visibility of the form of the steps* (the profile), and whether the *lighting was equally*

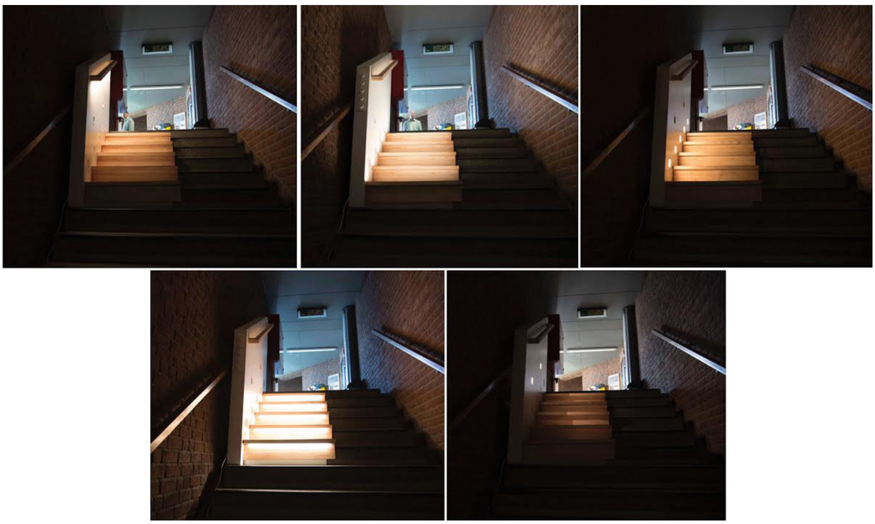


Fig. 2 Test model staircase with a *light wood* cover and five different light settings

distributed, whether the *lighting was pleasant*, whether the *lighting was blinding* and whether the *lighting was acceptable*. These questions were to be answered for each separate light setting on a 7-point Likert scale with answers ranging from 1 ('I do not agree at all') to 7 ('I fully agree').

On the second day, participants (N = 35) were asked to answer three questions regarding the light settings on the staircase. In addition, two types of magnetic coverings were used that can be placed over the steps: a light wood cover and a white cover, both in a matte finish. After all, the results of Study 1 showed that the lighter colored covers were preferred over the dark one regarding overall visibility and clear contrast. In addition, the glossy covers were evaluated as blinding.

3.3 Data Analysis and Results

Overall, the lighting under the stair nose scored highest on overall visibility ($M = 6.15$, $SD = 0.88$), on visibility of the separate steps ($M = 5.95$, $SD = 1.28$) and on pleasantness ($M = 5.85$, $SD = 1.46$). Differences were found in whether participants had to evaluate the stairs from the top or the bottom view. With regard to the evaluation of the profile of the stairs a significant difference was found between the top and bottom view for the lighting under the stair nose: $M_T = 6.60$, $SD_T = 0.52$ vs $M_B = 5.11$, $SD_B = 1.90$, $F\ (1,\ 17) = 5.71$, $p < 0.05$. Similarly, a significant difference was found between the top and bottom view evaluations of the lighting above the stair nose: $M_T = 3.64$, $SD_T = 2.01$ vs. $M_B = 5.75$, $SD_B = 1.28$, $F\ (1,\ 17) = 6.76$, $p = 0.02$.

When taking a look at whether participants find the lighting uniformly distributed a significant difference between top and bottom view was shown for lighting above the stair nose ($M_T = 4.30$, $SD_T = 1.89$ vs. $M_B = 6.14$, $SD_B = 0.90$, $F\ (1,\ 18) = 5.67$, $p = 0.03$.

Lighting under the stair nose was evaluated as most pleasant for the top and the bottom view, although a significant difference is noticed here: $M_T = 6.45$, $SD_T = 0.52$ vs. $M_B = 5.11$, $SD_B = 1.90$, $F\ (1,\ 17) = 5.09$, $p = 0.04$. Both top and bottom view of lighting above the stair nose was considered as the most blinding: $M_T = 6.27$, $SD_T = 1.19$ vs. $M_B = 3.50$, $SD_B = 2.67$, $F\ (1,\ 17) = 9.43$, $p = 0.007$.

From the top view, lighting under the stair nose scored highest on acceptable lighting ($M = 5.82$, $SD = 0.87$) whereas from the bottom view lighting in the handrail was better rated on acceptability ($M = 5.56$, $SD = 1.59$).

The lighting with two spot lights in the staircase wall was evaluated with the lowest scores on every question, except for pleasantness. The least pleasant setting from the top view was the lighting above the stair nose ($M = 2.18$, $SD = 1.17$). The most blinding setting was the lighting above the stair nose ($M = 5.11$, $SD = 2.36$), whereas the least blinding was considered the lighting under the stair nose from the top view ($M = 1.27$, $SD = 0.47$) and from the bottom view, the handrail lighting ($M = 1.88$, $SD = 1.73$). When rating acceptability, from the top view the lighting above the stair nose received the lowest scores ($M = 2.64$, $SD = 1.36$).

When covered with the light wood magnetic strip the lighting under the stair nose was rated as the light setting on which the separate steps are clearest visible (48.3 %). This was different for the white cover: participants indicated the handrail lighting to be the setting on which the separate steps were clearest visible. 74.3 % of the participants indicated that the lighting above the nose was most blinding for both cover materials. With the light wooden cover material, the handrail lighting and the lighting under the stair nose were preferred.

In order to address the problem of depth perception and contrast on stairs in elderly with future designers, students of the faculty of architecture and arts were asked to participate in Study 3.

4 Study 3

4.1 Participants

Twenty-four participants (5 female and 19 male students, aged between 18 and 25 years old) enrolled in an interior and architectural design educational program in Flanders, Belgium took part in this experimental study.

4.2 Procedure

A qualitative approach using semi-structured individual interviews was used to elicit participants' perspectives on preferred light settings and staircase cover materials in a nightly (half dark) situation. They were also asked to give advice from a designer's point of view on staircase design with young adults as well as elderly people in mind.

For this experiment the staircase test model was used again but contrary to Study 2 it was placed in a laboratory setting: a controlled environment with no other people passing by or interrupting the experiment. Magnetic coverings were placed over the steps: the strips are produced in a light wood structure, a dark wood structure and in a white coating, all in a matte finish (see Fig. 3).

Participants were asked to stand on a table (at the same height as the highest step of the stairs) and to look down, as if they were to descend the staircase. From a top view they then evaluated several combinations of cover materials and light settings on the staircase. Three settings were tested: lighting above the stair nose as a point of reference (remained unchanged for all further measurements) and two additional light settings, i.e. lighting under the stair nose and a handrail lighting. All measurements were repeated twice and results were based on the average of both measurements.

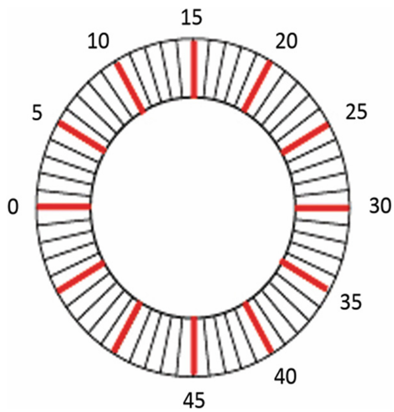
Fig. 3 All light settings with a *light wood*, *dark wood* and *white cover*

In addition, participants were asked—from their expert perspective as future interior architects—to indicate the most suitable combination of lighting and staircase cover material for both young adults and elderly people in a nightly situation. They had to specify at what point the illuminance level was adequately fit, according to them, so as the steps of the staircase were sufficiently lit and did not hinder depth perception. Participants were given one minute to adapt to the nightly situation before the actual evaluation began [15].

The experiment leader controlled the lighting by adjusting the light switch dimmers. A flexible ruler—adhered to the dimmers—contained markers (see Fig. 4) in order to be able to correctly measure the illuminance levels with a calibrated illuminance measuring device afterwards.

From the perspective of accessibility, stair nosing needs to have sufficient contrast with the steps of the staircase. Lighting above the stair nose is perceived as blinding and decreases depth perception but does indicate the position of the stair

Fig. 4 Flexible ruler with scale display



nose. Therefore, the goal of this study was to examine at what point and with what type of supplemental lighting this initial unwanted state would turn into a situation perceived as well-lit and safe. Hence, illuminance levels were decreased until they no longer were perceived as blinding and then supplemented with handrail lighting or lighting under the stair nose as to increase depth perception.

As mentioned before, participants were to evaluate the setting from the top view. As resulted from the previous studies, the top view gives the most problems with depth perception. Previous research already showed that falls on staircases in elderly people are three times more likely to occur when descending than ascending the stairs [7]. Hence, it was interesting to test this exact setting (lighting above the stair nose as seen from the top of the staircase) and test how this situation could be improved.

4.3 Data Analysis and Results

Overall, it seems that the referral scale display level (the basis lighting above the stair nose) remained reasonably constant over all cover materials: the light wood cover ($M_{LW} = 17.44$), the dark wood cover ($M_{DW} = 18.56$) and the white cover ($M_W = 18.06$). This scale display was used as the reference point: the experiment leader also measured the scale display when adding extra lighting (i.e. adding lighting under the stair nose or adding handrail lighting). These three different settings were tested to find out whether adding extra lighting would help participants to have a better depth perception.

When adding the handrail lighting to the lighting above the stair nose following measures were registered: $M_{LW} = 19.29$ (min. = 9 to max. = 30); $M_{DW} = 20.44$ (min. = 10 to max. = 36) and $M_{WH} = 18.58$ (min. = 12 to max. = 34). When the lighting under the stair nose was added to the lighting above the stair nose following scale displays were observed: $M_{LW} = 20.90$ (min. = 6 to max. = 32); $M_{DW} = 20.88$ (min. = 7 to max. = 36) and $M_{WH} = 18.44$ (min. = 6 to max. = 29).

The dark wood cover requires a higher illuminance level than the light wood and white cover when adding handrail lighting to the basis lighting above the stair nose. Apparently, depth perception is reduced when stairs carry a darker color. This result corroborates the findings of Study 1 where the renderings in a dark wood finish were also rated as the least clearly visible. The illuminance levels of the added lighting under the stair nose is similarly high in both wood cover finishes. When finished in the white cover the lighting under the stair nose requires the lowest illuminance level.

We also found a significant correlation between the illuminance levels of the sole lighting above the stair nose and the extra lighting in both handrail and lighting under the stair nose. Overall, the brighter respondents need the basis lighting—the lighting above the stair nose—the brighter they need the added lighting to be, with a significance level of $p < 0.001$ for all combinations of cover materials and light settings. More specifically, when only taking into account those respondents that already indicated being in need of a high illuminance level for the lighting above the stair nose (a high level is considered here as a level above average) analyses show that for the light wood cover a significant correlation can be found between the lighting above the stair nose and the extra handrail lighting, $r\ (11) = 0.82$, $p = 0.002$. When only considering respondents that needed an above average illuminance level for the lighting above the stair nose in a dark wood finish, a marginally significant correlation was found between the lighting above the stair nose and the handrail lighting, $r\ (10) = 0.63$, $p = 0.05$. A significant correlation was also found between the lighting above the stair nose and the lighting under the stair nose, $r\ (10) = 0.69$, $p = 0.03$. Results from respondents indicating the need for an above average illuminance level for the white cover show significant correlations between both lighting above the stair nose and the added handrail lighting, $r\ (11) = 0.66$, $p = 0.03$ and the lighting above the stair nose and the added lighting under the stair nose, $r\ (11) = 0.83$, $p = 0.002$.

Participants found all combinations of light settings and cover materials suitable for young adults. For the elderly people the majority of the participants ($n = 18$) agreed upon the lighting under the stair nose accompanied by the handrail lighting as most suitable for a nightly situation. In addition, the light wood cover material in combination with the aforementioned light setting was preferred and perceived as most clearly visible with regard to depth perception.

5 Conclusions

Results from Study 1 showed that, for the age groups of 65–75 years old and 75+, the renderings that were scored as best lit, most clearly visible and evaluated as with most ideal lighting were seen as from the bottom view and had a strong lighting under the stair nose. The cover material evaluated as the most clear and the least blinding was the light wood cover. The renderings with overall negative assessments had a dark wood material and a weak lighting under the stair nose. The renderings with 1 spot light per step and a white, glossy finish were indicated as the most blinding. As already mentioned, this could be the consequence of elderly people not having sufficient contrast between the steps of the staircase. The most important conclusions that can be drawn from the results of Study 2 are that seen from a top view, lighting under the nose is preferred and for a bottom view the handrail lighting is preferred. When the steps carry a light wood cover participants indicated the lighting under the nose in combination with the handrail lighting as the most clearly visible and thus was indicated as preferred. Participants agreed upon that the lighting above the stair nose was the most blinding. Study 3 indicated that the dark wood cover material needed a higher level of illuminance than the lighter colored coverings in order to have sufficient contrast and depth perception. The white cover required the lowest illuminance level. Results also show that the higher participants wanted the basis illumination level, the higher they needed the illuminance level to be of the two additional light settings. Additionally, the students (potential future interior designers) suggested to use lighting under the stair nose in combination with handrail lightings when formulating home adjustment guidelines on stair design for elderly people.

The goal of this research was to get more insight in how safety of a home environment could improve through intelligent stair design: what type of light setting at what illuminance level and what cover material are best fit to create a safe staircase situation for elderly in a nightly setting. As this research was conducted together with students in interior architecture the results are relevant in a context of education and provide opportunities to rethink staircase design for future interior architects.

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Part V
Multisensory Design and Mobility for Special Needs

A Design Toolkit for Visually Impaired People on Travelling Experience

Jing Guan and Clifford Sze-Tsan Choy

Abstract Designers, who are intending to design interactive systems for visually impaired people to enhance their travelling experience, should equipped with relevant knowledge, frameworks and methods to facilitate them to do better design. However, there is no holistic and systemic research focus on the visually impaired people's travelling experience, and many of existing design methods, techniques, and/ or tools are not suitable for user research, as these methods and tools rely on sighted information and communication. This paper aims to share a two-dimension design toolkit, which provides some important background knowledge on visually impaired people and some design tools and methods specific for visually impaired people so that designers can quickly start to identify issues and explore opportunities during visually impaired people's travelling experience and develop new products or services to support their everyday lives.

Keywords Design toolkit · Visually impaired people · Travelling experience

1 Introduction

Living with a visual impairment often means that they may have many practical and social obstacles for travelling, which influences visually impaired people's personal and professional life and can pose them exclusive form the mainstream society [1]. It is widely accepted that the right to fully participate into the community and enjoy the life is the same for people with or without a visual impairment [2]. According to De Potter [3] going out to do some activities can improve visually impaired

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people's well-being, the perception of self-esteem and self-competence, and preserve them from handicap. Thus, we conducted a study exploring how to assist designers to enhance visually impaired people's travelling experience. Specifically, travelling here can be defined as moving outside of the place visually impaired people familiar with.

There is a broad consensus that designers should draw upon a holistic understanding of the user [4]. People with visual impairment live in a different world that from other sighted people, thus designers need to make effort in to interact with visually impaired people and understand their preferences, behaviors, and activities. Although there have been some organizations, institutions and websites specific for blind and partially sighted people to supply some background knowledge about visually impaired people, like The World Health Organization (WHO) [5], Fashioneyesta [6] etc., all of these materials and researches are piecemeal. It will be time consuming for designers to absorbing these references. To the best of our knowledge, there is no holistic and systemic research focus on the visually impaired people's travelling experience, and many of existing methods, techniques, and/or tools are not suitable for user research, as these methods and tools rely on sighted information and communication. Therefore, to bridge this gap, this paper provides a design toolkit to help designers to do holistic research focusing on visually impaired people's travelling experience.

2 Literature Review

The research area of design toolkit for visually impaired people's travelling experience is a multidisciplinary field. It may include design theories, and specific on design process and development of design toolkit. It includes psychology through the study of making sense of experience, travelling system and the impact of visual impairment on these aspects. It also includes computer science, and more precisely human-computer interaction, through the study of interactive prototyping techniques and non-visual interaction.

2.1 Contextual Knowledge About Assistive Technology

Number of information is only presented in visual form, which result in a reduction of autonomy in visually impaired people's daily life. Assistive technology is designed to overcome these limitations and help visually impaired people seek more opportunities from society more independently. In order to promote the further development of assistive technology, an effective and on-going dialogue is required between the end-user communities, which is the visually impaired people, and the various professionals, including designers, engineers, technicians etc.

Therefore, to support this dialogue, there is a need for holistic study of assistive technology, including the common definitions, classifications and models. There are a number of different models or frameworks relevant to assistive technology (eg. [7, 8]) Specifically, the CAT model [8], which is a generic framework for classification, synthesis, development, evaluation and matching appropriate users of assistive technology systems, can assist designers to category, synthesize, assess a particular product or system in an effective way. The CAT model can be represented as a tree-like structure model, the top level of which contains four branched including: context, person, activities and assistive technology. However, the components in the activity attribute categorize the various activities into six main components: mobility, communication and information, cognitive activities, daily living, education and employment and recreational activities. It can be found that this categorizing system for activity attribute is not categorized in an efficient way. For example, the activity of shopping, which is classified into the daily living branch by the author, however, it is obvious that the process of shopping experience also involves mobility, communication or cognitive activities. Therefore, instead of categorizing by these functional activities, categorizing based on the experience of users will be more efficient and in a systematic way [9].

2.2 *Making Sense of Travelling Experience*

Existing literature tends to suggest that a number of researchers have shown their interest in experience study. The word "experience" here has always been defined as the areas of subjective senses, behaviors, or social scientific discourse [10, 11]. It is Dewey [10, 11], who firstly argued that "experience is the irreducible totality of people acting, sensing, thinking, feeling, and meaning-making in a setting, including their perception and sensation of their own actions." [9] Dewey mainly explained his theory towards experience in Experience and Nature [10] and Art as Experience [11], he proposed that a fulfilling experience includes a number of necessary conditions, including the anticipation about the experience, the continuity during the sense of anticipation, the process of unfolding and reflecting the experience, etc. Besides Dewey, another philosopher Bakhtin [12], who had great devotion to literary, put forward a supplementary theory of the relationship between experience and meaning-making. Bakhtin mainly involved trust, loyalty, commitment or identification etc., which belongs to some personal qualities into the experience consideration.

Based on the Dewey and Bakhtin's theory on experience, Wright, McCarthy and Meekison [9] developed an experience framework, which aims to figure out the different elements constitutes experience with technology and how they mutually constitute each other. According to their framework, there are six processes of sense making: anticipating, connecting, interpreting, reflecting, and appropriating.

This framework describes the processes people use when making sense of experience in a systemic view, which encourages people to think technology as experience. However, for the travelling experience of visually impaired people, it is also important to consider how to draw visually impaired people's attention and attract them to go outside, since it's much more difficult for them to gather visual travelling information from newspapers, magazines, or social medias than sighted people.

3 The Component of Design Toolkit

Through my practical project during my master period and the literature reviews above, we have developed a range of knowledge, tools and tips to enable designers and visually impaired people to become more actively involved in the research process. Therefore, we propose a design toolkit for visually impaired people's travelling experience, as a way to synthesize and share all of the resources we have designed and gathered over the years. The design toolkit will assist designers to conduct projects in support of visually impaired people's travelling experience. It will promote research that:

- Starts with comprehensive contextual review of target group then helps designers produce issues and strategies before first encounter visually impaired people
- Uses scenario-based and experience-based approach to assist designers seek more opportunities
- Based on an iterative user-centred design process

This toolkit proposes to have two dimensions: the first dimension follows an iterative design process that leads designers to implement research or design projects for visually impaired people; the second dimension is structured into nine sections with each section focusing on a key aspect in practice of designing for visually impaired people, that including background knowledge, design principles, design scenarios, travelling experience phases, person attribute, context attribute, technology attribute, prototyping techniques, and evaluation methods. Each section consists of various relative knowledge, tools and tips that should support the design process.

When designers intend to conduct a design project for visually impaired people in terms of enhancing their travelling experience, they can follow the design process in the first dimension, while choosing the relevant approached in the second dimension in each design stage. In other words, in each design stage, designers need to conduct their projects by using one or more approaches from the toolkit, and the specific usage can be seen in the Table 1. For example, in the understand stage, designers need the background knowledge approach and design principle approach, while in the study stage, design principles approach, design scenarios approach, and travelling experience phases approach need to be involved.

Table 1 Design toolkit for visually impaired people's travelling experience

	Understand	Study	Design	Build	Evaluation
Background knowledge	√				
Design principles	√	√	√	√	√
Design scenarios		√			
Travelling experience phases		√			
Person attribute			√		
Context attribute			√		
Technology attribute			√		
Prototyping techniques				√	
Evaluation methods					√

3.1 Design Process

The design process in this toolkit is mainly based on the Harper's user-centred design process, which is an iterative process comprised by understand stage, study stage, design stage, build stage, and evaluation stage. The details of each stage can be seen below:

Understand stage: making choice, choosing the particular focus group, and pursuing its relevant fundamental knowledge, like different kinds of domains of activity, cultures and environments.
Study stage: involving a grounded understanding of how individuals and social groups seek and accomplish those specific aspirations.
Design stage: a creative or design phase and involves figuring out what the design purposes should be, after considering the individual's characteristics, culture and context, and the different kinds of new technology will be situated.
Build stage: building something by using some prototyping techniques involving from low-tech methods to more high-tech methods for long-term field testing.
Evaluation stage: evaluating what has been built in the previous stage by some proper evaluation methods.

3.2 Background Knowledge

The background knowledge approach will include some fundamental and important information about visually impaired people's characteristics, needs, and daily behaviors etc. It will assist designers to have a general understanding for visually impaired people before they first encountering them. The background knowledge may from some **official website for some organizations**, like The *World Health Organization* [5], *The Hong Kong society for the blind* [13] and *RNIB* [14]; **website-based toolkits**, like the *inclusive design toolkit* [15]; **social media**

materials, like Fashioneyesta [6] and BreakingBlind [16]; and **other materials**, like academic paper, blog articles, accessibility design standard in terms of product design, architecture design, environment design etc., all of which will help designers to gather more contextual knowledge for visually impaired people.

3.3 Design Principles

"Design Principles are the guardrails of your solution—quick, memorable recipes that will help keep further iterations consistent" [17]. In this approach, there will be some design principles specific for designing for visually impaired people, all of which were generated through our practical research with visually impaired people. They are normally short and memorable, but contain the most important factors that designers need to follow when conducting a design project for people with visual impairment.

Avoiding block other senses. Since visually impaired people are only able to use their sense of sight to a limited extent possible not at all, and will be largely reliant on hearing, touching and olfaction, they need to receive and analyze large amount of travelling information during their travelling experience. For example, along the path to a certain destination, visually impaired people need to find object references and landmarks so that they can build their mental map. In addition to the tactile route information, it is also significant for visually impaired people to notice the sound changing of the environment. Not only the sound of nature, but echoes made by visually impaired people can also contribute to indoor navigation. Some visually impaired people can make clicking sounds with their tongues and listen to the returning echoes from which that acquire information about the changing of the space's size. Therefore, electronic navigation systems should be considered as supplementary equipment that could produces a small quantity but significant navigation information while not disturbing other information perceived from the environment.

No overwhelming information. Many of the existing devices have problems in the way that the information is presented to users. "They do not present relevant information in a way users can actually be oriented and sometimes overwhelm users with a huge amount of information" [18]. "This turn out to be an excessive, confusing and unnecessary amount of information which only confused blind users" [19]. Therefore, the evaluation of the product should be according to the contribution it produces, not the amount of information it generates [20].

Avoiding becomes a stigma. Most of the existing specialized products for visually impaired person are easy to recognize like a white cane or a guide dog, which will immediately become stigmatized. However, people do not want to stand out too much especially visually impaired people in mainstream society. They do not want to draw other people's attention to their visual impairment. Therefore, when designing for visually impaired people, designers should not only address the devices' function, cost, and usability, but also considering their aesthetics and social acceptance.

Translating the missing visual cues efficiently. The needs of people with visual impairment are vary depending on how the eye condition affects their vision. Therefore, accessible technology needs to be flexible in design so that they can offset the missing visual cues according to users' needs efficiently. For instance, some visually impaired people can read enlarged text on the screen, while some other users need synthesized speech software or braille software output the content of webpages, and some other low vision users may need highly contrasting color aids.

3.4 Design Scenarios

Using design scenarios approach can enable designers to rapid communicate with users about their usage possibilities [21, 22]. Some existing studies showed that regarding to the travelling experience, customers, including both mainstreams and disabled people, will have particular information needs for different scenarios [23].

Within the tourism field, according to the Leiper's tourism framework, the scenarios of travelling can be separated in three kinds: Leisure travel, business travel and other travel (eg. health or study).

Besides the tourism field, some other characteristics of travelling experience (e.g., whether it is goal-oriented or goalless-oriented) should also be considered. Because visually impaired people are hard to sense visual oriented information during their travelling experience, planning the path ahead and rehearsal it is vital important for their navigation. Therefore, goal oriented travelling is the experience that can be planed ahead and compared easier for visually impaired people while goalless oriented travelling is much more difficult for them. Since it need visually impaired people to make sense of the current information from the environment and make the navigation decision immediately.

3.5 Travelling Experience Phases

This approach expects designers to figure out what the design goals should be. In this stage, we provide a structured approach to help designers to identity and explore issues and opportunities during visually impaired people's travelling experience. Combining with Wright, McCarthy and Meekison's [9] research, we proposed that there are seven phases in travelling experience of visually impaired people: attraction, anticipating, connecting, interpreting, reflecting, and appropriating.

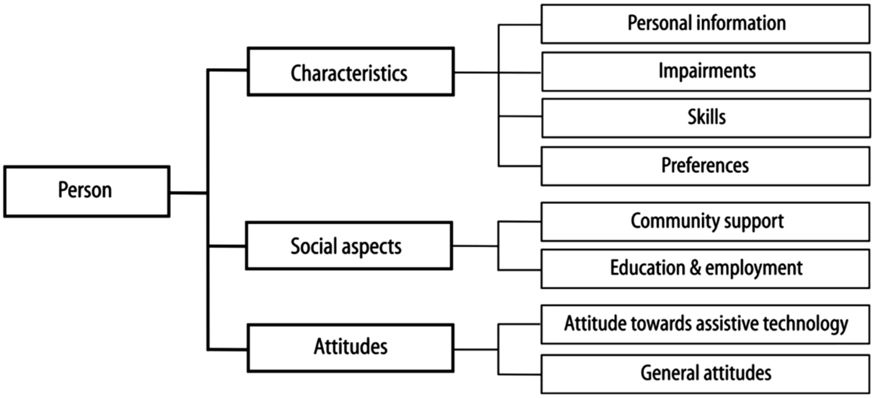

Fig. 1 Model for person attribute [8]

3.6 Person Attribute

When designing a specific assistive technology, the people who are going to use is one of the most important factors refer to the success of the design. According to Hersh and Johnson [8], the people attribute can be considered in three aspects: characteristics, social aspects and attitudes (Fig. 1).

3.7 Context Attribute

The existing context that the user belongs to is also very important but unchangeable in terms of assistive technology design. According to Hersh and Johnson [8], the context attribute includes the following three factors: cultural& social context, national context, and local settings (Fig. 2).

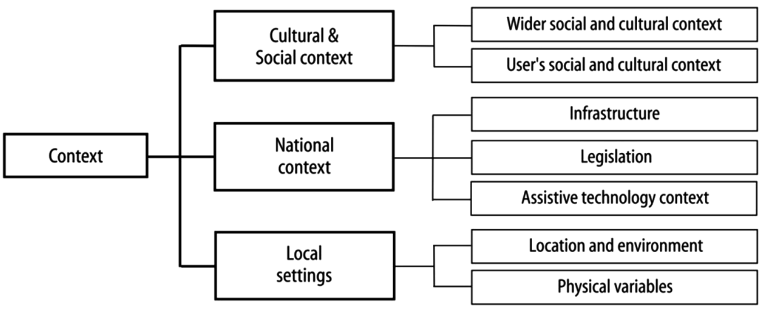

Fig. 2 Model for context attribute [8]

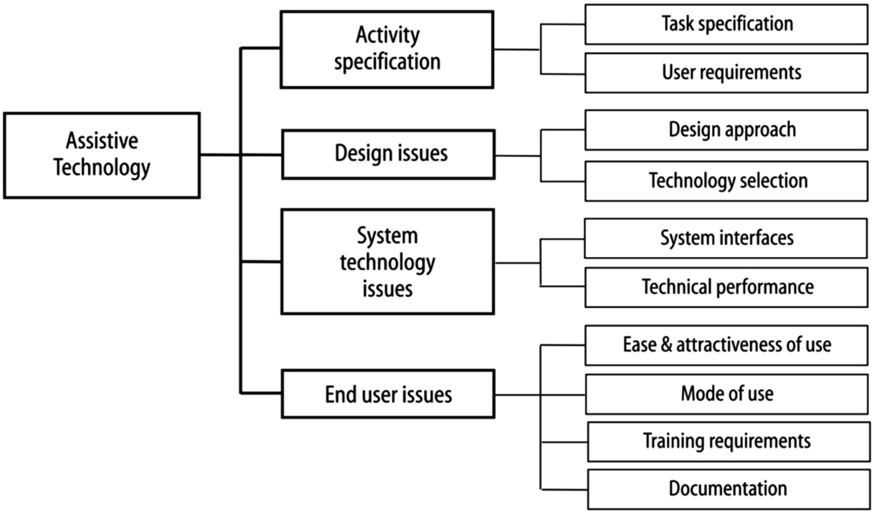

Fig. 3 Model for technology attribute [8]

3.8 *Technology Attribute*

According to Hersh and Johnson [8], there are four aspects in technology attribute: activity specification, design issues, system technology issues, and end user issues (Fig. 3).

3.9 *Prototyping Techniques*

Making prototypes including both low- fidelity prototypes and high-fidelity prototypes can help designers select or propose new ideas, get feedback from users or customers choose among design alternatives, and articulate reasons for their final choices [24]. It will raise specific challenges when including visually impaired users in the design process since they may have very specialized and little known requirements [25]. Mock-ups prototype method and Wizard of Oz method which mainly relay on touching and hearing feedback are suitable for design project for visually impaired people.

3.10 *Evaluation Methods*

The emphasis of interaction design is considering those who are going to use or benefit from the design during the design process. Design practices should consider people's emotional needs rather than only their capability to use design, and should seek to involve them actively in a co-design process. When evaluating a system in Human-Computer Interaction, usability, which is defined as "the extent to which a system […] can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [26], is an important measure. There are three factors for evaluating the usability: efficiency, effectiveness and satisfaction.

Efficiency is defined as the resources expended in relation to the accuracy and completeness with users achieves goals [26]. A common measure of efficiency is time on task, but efficiency may also relate to other resources [27].
Effectiveness is defined as the accuracy and completeness with users achieve specified goals [26]. It is commonly measured as error rate, completion rate, frequency of assist to the participant from the tester or frequency of accessing help or documentation [27].
Satisfaction is defined as the freedom of discomfort and positive attitudes towards the use of the product [26]. It is common to assess satisfaction with a Likert-scale questionnaire [27]. It is generally to make questionnaires accessible through technology like "Google Forms". However, even though visually impaired people can access the questionnaires through a screen reader by using the Google Forms, it still existing the risk of pressing the wrong button, therefore it will be much easier to present these questionnaires as interviews. The USE questionnaire is one kinds of good measurement to be used to evaluate user attitude towards a specific product [28].

4 Conclusion

There is a broad consensus that when conducting a design project, designers should draw upon a holistic understanding of the user. However, most of the designers are not experienced to interacted with visually impaired people and have no background knowledge about their preferences, behavior, and activities. This design toolkit was developed on the basis of literature and our own design experience for visually impaired people. The aim of this paper is to share this design toolkit for visually impaired people's travelling experience with the design research community, so that others can use it as a starting point for their design project. We encourage others to use and improve our design toolkit, and formulate new ones.

Furthermore, further exploratory research and evaluation research will be conducted to develop this toolkit. In the long term, we hope this toolkit will be developed to be an dynamic web-based resource, that more people can contribute to it.

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Sensory—Friendly Grocery Store for the Visually Impaired Shoppers

Doaa Khattab

Abstract Grocery stores include many different zones and services, the aisles area being one of the main barriers to access for people with different disabilities. This area features many different sections such as canned goods, dry packaged goods, spices, drinks and snacks, baking supplies, baby items, cereals, cleaning products, pet supplies, and health and beauty items. For visually impaired individuals, however, it can be hard to reach these various sections and find the relevant products. The objective of this research paper is to present an inclusive and innovative wayfinding system in grocery stores for visually impaired shoppers in order to help them find the center zone, orient between different aisles, decide where to go, move easily between different sections, and select products with ease.

Keywords Grocery store · Wayfinding · Visually impaired shoppers · Vision impairment · Accessibility · Inclusive design · Sensory environment · Systems engineering

1 Background

Grocery stores are self-service stores that provide the consumer with food and household supplies. The first self-service grocery stores began to emerge in North America and Western Europe in the middle of the 20th century, and large self-service supermarkets became common from the late 1960s onwards [1, 2]. In-store grocery shopping has emerged as a common personal task indicative of our ability to lead an independent, capable, and engaged life. Shopping in grocery stores however commonly requires the use of visual and physical abilities.

People who are visually impaired (VI) face considerable barriers while shopping in grocery stores. They cannot find their way around easily, especially when they visit a grocery store for the first time and have not yet built a cognitive map of the

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grocery store environment. They may also experience difficulty in finding desired products or delays while waiting for assistance from store employees. This often leads to their reliance on family, friends, relatives, or volunteers to help them with their shopping. When such help is not available, they are forced to cancel their visit to the grocery store or reschedule the visit [3].

Grocery stores contain so many different types of food, such as fruits and vegetables, which can be identified either by color or touch. A common problem that visually impaired shoppers have is differentiating canned products, which feel the same but have different contents. This may become more serious if the canned products are hazardous (Lanigan).

Grocery departments have expanded to include many more products than they used to in the past. Grocery stores organize products in an organized aisle format where each aisle is labelled and numbered and similar products are placed together in the same sections. The aisles area considered to be the most challenging zone for VI shoppers is the center zone with aisles as they are often challenged to shop independently in that zone even if they are familiar with the store.

The aisle areas have special formats that allow shoppers to pass through the different aisles with their shopping carts or baskets to select their desired products. The aisle areas consist of different types of aisles, such as aisles for cleaning supplies, dry and canned foods, baby products, and health products, and there is minimal visual or physical differentiation among these aisles. In each aisle, there are many sections, and in each section, there are different types of products. The built environment in the center zone is not specifically designed to be accessible to shoppers with different abilities, and for this reason, VI shoppers often have difficulties orienting, navigating between the different aisles and sections.

The questions that naturally arise are the following: What about VI people who want to shop independently? How can we design an inclusive system to help them find their way around the grocery store independently? And what is the role of interior design in the solution of this problem [3]?

1.1 What Is Visual Impairment?

The term "visually impaired" (VI) refers to individuals with low vision (LV) who can rely on a combination of their limited vision and other senses to do daily tasks. VI individuals are unable to read from a normal viewing distance, even with the aid of eyeglasses or contact lenses [4]. Two terms associated with vision impairment that should be understood are "object vision" and "travel vision." Object vision is the ability of a person to determine what kind of object he or she is seeing without knowledge of its type or details, for example, when he or she sees a person but is unable to recognize that person. Travel vision refers to a person's ability to move in space independently without the help of a cane, guide dog, or guide [5].

1.2 Understanding the Barriers

VI people experience difficulties related to their conditions in their daily activities, and these include their ability to shop individually for groceries. Architects and designers of grocery stores ought to consider developing and incorporating revisions to store designs that facilitate access for VI individuals and enable them to independently find their way to products. This requires designers to understand each task that grocery shopping entails. The tasks can be divided into seven stages: preparing the shopping list, going to the grocery store, finding the different zone(s), finding the right product(s), purchasing the product(s), exiting the store, and going home [6].

1.3 Stages of Shopping

According to the literature review and Delphi survey, VI shoppers face many barriers in different stages of their shopping experiences.

Pre-shopping stage.

- Rely on a friend or a family member to go with them to do the grocery shopping.
- Rely on a friend or a family member to drive them to the grocery store in case the store is not within walking distance or if they are not familiar with using public transportation.

Shopping stage.

- Shoppers with vision impairment are not able to shop with comfort and ease in grocery stores on their first visit since they have not yet built a mental map of the store. Additionally, grocery stores are primarily designed for sighted shoppers. As a result, VI shoppers are not able to easily locate specific areas in the store, including the entrance, the cart zone, and other departments; this will likely lead to frustration and anger in their shopping experience.
- Customer service is unavailable to them upon entry, and most grocery stores are not designed with the customer service area near the main entrance; rather, the customer service area may be located in inaccessible or inconvenient locations in the store.

- Due to illegible signage in the stores, VI shoppers may experience delays in finding their desired zone, section, and/or product.
- VI shoppers may be able to shop within the perimeter of the store, but the center zone, which contains aisles, is their main challenge. Although each aisle contains many sections and each section contains different types of products, the built environment in the center zone is not accessible, safe, convenient, or easy to shop for customers with different abilities. It is often not designed with well-placed legible signage for VI shoppers. For this reason, they are challenged in orienting and navigating between different aisles and sections.
- VI shoppers have several difficulties as listed below:
- They are not able to locate produce bags in the vegetable and fruit section because the signage is illegible to them.
- They bump their cart into the freestanding displays within the aisles area, and this is not safe.
- They are unable to find the items on sale without depending on another individual because the signage is illegible to them.
- Information for most products is not accessible or conveniently accessible for VI shoppers.

Checkout stage.

- VI shoppers do not know what products are being tallied while checking out.
- VI do not know the price of the item being checked out.
- VI shoppers cannot take advantage of price matching.
- VI shoppers are less likely to use cash and are more likely to use credit or debit cards.
- Changing the terminal layout makes them inaccessible to VI shoppers.
- VI shoppers do not know if the total price is measured using standard units (ounces and pounds) or metric (grams and kilograms).
- VI shoppers require assistance in bagging their items.

The objective of this research paper is to enhance the center zone shopping experience (i.e. that in the aisles) for VI shoppers using a model that other grocery stores can incorporate effectively into their current systems. The design is based on the use of effective wayfinding cues, the creation of a multisensory environment, and the adjustment of the current shelving system and the physical environment that surround them [3].

Two questions that have to be answered in order to achieve the objective:

1. What physical environmental features should be used in the new design for VI shoppers in order to create successful wayfinding systems in the center zone (aisles) in premium grocery stores that will not adversely affect the general population?
2. How can designers create a wayfinding system that may be effectively adopted by service providers (premium grocery stores)?

2 Social-Ecological Model

In order to arrive at an accessible grocery store design that will enhance the shopping experience of VI shoppers, this study adapts the social-ecological model (SEM) [7] to examine the relationship between the individual factors, the environmental factors, and the organizational factors. Individual factors are the factors that influence the personal shopping experience. Organizational factors are considered in relationship to the individual factors and the environment. Environmental factors are the physical, digital, and other non-digital factors that are the focus of the study (Fig. 1; Table 1).

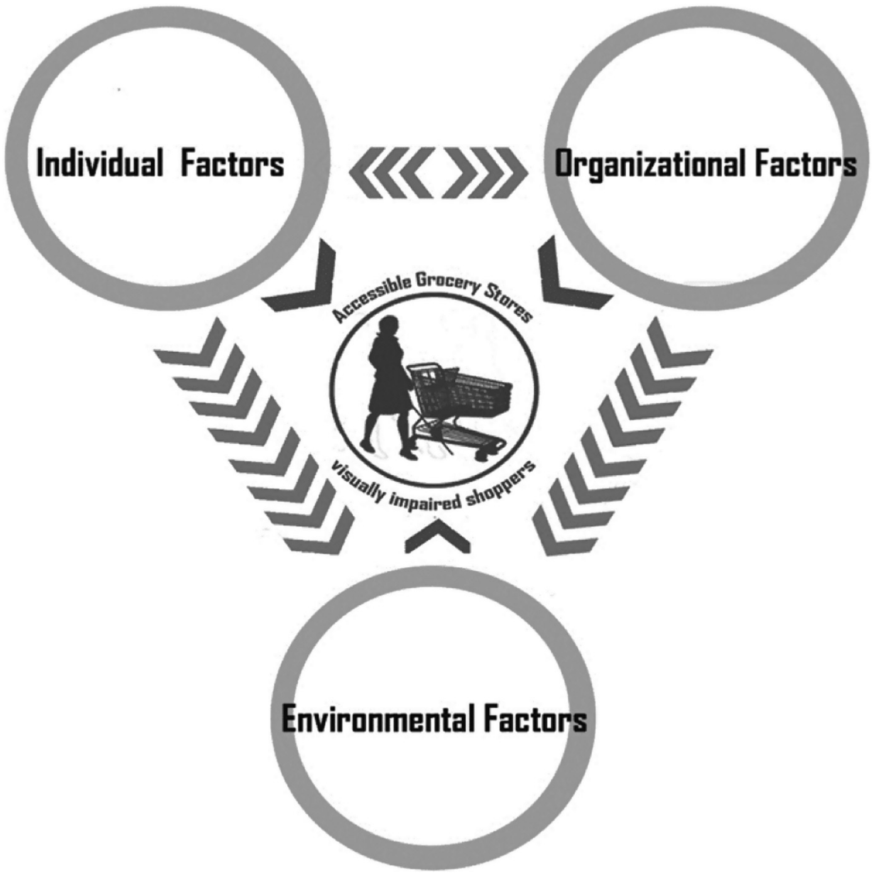

Fig. 1 Social-ecological model 1

Table 1 Social-ecological model in relation to the five main themes (inclusive approach)

Individual and social factors that influence the personal shopping experience such as the following	Organizational factors are in relation with individual factors and environmental factors such as the following
Demographics and health factors	*Organizational factors*
Age	Type of grocery store (premium grocery store)
Gender	Company policy
Income	Grocery image
Vision impairment	Market focus
Other disabilities	Flexibility in design
Social factors	Products and products on sale
Help from friends and family	Furniture (shelving system)
Behaviour factors	
Coping with vision loss	
Environmental factors (digital/non-digital) for inclusive design	
Appeal/comfort	
Accessibility	
Convenience	
Legibility	
Safety	

3 Wayfinding Model

The design proposes creating a dual-sensory environment that incorporates visual and haptic elements. For this dual-sensory environment, eight elements related to individual and organizational physical environmental factors for shoppers with VI will be presented. The wayfinding model consists of eight design features:

(1) Aisle signage, (2) Product signage, (3) Metal transition stripes at the two ends of each aisle, (4) Light-projected floor numbers, (5) Coloured flags, (6) Raised texts and number, (7) Red clip to code products on sale, (8) Clear pathways.

Figure 2 presents the 3-D wayfinding model with these eight components. The image presents five aisles. The shelving system is gray, and the product signage and the shelves' skirting is white. In addition, it uses vertical metal dividers to create different sections in each aisle. The floor for this design is light gray colour in which it will create a colour contrast with the white skirt and the dark grey shelves, with stainless steel floor stripes at both ends of the aisles. The lighting system consists of two types of lighting fixtures: general lighting fixtures and projected light (which projects the aisle's number on the floor when the grocery store recognizes the presence of VI shoppers) [3].

Fig. 2 Center zone (aisles) with eight design features [3]

4 Results

Grocery store planners(PLs) had agreed on six design features that would enhance the shopping experience for LV shoppers, which are aisle signage, product signage, light-projected floor numbers, raised text, coding products on sale using red clip, and remove all freestanding elements in the center aisle, but their main concern was the cost, as per Lawrence Polyner “A ‘decor’ package such as this would be costly and would need to be able to flex with seasonal and economical changes in order for the business owner to make it work for their purposes.” On the other hand, PLs have agreed that aisle signage, using coloured flags, raised text, and red clip to code products on sale are the most applicable elements of design by grocery store organization. Also, they have ensured that most of the physical features would not affect the general shoppers, but it will enhance their shopping experience. As per Dan Philips and Lawrence Polyner, using product signage would significantly increase the legibility for the shopping experience for the general population. Also, Lawrence Polyner and David Yehuda have ensured that using the red clip to code products on sale will help LV shoppers as well as the general population to find products on sale easily and would increase the unplanned and impulsive purchase for the LV shoppers.

Low vision (LV) experts agreed on seven design features, which are aisle signage, product signage, metal transition stripes, light-projected floor numbers, raised text, coding products on sale using a red clip, and removal of all freestanding elements in the center aisle. LV experts ensured that aisle signage and the removal of freestanding elements are the most important features since they would provide comfort, accessibility, convenience, legibility, and safety in the shopping journey; also, they ensured that these two features are usable for all types of shoppers with different vision impairments.

The two groups of experts have agreed on six design features that would enhance the shopping experience for VI shoppers, which are aisle signage, product signage, light-projected floor numbers, raised text, coding products on sale using red clip, and remove all freestanding elements in the center aisle. Table 2 will present the six design features that were agreed on, the applicability of these elements by grocery store organizations, and the usability by different shoppers with vision impairment.

In conclusion, wayfinding is about effective communication, and it relies on the successful delivery of communication cues to the sensory system. Wayfinding is the ability to know where one is, where one is headed, how to reach one's destination, and how to find one's way independently and safely. The wayfinding system should offer the user comfort, accessibility, convenience, legibility, and safety. A successful wayfinding system should provide users with information that will enable them to achieve the actions in Table 3 [8].

Table 2 Final results, agreement between both groups of experts on the design features, applicability, and usability

Design features	Applicability by grocery stores	Usability by shoppers with different vison impairment
Aisle signage	9.5	Usable for all types
Product signage	5.25	Usable for all types
Light-projected floor number	5.25	Three experts agreed on all, one expert agreed on RP only
Raised text	7	Three experts agreed on all, 2 experts agreed on Glaucoma, MD, RP
Coding products on sale	6.5	Three experts agreed on all, 2 experts agreed on Glaucoma, MD, RP
Removing the freestanding displays	5.5	Usable for all types

Table 3 Inclusive wayfinding system [3]

Inclusive wayfinding system should provide information for users	Design feature
The start and finish of the wayfinding journey	Metal transition strips and aisle signage
Identify their location	Aisle signage, light-projected floor numbers, and product signage
Ensure they are travelling in the right direction	Aisle signage and light-projected floor numbers
Orient themselves within the space	Aisle signage, light-projected floor numbers, product signage, and metal transition strips
Identify their destination on arrival	Product signage and raised text
Escape safely in an emergency	Remove all freestanding and fixed elements from the center aisles

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Can You Hear Architecture: Inclusive Design and Acoustics in the Nordic Region

Camilla Ryhl

Abstract Taking an off set in the understanding of architectural quality being based on multisensory architecture, the paper aims to discuss the current acoustic discourse in inclusive design and its implications to the integration of inclusive design in architectural discourse and practice as well as the understanding of user needs. The paper further points to the need to elaborate and nuance the discourse much more, in order to assure inclusion to the many users living with a hearing impairment or, for other reasons, with a high degree of auditory sensitivity. Using the authors' own research on inclusive design and architectural quality for people with a hearing disability and a newly conducted qualitative evaluation research in Denmark as well as architectural theories on multisensory aspects of architectural experiences, the paper uses examples of existing Nordic building cases to discuss the role of acoustics in both inclusive design and multisensory architecture.

Keywords Universal design · Inclusive design · Sensory accessibility · Sensory experiences · Architectural quality · Acoustics · Hearing impaired

1 Background

> It is not possible to work with varied acoustics anymore (…) Longer reverberation time is no longer allowed in the building regulations and the resuls is a diminishing of sensory qualities of architecture.
>
> —Knut Hjeltnes, Norwegian Architect

Inclusive design and accessibility has become core elements in Danish and Norwegian building legislation and vocabulary within the last 10–15 years. Regardless of national variations and nuances, the understanding that the built environment should be accessible for all has been disseminated and integrated

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slowly but consistently in architectural policies, building legislation, design school curricula and work methods in both public and private sector throughout the Nordic region.

In Norway the most commonly used term is Universal design while in Denmark it is accessibility. They are however used in the same manner in practice; to describe inclusive design solutions accommodating for diversity in abilities and mainly targeted to disabled users. As concepts they both represent a vocabulary to discuss inclusive design solutions as well as specific design requirements in the building legislation. Significant to both factors is the fact that the user needs most often in focus are user needs related to wheel chairs and white canes. In other words most emphasis is being placed on requirements related to physical access for wheel chair users and visually impaired users.

Both countries has enhanced accessibility/Universal design requirements in the building regulations significantly within the past 5 years and as a result seen an increase in professional design and construction cultures. Yet specialized knowledge most often appears to be based on personal experience as opposed to relevant theory and research data [1, 5]. This narrow approach amongst practitioners is further underlined by accessibility/universal design being interpreted primarily as related to physical disabilities and specifically to measurable physical aspects like threshold heights and ramp slopes. Sensory aspects of disability or architecture, such as daylights and acoustic quality or wayfinding is generally rarely perceived as related to accessibility [8].

Yet, research also shows that acoustic quality of a solitary space or an entire building is decisive to people with a high sensitivity to acoustic quality, such as people with a hearing or visual impairment. If a given space does not offer a high quality of reverberation time or speech perception, the space becomes significantly inaccessible to numerous people living with a sensitive hearing ability. The space may be physically accessible, but if it is acoustically inaccessible, it becomes useless to these users. And the consequences of having to stay in acoustically inaccessible spaces, for people with an acoustic sensitivity, may be a physical reaction in the days or weeks to follow. For some it may trigger a Mèniére attack and for others it simply results in inability to participate in social life [4, 5].

Hence, sensory aspects of architecture and especially acoustic quality should be considered a core element of inclusive architecture.

Statistical data show that the group of users living with a hearing impairment is large and growing. In most Western countries, including the Nordic Region, it is estimated that 13–15 % of the population lives with a hearing impairment. Yet, acoustic quality is not only important to users with hearing impairments, but to all users with acoustic sensitivity as well as all users in general. Research also shows that users with hearing or visual impairment, due to their increased sensitivity can inform us of details in the acoustic environment we are all exposed to, and as a result contribute with important information of the role of our acoustic experiences [5].

Traditionally, both in general and in the Nordic region, architecture as a discipline includes the art of designing spaces that combine functionality and sensory experiences in an understanding of the human body and human ability. Sensory aspects of architecture, as well as physical expression and usability, are traditionally core values of architectural quality and as such not new to any architect practitioner. Contemporary Nordic architects emphasize their professional intentions to design multi-sensory architecture and their understanding of sound being one of several important sensory elements which can be used to create diversity in spatial experiences as well as architectural quality. Yet the link between Universal design and these traditional architectural values and qualities does not seem apparent to many architect practitioners in the Nordic region. And it appears that the accessible solution when it comes to sound is most often understood as induction loop or other assistive technology, as opposed to accommodating for acoustic quality in the architectural design itself [8].

2 Acoustics in Architecture and Inclusive Design

> We have found very important knowledge and information in the old houses, and they are often multi-sensory (…) you can smell the difference from room to room, you can hear the difference, you can feel the difference. (…) In our work we don't talk about how it should look but only about how it should be experienced.
>
> —Merete Lind Mikkelsen, Danish Architect

In Norway the concept of Universal design was introduced late 1990s and since adopted into political visions and plans of actions, followed up by programs, funding and dissemination and as a whole introduced as a key concept in Norwegian context. In 2010 the new building regulation (TEK 10) enhanced this process through new and increased regulations defining Universal design in the building regulations and in practice.

In Denmark the concept of accessibility has been prevalent and Universal design as a concept has not been adopted into the Danish context until the signing of ICPD. Accessibility is still prevalent and in regards to how it is understood and interpreted by practitioners it is equivalent to the Norwegian use of Universal Design; a legislative tool defining minimum requirements in building regulations [5, 8].

Hence, Universal design, although developed and defined as a design concept with the aim of thinking diversity of bodies and abilities into the architectural design process in a holistic manner, is generally understood by many practitioners in the Nordic region as a legislative concept defining minimum requirements in the building regulations. And as a result often design solutions reflect the defined solution as shown in the guidelines and regulations. Furthermore many architects criticize Universal design in the building regulations for being prescriptive and hence restrictive to the creative process, as well as lacking room for variation and innovation [8].

Historically the user organizations have played a decisive role in implementing accessibility requirements in the building regulations as well as on the political agenda. The architectural profession has not taken an active role in the process, only within the past few years has both Denmark and Norway seen an increase in the involvement of the professional stakeholders. Parallel to the political activist process many key architects has studied and designed with an architectural focus on the relationship between body and space, but with an emphasis on humanistic and general issues rather than disability or accessibility. As architects and practitioners did not involve themselves in the political or legislative process, the more qualitative, architectural and nuanced approach towards universal design and accessibility appears lost. The result is that most practitioners and architects in the Nordic region associate accessibility/universal design with a legislative framework defined by minimum requirements in the building regulations.

Critics of the current legislative focus point to it being narrow in its' approach to user needs and solutions and void of variation, context specific solutions and innovative approaches. Furthermore sensory aspects of universal design are lost and as a result many users are still not included. Sensory aspects of Universal design, and in particular sound, is under prioritized, and generally represented through assistive technology solutions instead of architectural design. Furthermore, guidelines, recommendations and requirements are criticized for minimizing the possibility of variation through focusing on 'average', a factor mostly perceived by practitioners as being the lowest common denominator [8].

Ryhl, in her work, defines the concept of sensory accessibility as an equally important aspect of universal design as physical accessibility. She has documented the importance of sensory experiences, especially acoustic experiences, as decisive accessibility aspects for visually and hearing impaired user. Her work offers a more detailed concept vocabulary to the design process than the one currently prevalent in the Nordic region, where accessibility in general is tacitly perceived as physical accessibility [4, 7]. Ryhl has also in her work developed models to illustrate the relationship between accessibility and UD, as well as the complexity of accessibility (Figs. 1 and 2).

In her work, Ryhl demonstrates how although sensory aspects of universal design are generally over looked, they hold a crucial role in terms of creating an inclusive and universal designed environment. In some cases the absence of sensory accessibility requires people to leave a given space, even if absolute physical accessibility is present. Access to sensory aspects of the architectural experience is shown to be of such importance that the concept of sensory accessibility must be included on the accessibility agenda and given high priority. Furthermore, the

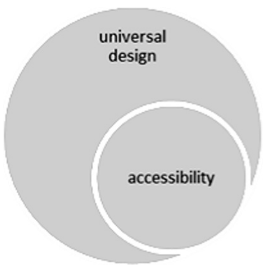

Fig. 1 Model showing the relationship between universal design and accessibility

Fig. 2 Model showing different aspects of accessibility

architect needs to understand the nuances and variation in the spatial experiences, and that this variation of sensory qualities is important for the sense of inclusion and sensory accessibility for the user, as well as the sense of belonging and existing in a larger social context [4–7].

Sensory and multisensory aspects of architectural experiences as a decisive key to architectural quality has been investigated and elaborated on by many architects and researchers. Pallasmaa [2] argues that all experiences of architecture are multi-sensory, even if we have lost the awareness of it in our contemporary mono-sensory and visual focus.

Pallasmaa's viewpoints are supported by the work of Zumthor, who also argues that architectural quality and quality of the architectural experiences are based on sensory, context specific and atmosphere as much as on physical aspects of architecture. And furthermore Zumthor describes the complexity of Atmosphere as he breaks down the experiences of architecture into a number of qualitative and sensory factors [9]. The Danish architect Eiler Rasmussen elaborated on the various sensory qualities of architecture and the role our sensory experiences play in our understanding as well as use of a space and also demonstrated in his work how acoustics should be emphasized as an architectural element [3].

Furthermore research has also shown that poor quality of acoustics becomes a barrier to inclusion for people with hearing or visual impairment. Lack of acoustic quality will result in physical discomfort, headache, dizziness, fatigue and to some, Mèniére attacks. Furthermore, if users with acoustic sensitivity remain in spaces which in reality are acoustically inaccessible to them, they are often still socially excluded, as they are still unable to hear. This is not only due to a hearing impairment, but just as often due to fatigue. Hence the lack of sensory/acoustic accessibility becomes a factor as decisive to these users, as lack of physical accessibility is to people dependent on that factor [4, 5].

Sensory aspects of architectural experiences are decisive to users in general, and to users with sensory impairments in particular. As such, it is problematic for the development of Universal design as a whole, that the concepts in the two Nordic countries in general are perceived only as a legislative tool represented and defined by minimum requirements in the building regulations, and not as a core aspect of architectural quality.

3 The Case of Acoustic Quality in Nordic Architecture

The Nordic understanding of universal design and accessibility through legislation and hence in the general interpretation in practice, has a strong focus on wheel chair users and visually impaired. The focus generally emphasizes solutions which point to a way of accommodating through the assistive technology; the wheel chair and the white cane. As for hearing impairments or acoustic sensitivity, the regulations mainly point to technological solutions, such as induction loops. Ways of accommodating for acoustic sensitivity through architectural design, e.g. through deliberate acoustic variation, is not prevalent, if existing at all. This situation points to the need for a general discussion of acoustic and architectural quality versus regulations and tacit understandings of acceptable levels within the field of architecture and Universal design. Furthermore, it becomes quite essential in relation to people with acoustic sensitivity. The absence of acoustic consideration in the general architectural design, and not in regards to assistive technology, is important to the acoustic sensitive users in both housing and public space/workplace [4–6], but in the Nordic context housing is significantly less regulated than public buildings. This does not mean that the result is more significant in one building typology, though.

One example of housing is Dianas Have in Denmark, designed in 1991–92 by Vandkunsten Architects. It is a development consisting of 41 privately owned row housing units in one to three stories. One example of a unit is a 85 m^2 one-bedroom apartment on the ground floor, with a large living/dining room including the kitchen. This core room in the unit has a level difference of 90 cm marking the difference of the living room zone and the kitchen/dining room zone. The ceiling height is 4 m in the living room zone and 3.1 m in the kitchen/dining room zone. The reverberation time in the room is 0.9–1.2 s, which by far exceeds the average accepted, but not regulated, level of 0.5 s. Testing of the perceived acoustic quality in this room shows that users with acoustic sensitivity did not feel comfortable or safe in the room. People who were congenitally blind stood still as they did not feel safe to move around, expressing a feeling of 'having no sense of the extent of the room at all' and hence not wishing to explore it. They were not able to sense a significant difference between the two levels in the room. People who were hearing or visually impaired also expressed feelings of discomfort, inability to hear or communicate, physical stress and enhanced dizziness or headaches. None of the participants in the test had a wish to live in the housing unit solely due to the reverberation time. The residents of the unit were also interviewed and expressed feelings of frustration, fatigue and increased need for silence while using the room [4, 5].

An example of a more public building/office building is the new headquarter for the Danish Disability Organizations (DH), designed in 2012 by the two architect firms Cubo and Force4 in collaboration, and recently evaluated in an extensive qualitative research project. This is a large office building of 12.600 m^2 and 300 employees. The aim of the project was to build a 100 % accessible office structure, where access was incorporated from start and hence integrated in the design. Acoustics was mentioned in the Program, but the few specifications on sound were primarily related to induction loop and other assistive technology. The spatial program of the structure is extensive, but the structure holds a central atrium space, spanning through the five levels of the building. From the central atrium four 'arms' stretch out holding offices, meeting rooms, canteen etc.

For the central atrium there was no specifications of induction loop system (except for the reception area) but a maximum of 1.6 s reverberation time was specified. The actual reverberation time in the atrium measures 1.3 s and the users express only positive experiences of the acoustic qualities of the atrium. Several users mention the sound of the atrium as one of the best aspects of the new building and many express the impact of the sound in a very nuanced, positive and excited way. It is clear that the acoustic quality of the atrium is a decisive quality of the experienced space. And that the experiences of the spatial acoustic qualities are regardless of user abilities, as it is everyone using the building who emphasizes the positive experiences of acoustics in the atrium (Fig. 3).

The DH headquarters also offers an example of the role of acoustics when it is perceived as more problematic by the users, as it is the case with the meeting rooms. The spatial program specified a maximum of 0.6 s reverberation time as well as installation of induction loop in all meeting rooms on the ground floor. The actual

Fig. 3 Space to the *right* shows the living/dining room in the housing unit at Dianas Have (Photo by Camilla Ryhl) and space to the *left* shows the atrium space at DH headquarters (Photo by René Sørensen)

reverberation time is 1.0 s in most rooms and qualitative interviews with the users point to very mixed experiences with the quality of the induction loop technology. The reverberation time is most challenging in the meeting rooms with mobile walls, and the acoustical engineer explains the higher reverberation time in all the rooms with the lack of sound absorption between the bare and sound reflecting walls.

Interviews with architects, engineers, builders etc. point to the construction team and builder not considering acoustics as a core factor offering potential quality for all in the spaces outside of the atrium. The interviews also show a strong emphasis has been placed on the induction loop as design solution to accommodate for hearing impairment.

As such the DH headquarter offers an example of perceived acoustic qualities in different spaces and as result of different focus from the both a programmatic and a design point of view. In the atrium the specifications were few, but the understanding of the room as the core of the building meant that a lot of architectural consideration was placed into securing a high level of acoustic quality for all. In the many standard meeting rooms specifications were more specific and the actual design relied more on traditional solutions, materials and use of induction loop as a technical solution to meet a user need.

The user experiences point to the atrium being perceived as a specifically positive room in regards to acoustic quality and the meeting rooms as much more problematic and in particular problematic for users with an acoustic sensitivity.

Two examples of architects working very deliberately and intentionally with acoustics are Dalsåsen Artcenter is a Norwegian project designed in 1994–97 by the architect Knut Hjeltnes and Lungholm Manor (Lungholm Gods), first built in 1639 and renovated in 2007–10 by the Danish architect Merete Lind Mikkelsen.

In Dalsåsen Hjeltnes has designed a building (both housing units and workshops for artists-in-residence) using wood as core material. He emphasizes and studies the different abilities and possibilities of wood as a material and as a result he was also able to create a very varied acoustic environment. Differences in texture and treatment of the wood, as well as differences in proportions and tactile surfaces creates a very nuanced building acoustically, which offers rich and diverse sensory experiences to the users. Not only can the soundscape support wayfinding for people with visual impairments, but it may also offer physical, emotional and sensory stimulation through variation.

In the same way Mikkelsen aims at creating richness in different stimulation at Lungholm Manor. Lungholm is classified as cultural heritage and hence listed. Mikkelsen's approach was very intentionally to preserve the rich sensory qualities of the existing historical buildings, while at the same time defining new ways of using the listed manor. The building in its original and historical plan offers great variation in spatial proportions and sequences, as well as an original use of sound absorbing materials, such as wood, stone and brick. The soundscape throughout the buildings hence offer very different acoustic experiences, and hence, like in Dalåsen by Hjeltnes, stimulates as well as supports wayfinding, functionality and sensory experiences for people with acoustic sensitivity.

Both these buildings are examples of architects working intentionally with acoustic variation and experiences as opposed to meeting standards and creating the same acoustic experiences or relying on induction loops or other technical solutions in all spaces as a means to accommodate for sensory impairments [8].

4 Acoustic Perspectives in Universal Design

The case of the DH headquarter is an example of what may happened when acoustic sensitivity is considered a special user need and the solutions is interpreted as a technical solution as opposed to an integrated architectural design solution. In the case of the meeting rooms, the induction loop has replaced a design based on sensory qualities and consideration in a misunderstood attempt to accommodate for acoustic sensitivity. And the result in this case is perceived by the daily users as less successful than in the atrium where the induction loop was not an option and instead the holistic architectural design accommodated for all.

Hjeltnes and Mikkelsen both offer examples of an architectural approach as well as designs that consider acoustics as an architectural element to be used to stimulate, accommodate and investigate. Through variation as opposed to sameness, their work becomes practical examples of Pallasmaa and Zumthors theoretical studies: through sensory stimulation acoustics as an architectural element can offer core experiences decisive to the human sense of existence and being in a social space. And this architectural approach furthermore enhances spatial experiences and social participation for people living with an increased acoustic sensitivity.

It is in other words important to start discussing acoustic variation and stimulation as core architectural elements in universal design and as a decisive means to accommodate for visual or hearing impairments, specifically through nuances and variation. Acoustic quality and experiences needs to be included as a core element in a universal design discourse and development in the future.

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An Experimental Study on Fused-Deposition-Modeling Technology as an Alternative Method for Low-Cost Braille Printing

Claudio Loconsole, Daniele Leonardis, Massimo Bergamasco and Antonio Frisoli

Abstract In this work we investigate how Braille characters can be produced through the upcoming 3D printing technology. Braille characters were experimentally printed through the widely diffused Fusion Deposition Modeling method, by different printing approaches: by using a professional-level printer, a low-cost 3D printer and a novel printing strategy optimized for Braille. Such novel printing strategy was developed to overcome common 3D printing issues, in particular on low-cost printers introduced by small details such as Braille dots. Braille writing samples produced using different techniques were compared in terms of geometrical defects. Finally, a human study enrolling visually impaired volunteers evaluated the different printing approaches in terms of readability and comfort in reading.

Keywords Design for inclusion · Braille printing · Human factors · 3D printers · Fused-deposition-modeling

1 Introduction

Braille method constitutes the main pathway to access written information for visually impaired people. Though nowadays refreshable Braille displays are available on the market, both the cost and the strict limit on the number of characters available, make Braille printing a more comfortable option for reading.

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Unfortunately, Braille printing is still far from being affordable and easy accessible to everybody. The common method for printing Braille is based on paper embossing: it requires precise and robust mechanical components which raise the cost of the printer to several thousands of dollars. Since embossing is a consolidated technology, and in the past decades no innovation or optimization in the method has shown any dramatic decrease of the final cost, the effort in making Braille printing affordable to everyone might be found in other upcoming and promising technologies.

3D printing has shown in the last years constant technological advances, and presents capabilities directly applicable to Braille printing. Though several 3D printing methods exist and some of them (i.e., photo-litography, selective-laser-sintering) already fulfill the requirements for precision of Braille dots, the purpose of this work is to evaluate affordable and easy to access methods and technologies for printing Braille. In particular, the Fused-Deposition-Modeling (FDM) 3D printing method is widespread in the market of 3D printers and in the worldwide community. Starting from just a few models of high-end 3D printers available on the market ten years ago, nowadays there exist hundreds of models commercially distributed below 1000 dollars, whereas the price and optimization is expected to decrease even more, as soon as the market of 3D printers will reach the broad audience [1].

In this work, we evaluate the capability of two commercially available FDM 3D printers to produce Braille characters: the first a professional-level printer, the second a low cost 3D printer. We investigate how the printing algorithm and printer parameters can be modified and optimized for Braille considering that, in general, the small dots of the Braille language are difficult features to be printed through FDM.

Samples printed using different techniques have been evaluated by detecting the geometrical characteristics and defects of the Braille dots with respect to Braille standards.

Finally, an experimental test with three blind people have been conducted to compare Braille printing techniques according to three different evaluation metrics. Outcomes of the work might improve and foster Braille printing through a new technology, the FDM printing, that is rapidly becoming accessible to most people.

2 Specifications of Printed Braille

Braille is a reading and writing method using the sense of touch instead of vision. It is based on raised dots on a flat surface that can be read by stroking fingers on the surface. Invented by Louis Braille (1809–1852), Braille has become the reference written communication method for visually impaired people. The braille system uses six raised dots in a systematic arrangement with two columns of three dots, known as a braille cell.

Table 1 Braille dimensions considered in the presented work according to the European Blind Union recommendations

Feature	Dimensions (mm)
Dot height	0.5
Dot diameter	1.5
Intra-cell horizontal distance	2.5
Intra-cell vertical distance	2.5
Inter-cell horizontal distance	6

Braille decodes each symbol (i.e. characters of the alphabet, numbers, or musical notes, etc.) in a cell composed of up to six dots. Dots of each cell are arranged in a matrix of two columns by three rows with fixed dimensions. Each Braille character is decoded by a cell with different number and positions of the raised dots.

Cell dimensions have to be optimal in order to allow the fingerpad to cover the whole area of the cell and, at the same time, discriminate the different dots. During the years, Blind Unions and Authorities of different countries converged to a standardization of the Braille cell and dot dimensions [2–4].

According to the above recommendations, specifications of the braille cells that are considered in the presented paper are summarized in Table 1.

3 Fused Modeling Deposition for Braille Printing

FDM is a 3D printing method widely diffused in both professional-level and low-cost consumer 3D printers. It consists of printing objects by adding layers of material deposed by a computer-controlled moving nozzle. The printing material is usually a filament of plastic [Acrylonitrile butadiene styrene (ABS) or polylactide (PLA)] that is molten within the printing nozzle and extruded as a thinner filament. The molten filament sticks on the underneath printed layers and cools down to the ambient temperature forming a new printed layer.

3.1 Layered FDM Braille Printing

The typical printing strategy for a generic 3D printed object is layer by layer: the object is sliced along the horizontal plane and the printing of each layer, starting from the bottommost, is completed before starting deposition of the layer above.

Considering the above method, printing Braille characters through FDM could be divided in two subsequent phases: deposition of a thin layer of material as the substrate, and then deposition of the dots of the Braille cells. It requires the flow of molten material has to be stopped and restarted between depositions of two different dots. Interruption and restarting of the flow of molten material is a critical issue in FDM printers [5].

Since the material is molten in the extrusion nozzle, sudden stop of the flow is difficult to achieve and it usually requires particular methods in the actuation of the extruder called "retraction": the extruder inverts the direction of the solid part of the filament retracting it by several millimeters, in order to reduce the pressure in the melting chamber. The retraction distance is then recovered when the flow of the material has to be restarted.

Such method requires fast and precise actuation of the extruder, and precise construction of the melting chamber. Precision and quality of the extruder might be achieved by professional-level 3D printers but might be a critical factor for low-cost, consumer 3D printers. Moreover, an additional issue related to retraction affects FDM printers: since the flow of material between two subsequent retraction points might be less than the retraction distance, a section of the solid filament can be pressed back and forth in the extruding mechanism several times. Due to the relatively high mechanical forces involved in the extrusion, this process is prone to induce deformation and breaking of the filament, resulting in grinding of the extrusion mechanism.

3.2 Continuous-Flow FDM Braille Printing

Braille printing through the classic FDM layered method induces repeated stop and restart of the flow of material. In this work, an alternative method for printing Braille through a FDM 3D printer was explored and compared to the classic layered method. A novel trajectory of the nozzle was developed to achieve printing of raised dots with continuous flow of material. Differently from the layered approach, the "Continuous-flow" method for printing Braille deposes a thin substrate and raised dots at the same time, row by row. While printing each row, the nozzle deposes material at the height of the substrate. When a dot has to be printed, the printing nozzle is raised on the vertical axis and then lowered again while still scanning on the horizontal axis. The comparison between the layered and continuous-flow method is shown in Fig. 1.

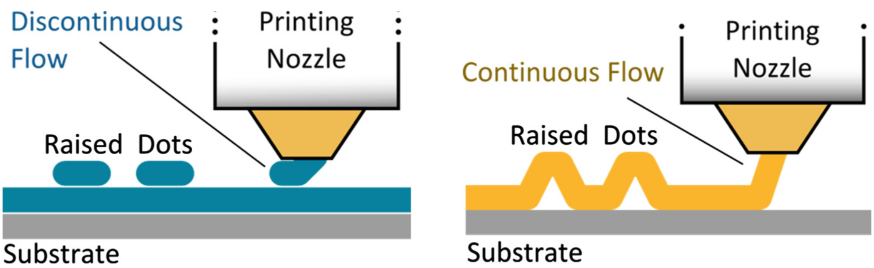

Fig. 1 Scheme of the layered FDM technique (*left*) and of the continuous flow (*right*) 3D printing technique

4 Experimental Description

In the presented work, three different FDM approaches for printing Braille were investigated through experiments: the classical layered deposition performed through a professional-level 3D printer, the classical layered deposition performed through a low-cost 3D printer, and the alternative continuous-flow printing method performed with the same low-cost 3D printer.

4.1 *FDM Printing of the Braille Samples*

The word "laboratory" was printed with Braille characters using the three different printing approaches. In addition, a classic embossed-paper sample was prepared for comparison purposes:

– **Sample 1: Embossed Paper (EPS):** The sample was prepared for comparison purposes by embossing the selected word on a sheet of paper;
– **Sample 2: Layered FDM with Professional-level 3D printer (LPS):** The sample (see Fig. 3) was printed with the Stratasys® Dimension Elite 3D printer (http://www.stratasys.com/it/stampanti-3d/design-series/dimension-elite—see Fig. 2 right), using ABS filament, and standard printing parameters (0.254 mm layer height, full infill, 20 mm/s speed) dots were modeled as cylinders, with 1. 5 mm diameter and 0.5 mm height;
– **Sample 3: Layered FDM with Low-cost 3D printer (LLS):** The sample (see Fig. 4) was printed with a low-cost (below 800 dollars) assembled 3D printer (see Fig. 2 left) with the following specifications:

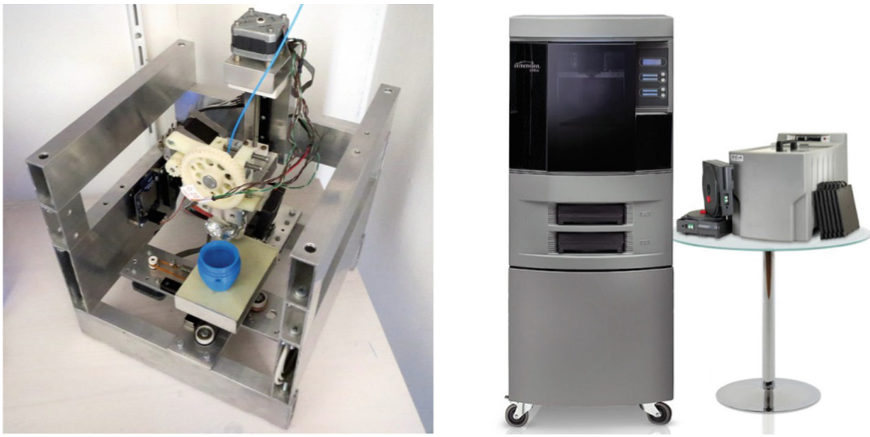

Fig. 2 The low-cost assembled 3D printer (*left*) and the Stratasys® Dimension Elite 3D printer (*right*, image courtesy of Stratasys)

- Extruder: Wade's extruder [6, 7] 1.75 mm diameter solid plastic filament, 0.4 mm diameter extruded filament.
- Actuated axes: stepper motors with belt driven X-Y plate, resolution below 0.05 mm; stepper motor with screw driven vertical axis (mounting the extruder), resolution below 0.05 mm. All axes are mounted on linear ball bearings.

The sample was printed in PLA plastic, with the following parameters: 10 mm/s speed, 180 °C nozzle temperature, 2 mm retraction, 0.25 mm layer height. Dots were modeled as cylinders, with 1.5 mm diameter and 0.5 mm height;

– **Sample 4: Continuous flow FDM with Low-cost 3D printer (CLS):** The sample (see Fig. 5) was printed in PLA plastic with the same assembled 3D printer described above (see Fig. 2 left). The following printing parameters were used: 8 mm/s speed, 180 °C nozzle temperature, 0.5 mm dots height.

4.2 Participants and Procedure

Three visually impaired subjects (2 males, 1 female, age: 73, 24, 25 respectively) were involved in the experiment. All subjects were blind (total vision loss equal to 100 %) and able to read Braille writings.

The subjects were asked to read all four Braille samples described in Sect. 4.1 and to provide, for each sample, an evaluation of the printing method according to three metrics:

1. readability;
2. effort for reading;
3. tactile comfort during the reading process.

For each couple of board and metric, a five-point Likert-scale question was administered to the subject (oral question) for a total of 12 (4 × 3) questions. In Table 2, we report the five-point Likert-scale questionnaire.

Table 2 The five-point Likert-scale questionnaire used to evaluate the different printing technique of text in Braille

N	Label	Question
1	Readability	The sample is readable and I have no difficulties to read the text written in Braille
2	No effort	Reading the text written in Braille on the sample did not require any effort to me
3	Comfort	Reading the text written in Braille on the sample was comfortable under a tactile point of view

The possible answers were: (1) Strongly disagree; (2) Disagree; (3) Neither disagree or agree; (4) Agree; (5) Strong agree

5 Results and Discussions

5.1 Braille Printing Technique Results

The samples produced with the three different FDM printing approaches are shown in Figs. 3, 4 and 5. The time required for printing each sample was of 5 min for LPS, and 8 min for samples LLS and CLS. The most of the printing time was spent for deposing the first uniform layer of material beneath the Braille dots. The time required for deposition of dots only was 25 s for sample LPS, 30 s for sample LLS, and 40 s for sample CLS.

Measurement of geometrical dimensions and printing defects: Geometrical dimensions of the printed Braille cells were measured by the experimenters using a digital caliper (precision 0.1 mm) and reported in Table 3.

Fig. 3 The layered FDM with professional-level 3D printer sample (LPS)

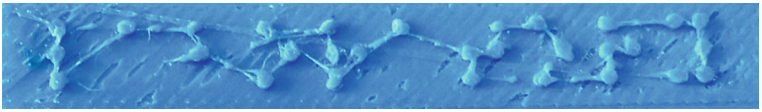

Fig. 4 The layered FDM with low-cost 3D printer sample (LLS)

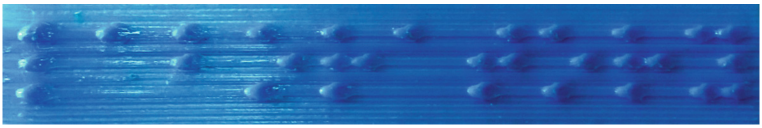

Fig. 5 The continuous flow FDM with low-cost 3D printer sample (CLS)

Table 3 Measured geometrical dimensions of the Braille cells printed in the experiments

Dimensions	Braille sample		
	LPS	LLS	CLS
Dot distance (mm)	2.5	2.5	2.5
Dot radius (mm)	1.1 ± 0.05	1.23 ± 0.20	0.91 ± 0.07
Dot height (mm)	0.5	0.5	0.5
Number of defects	0	20	1

Achieved accuracy in distance between dots was estimated below 0.1 mm for all the measured samples (no position error was detectable by measuring distances with the caliper). Such result was expected since the positioning mechanism of 3D printers, even for low-cost devices, is usually in line with the estimated value of accuracy. A similar result was achieved for dot height, since for similar reasons the height of the printing nozzle is set with relatively high accuracy, and the printed material is leveled by the horizontal translation of the nozzle.

Diameter of dots was highly repeatable for the LPS and CLS samples (0.05 mm and 0.07 mm standard deviation), while more variable for the LLS (0.2 mm standard deviation) probably due to the minor precision of the extruder in managing the intermittent flow of material. All samples presented dots with mean radius minor to the expected one (1.5 mm).

Shape of dots and possible defects were visually inspected:

- LPS presented circular dots without any noticeable defect;
- LLS presented dots with irregular shape heavily affected by stringing defects (dripping of material between two dots);
- CLS sample presented dots with repeatable shape but not strictly circular. The different shape was due to the particular continuous flow printing technique, which does not produce circular trajectories on the horizontal plane. Though with not circular shape, the CLS sample presented repeatable dots with only one minor detectable defect.

The obtained results are reported in Table 4.

Discussion of Braille printing technique results: The "continuous flow" printing method was tested in the current experiment by using the assembled 3D printer only, which allowed low-level programming of the nozzle trajectories. Though the method is suitable for implementation on any FDM 3D printer, off-the-shelf 3D printers are usually controlled by proprietary software: the printing strategy is the classical layered method and it is not possible to access low level controls.

In future works, it would be interesting to implement the proposed "continuous flow" printing method on professional-level 3D printers, in collaboration with the producer, by using a modified control software.

Table 4 Results of the experiment on the four Braille samples

Evaluation metric	Braille sample			
	EPS	LPS	LLS	CLS
Readability	5/5/3	5/5/5	1/2/2	3/5/5
No effort	4/5/5	5/5/5	1/2/1	3/5/5
Comfort	5/5/3	4/5/5	1/2/1	1/5/5

The evaluation of the three subjects is reported as S1/S2/S3. *EPS* Embossed paper sample; *LPS* Layered FDM with professional-level 3D printer sample; *LLS* Layered FDM with low-cost 3D printer sample; *CLS* Continuous flow FDM with low-cost 3D printer sample

In the presented study we investigated and assessed how readable Braille cells can be produced on generic 3D printed objects (including device covers, interfaces, labels, keys, etc.). Regarding Braille printing in full text documents some additional consideration has to be made especially for paper sheets used as substrate.

A critical point of the FDM method is the adhesion of the first layer of molten material on the substrate. Such adhesion is in general not reliable and is facilitated by coating or by pre-heating the substrate. A technique for improving adhesion consists in printing a pattern (called "brim") around the first layer of the object to start the adhesion of the material before the actual printing of the object. Though additional experiments have to be conducted testing paper as substrate, above consideration suggest that the "continuous "flow" printing method could be a better choice for printing Braille directly on paper, without any additional layer, since the adhesion of the material to the substrate is never interrupted.

Finally, considering capabilities of the current FDM technology, printing speed are still low for a direct comparison with Braille embossers, which are devices specifically designed for printing braille on paper sheets. The time required for printing each of the samples used in the experiment was of several minutes (5–8 min). However, most of the time was spent for deposing the first layer of material, whereas deposition of dots requires only a fraction of the time (25–45 s).

5.2 Perceptual Evaluation of the Braille Printing Techniques

The results of the experiment with the three blind subjects described in Sect. 4.2 are reported in Table 4 and in Fig. 6. According to the three defined metrics of evaluation and with the exception of the Layered FDM with low-cost 3D printer technique, the results are promising. All the subjects were able to read all four

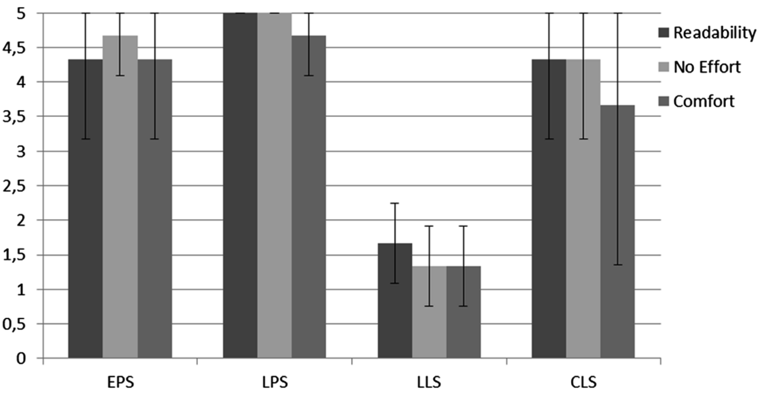

Fig. 6 Results of the evaluation experiment with blind people of the four Braille samples

Braille samples and at the end of the experiment they reported positive feedback on the experience with LPS and CLS.

Even if this is a preliminary experiment with low statistical significance, it is possible to observe a difference in the evaluation of the perceptual experience in reading the four Braille samples between the older subject (73 years old) and the other two subjects (24 and 25 years old respectively). More in detail, the lower evaluation of the CLS sample provided by the older subject, and in particular the evaluation related to the comfort, can be due to the different perception of the Braille pins due in turn to the thickening of the skin of the subject's fingertip used to read the Braille writings.

In fact, considering only the two younger subjects, they found equal the perceptual experience in reading LPS and CLS Braille samples.

Overall, we demonstrated that Fused-Deposition-Modeling technology can be an alternative method for Braille printing:

- with professional-level 3D printers, the layered FDM technique is sufficient to produce quality Braille writings;
- with low-cost 3D printers, it is necessary to use the continuous flow FDM technique instead of the layered FDM technique to produce quality Braille writings.

6 Conclusion and Future Works

In this paper, we investigated the possibility for the widely diffused Fusion Deposition Modeling (FDM) method to represent an alternative to the current Braille printing techniques.

Three 3D printing techniques using two different 3D printers, one professional-level and the other low-cost, were analyzed. A common embossing paper sample was also produced for comparison purposes, for a total of four different Braille samples.

In the conducted experiment, we firstly compared the four Braille samples in terms of geometrical defects and secondly in a human study. Three blind people were enrolled in the experiment and evaluated their perceptual experience in reading the Braille samples according to three evaluation metrics.

The results have revealed that layered FDM technique used with low-cost 3D printer instead of professional-level 3D printer, does not allow to produce readable Braille writings. Moreover, we found a substantial perceptual equivalence of the embossed paper technique and both the layered FDM used with professional-level 3D printer and the continuous flow FDM used with low-cost 3D printer techniques.

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Using a Mobile Application to Help Visually Impaired Individuals Explore the Outdoors

Shelby K. Long, Nicole D. Karpinsky, Hilal Döner and Jeremiah D. Still

Abstract Visually impaired individuals face a variety of challenges when navigating outdoors, including uneven terrain, unexpected obstacles, safety concerns, and reliance on others for information. The goal of this study was to understand further the navigational needs of visually impaired individuals and to develop a mid-fidelity prototype to address these needs. Through interviews with visually impaired users and accessibility professionals, researchers found that present technology leads to an incomplete understanding of the trail and harmful situations. Currently, there is no known technology available that integrates real-time updates with static trail information for individuals navigating outdoors. In response, a mobile prototype was proposed, integrating user-provided updates with static trail information in a format that caters to all users. Our usability testing showed visually impaired users made few errors using the prototype and were satisfied with their experience.

Keywords Wayfinding · Visual impairment · Assistive technology

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1 Introduction

According to the World Health Organization, 285 million individuals suffer from visual impairment [1]. This term describes a range of ability from blindness to low vision, defined as visual acuity of not greater than 20/200–20/70 with correction [2]. Although 4 % of the world's population is visually impaired they still encounter many barriers to living an active lifestyle. In particular, it is hard to navigate new and unpredictable environments. For instance, hiking presents too many obstacles for most visually impaired to safety attempt.

When hiking, sighted individuals rely heavily on visual cues to successful move through unpredictable environments. Seeing obstacles, such as downed trees or uneven terrain, allows sighted individuals to avoid the hazard and plan an alternative route. Visual signs and landmarks help the sighted navigate successfully. Public nature trails were developed with the expectation that hikers have normal vision. Those who are visually impaired and motivated to hike. Must complete extensive planning like creating and reviewing a tactile map. During the hike, they must carefully use a white cane to identify hazards. However, they are still unable to access crucial visual cues to facilitate safe and comfortable hiking. Clearly, disabilities arise from the inaccessibility of crucial cues needed for successful interactions between users and their environments. If visually impaired individuals could access crucial cues at this right moment, they could enjoy the benefits of hiking. We suggest that technology may provide the visually impaired with access to crucial cues through auditory and tactile modalities. However, we still need to understand further their hiking needs to provide human-centered design recommendations [3].

1.1 Current Navigational Strategies and Technologies

Design Principles. Hersh and Johnson [4] defined design principles for visually impaired individuals' independent travel. The authors asserted that an assistive technology should be easy-to-use and cost-effective. Also, the technology should provide more information than widely-used solutions, such as the white cane. For example, assistive technology should aid in avoiding obstacles, minimizing hazards, and understanding orientation information, such as signs.

Currently, many visually impaired individuals use a white cane or a dog guide to aid in autonomous navigation and travel [5]. Both of these methods are limited when used outdoors. Although the white cane is effective in many developed environments, it cannot always guarantee safety to the user, as obstacles such as potholes or debris may block the user's pathway unknowingly [6]. Guide dogs offer a viable alternative, but many training organizations limit use in hazardous situations, such as hiking independently [7]. Considering these limitations, many researchers have implemented solutions.

Current Technology Advantages and Disadvantages. One approach used to aid navigation is accessing tactile and embossed maps. Before a trip, visually impaired individuals use the map to gain information about elevation changes and the location of major landmarks. With the advent of 3D printers, printing maps with tactile feedback has become easier, though these maps still have drawbacks. When tactile labels are also used on the map, legibility of these maps decrease [8]. Further, tactile and embossed maps only reflect static information about the trail. Also, their size makes them unpractical to carry on the trail. Götzelmann [9] developed an approach which allows a smartphone to scan a tactile map and identify labels via barcode. Exploring the tactile map with one hand and reading the labels with the other is possible. Plus, Hamid and Edwards [10] added an egocentric rotation component to help with cognitive mapping. The prototype was implemented on a Talking Tactile Tablet. These studies are helpful for planning a hike but are not a solution for active hiking.

Recently, some researchers used newer technology, including ultrasonic, infrared, camera, global positioning system (GPS), and sonar to develop an electronic stick [6, 11–13]. These devices scanned the environment for obstacles and communication information about the environment using tactile feedback. Although these systems improved navigation, the devices require extensive training. Unfortunately, electronic sticks are costly and too bulky to use on the trail [14, 15].

Mobile applications are particularly promising as an assistive technology for visually impaired individuals because of their size, cost, and feedback capabilities. Applications such as Google Maps, The Seeing Eye GPS, and Navatar address some of the current limitations. These applications rely on auditory feedback to help the user determine their present and future locations. Navigation information from these applications is limited to boundaries previously established by aerial mapping and do not assist off-road navigation. Hiking-specific applications, such as Trail Tracker or AllTrails, function primarily as a recording device to track performance and only provide static information about the trail. Interestingly, these hiking navigational applications for sighted individuals are also lacking. Current applications provide little to no real-time information and are only available along roads or sidewalks. If sighted individuals had access to real-time information, they could plan their hikes around poor trail conditions or improve the conditions of the trail (e.g., moving downed trees). The proposed mobile application would benefit both sighted and visually impaired populations.

1.2 Benefits of Increased Mobility

Adults with visual impairment report poorer or declining health in comparison to sighted adults [16]. Similar trends have been found when comparing visually impaired and sighted children [17]. This disparity is caused in part by less physical activity in the visually impaired population. Real and perceived barriers to exercise, including barriers to walking alone outdoors, may be to blame [18]. By creating a navigational mobile technology, the activity level of visually impaired individuals may be greatly increased.

Exploring the outdoors provides many potential health benefits. In addition to improved health, increased mobility can lead to improved physical activity, which improves the quality of life for all individuals. Walking independently increases overall feelings of independence for visually impaired people [4].

1.3 Purpose

The goal of this study was to understand further the navigational needs of visually impaired individuals and to develop technology to address these needs. Existing technology is limited and does not encourage the visually impaired to explore the outdoors. Ideally, this application will equip visually impaired individuals with the crucial cues to navigate more effectively outdoors.

2 Design Overview

2.1 Interviews

To further understand how visually impaired individuals navigate outdoors, the researchers conducted a series of interviews with subject-matter experts and potential users. Subject-matter experts included an avid distance blind hiker and three accessibility professionals (e.g., Orientation and Mobility Specialist). Five visually impaired participants (3 Turkish, 2 American) were also interviewed. Researchers developed a semi-structured interview script with questions regarding levels of visual impairment (or the degree of visual impairment of a typical client), typical strategies, and navigation experiences. Additionally, participants were asked about current technologies and the qualities he or she would like to see in a potential navigation tool.

Researchers found that lack of map accuracy, lack of accessibility, and lack of compatibility with certain phones frustrated users. According to these participants, their frustration often superseded the benefit of the technology; many opted to forego newer technology. Instead, they relied on white canes and pathway memorization exclusively. Given the required effort for travel and fear of falling on the trail, they rarely traveled outdoors for recreation. When they did travel outdoors, they dependent on nearby pedestrians due to the poor performance of navigation technology. Additionally, participants mentioned having difficulty quickly identifying the battery life on their device and were concerned about their phone dying on the trail. This information confirmed barriers and needs found in the literature. Because all participants possessed a cellular phone and attempted to use it at least once for navigational purposes, we then asked participants about a potential need for a new navigation tool. Users expressed a need for a map function with auditory feedback and obstacle warnings.

2.2 Storyboard and Sketching

After evaluating interview data, storyboarding began. Researchers created storyboards for situations that might occur when using a navigational mobile application. These storyboards were presented to two potentials users. One potential user suggested adding locations of interest to the map, such as shelters and trail markers. The potential users also reemphasized the importance of safety. From this, researchers added a quick way to call emergency services.

2.3 Personas and Scenarios

From the literature review, interviews, and sketches, researchers developed three personas and scenarios to help contextualize user needs (Table 1).

2.4 Design and Usability Goals

We needed to provide a portable map for users to access while anywhere. Portability was an emphasized need our interviewees reported and our literature review revealed. This map should allow users to tag obstacles in an outdoor setting like downed trees, mud, possible wild animals, and holes. Plus, obstacles in an urban setting like downed trees and construction (see, Jiun-Huei). Another important feature was a way to check the weather updates and phone status (like in Barbara's scenario). The design should enable users to share their experiences and

Table 1 Personas and scenarios of potential users

Name	Personas	Scenarios
Juin-Huei	• 43-year-old male • Blind since birth • Lives within walking distance of work • Spends little time outside recreationally for fear of getting lost	• Typical route to work is blocked by construction • Uses white cane but cannot navigate around the construction • Can walk through the park but chooses not to because unfamiliarity
Melek	• 24-year-old female • Low vision due to disease since age 20 • Former cross-country athlete • Rides the bus but the system is often busy and unreliable • Occasionally goes outside for recreation	• Decides to walk a familiar path that she knows from when she ran cross country • Uses a white cane and her memory to navigate • Twists her ankle on the trail due to downed tree and needs help walking home
Barbara	• 67-year-old female • Low vision due to cataract • Lives in mountains and enjoys hiking • Attempts to use tactile maps and mobile applications to aid hikes	• Hikes alone but prefers a partner • Navigates using a hiking pole and a mobile application • Finds mobile application frustrating and inaccurate • Rain begins halfway through hike

connect with other hikers. Also, as emphasized by our interview findings, a quick way to contact emergency services is essential to feel confident hiking alone.

Regarding usability goals, the mobile application should have an interface that is easily accessible to a range of users as barrier exist for all levels of visual impairment. It should also enable current technologies (e.g., VoiceOver) to be easily integrated into the design, a frustration our users commonly reported about current solutions.

2.5 Tasks

A mid-fidelity prototype was created using Axure software. Auditory feedback for each screen option was provided by activating Apple's accessibility settings and VoiceOver.

Task 1 required participants to check the battery life of the device. The user was expected to select the Phone button and read the battery life information (Fig. 1). Task 2 asked participants to imagine falling and needing to call emergency services for help. The user was expected to select the Emergency button and Emergency Services (Fig. 2). Task 3 required the selection of a recent trail (i.e., the Osmanthus Trail). They were expected to select Route, Recent, Osmanthus Trail, and identify trail information (Fig. 3). Task 4 involved reporting a downed tree. The user was expected to select Social, Report, record the trail condition, and review on the map (Fig. 4).

Fig. 1 Sequence of events for Task 1. Users select the bottom button to begin, select Phone, and then access information about battery life using a screen reading software (e.g., VoiceOver)

Fig. 2 Sequence of events for Task 2. Users select the bottom button to begin, select the emergency button, then select Emergency Services (e.g., 911 in the United States)

Fig. 3 Sequence of events for Task 3. Users select the bottom button to begin, select Route, and then select Recent. Next, they select Osmanthus Trail and access important trail information, such as shelters, water, or user-tagged hazards

Fig. 4 Sequence of events for Task 4. Users select Social, Report, record the trail condition by holding the button and speaking, and review on the map

2.6 Use Cases

To understand the usefulness of this application, researchers developed use cases for each of the personas. In the scenario about Jiun-Huei, he encounters construction on his typical route and needs to find an alternative route. Using the application, Jiun-Huei would open the mobile application, identify the alternative route through the park through Recent or Nearby Trail, and select the route. After selecting the route, he could touch the pathway to learn about elevation changes through tactile feedback and major landmarks and user-tagged obstacles through auditory feedback.

When Melek encountered a downed tree, she could have tagged the obstacle by selecting the Report function, which recorded the trail condition for future users. She could also quickly call Emergency Services from the home screen.

Barbara would be able to identify dangerous weather before it began storming using the Weather button on the home screen. She could then seek shelter immediately as instructed.

3 Design Overview

The goal of our usability testing was to determine whether the created prototype was easily accessible to a range of visually-impaired users. Here, the most important usability dimensions were errors per task, efficiency, satisfaction of application, and clarity of design. These dimensions were measured time on task, errors on task, and perceived satisfaction.

3.1 Method

Six participants (M = 37.75, SD = 28.86) from two different countries (2 Turkish, 4 American) tested a mid-fidelity prototype of a mobile navigation application. Participants ranged in visual impaired from low vision to total blindness. They were recruited by public flyer and entered to win a $50 Amazon gift card as compensation.

All participants completed a demographic and a navigation-related questionnaire before beginning. Next, participants were asked to imagine navigating outdoors. During usability testing, the four tasks previously mentioned were complete using the mid-fidelity prototype. Upon completion of the fourth task, the System Usability Scale (SUS) was administered, and participants answered a post-task questionnaire [19].

3.2 Results

Usability dimensions for testing the prototype, including errors per task, efficiency, satisfaction of application, and clarity of design to receive constructive feedback for improving the mobile application. Participants completed all tasks in under one minute (M = 27.82, SD = 9.47). Minimal errors were made in the first three tasks (Fig. 5). An error was made when participants clicked the wrong button on the screen or had to ask for help. Any number of errors could be made during each task. Due to most errors being made in the fourth task, changes were made to the initial prototype. Interestingly, scores on the SUS signified high satisfaction with the

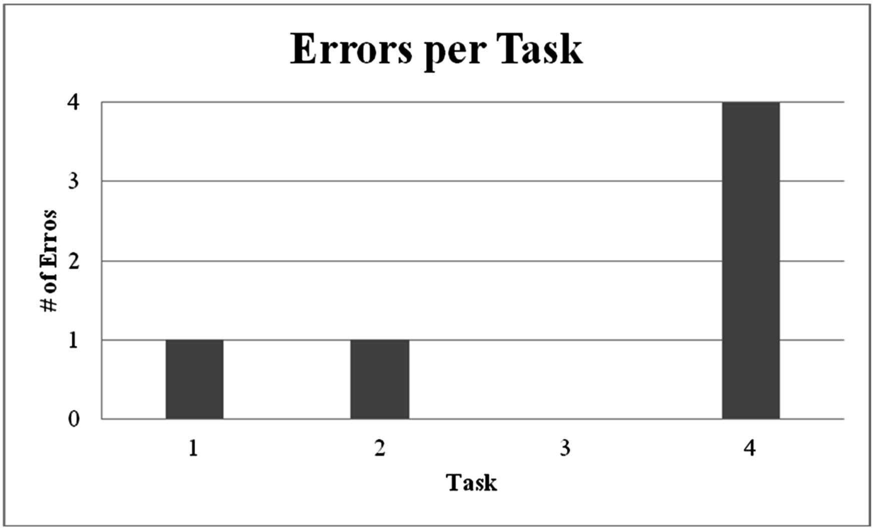

Fig. 5 Number of total errors per task. Task 3 contained no errors

application (M = 88.33, SD = 9.04), revealing positive feedback towards the proposed navigational mobile application.

3.3 Discussion

Independent navigation outdoors is a problem for a range of visually impaired people, from low vision to fully blind. A lack of physical activity in this population may be a detriment to overall health and feelings of independence. Based on information gathered from previous research, subject-matter experts, and potential users, there are many barriers to walking independently outdoors, including fear for safety and frustration with current technology. In particularly, current technologies are either unreliable or are not compatible with uneven terrain encountered outdoors. Users desire a reliable way to access information about weather, obstacles, and emergencies on their phone. Through an iterative human-centered design process, we created a mobile application prototype with auditory and tactile feedback. This prototype includes a way for users to tag obstacles to notify future users who may encounter the same obstacle in their path. It also includes a quick way to call emergency services for help, as well as gather information about the weather or phone status quickly. Currently, no technology like this exists on the market for visually impaired or sighted people.

In the future, researchers should continue investigating how to communicate best visual cues to visually impaired people. New technologies like Tactus make gaining this understanding now particularly important. Finding how to communicate best cues that sighted people identify visually is essential to bridging the current accessibility gap. Additionally, most novel technologies developed by researchers have not been testing in the field, particularly on uneven terrain. Researchers need to test navigational tools in both laboratory and field settings.

By providing an easy to use interface with constantly-updated trail condition and obstacle information, visually impaired people and sighted people will be able to navigate more effectively uneven terrain. This opportunity allows visually impaired people to exercise more. This increased exercise can lead to improved health, independence, and overall quality of life. By giving them access to visual cues through tactile and auditory feedback, individuals can spend less time worried about hazards and more time enjoying the outdoors.

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Part VI
Inclusive and Universal Fashion Design in Clothing, Footwear and Accessories

Inclusive Fashion Design: Interdisciplinary Practice in the Fashion Design Degree Program at SENAC-PE College

Christianne Falcão and Danielle Simões-Borgiani

Abstract Inclusive fashion design in the fashion design degree program at SENAC—Pernambuco (PE), Brazil college is the core module for interdisciplinary practice for college students. Based on the principles of ergonomics, modeling, aesthetics, design, materials and fabrics, students work on projects that culminates in inclusive clothing design. The discipline of study in fashion design helps achieving critical objectives such as intellectual expansion and autonomy, as key components for social and professional integration. The program also contributes to the development of skills, values, knowledge components and competency based practice. This paper aims to describe the methodology used in the fashion design degree for development of garments by students for people with disabilities, with special emphasis on ergonomics for people with disabilities.

Keywords Design for inclusion · Ergonomics · Usability · Fashion design

1 Introduction

In Brazil, according to the latest survey conducted in 2010 [1], 23.9 % of the total population, significant number of people, reported some kind of disability. However, in the apparel and garment industry this population is usually not considered in view of their clothing needs. As a result, people with disabilities use larger, most often not comfortable, clothes than their actual body size, without modeling or any adjustments, this constrain and affect their daily activates, and most importantly exclude them from fashion trends and standards.

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In view of the above, inclusive fashion design is sought as a factor to help change this condition and support developing new approaches that value and includes disabled users in a more humane and welcoming way.

Paying attention to current societal needs and all population clusters, the interdisciplinary approach in the fashion design degree program at SENAC—PE college has been generating effective results in recent years. The program starts with a discussion about the design for inclusion with students, addressing specific features of each type of disability and its relation with usability factors and the ability to wear issues, focusing on identifying physical limitations and dressing/undressing dissatisfactions. Every discipline developed in the first module of the program covers aspects of the interaction between the human body and the product (clothes and accessories), and how the clothing or accessory items can guarantee protection and comfort for the person who dress them. With an emphasis on agronomics and human factors aspects in the discipline, task analysis tools are presented to students to be applied during the design stages, considering not only the physical and physiological aspects of the user with disabilities, but also social and cultural issues. In this paper, authors present the methodology used by students for developing garments for people with disabilities, their experiences, feelings and best practices.

2 The SENAC-PE Fashion Design Degree Program

Integration projects take place at SENAC Pernambuco college. From the first to the fifth modules, student receives a challenge to design projects that integrate and apply the knowledge related to the disciplines that are given throughout the semester. Projects stimulate students to apply what they learned in the current and previous semesters, and fosters reflection on current topics. The theme implemented in the interdisciplinary practice since 2012, includes, but are not limited to: Inclusive Fashion design, sustainability, innovation, technology and current affairs, each related to a module of training.

The interdisciplinary of higher education has been discussed by several authors since 1990s. Facing new trends, colleges and universities in Brazil has been searching for alternatives for developing interdisciplinary teaching in practice. For example, the United Nations Organization (UNESCO) for Educational, Scientific and Cultural issues, according to Fortes [2] contemporary education has four columns which are: learning to be, learning to do, learning to live together and learn to know. Thus, interdisciplinary and integrated activities with practical nature provide students with these columns.

As a common practice, students across the five modules of the fashion design program, who take the interdisciplinary course, has the role of assisting others in critical sense, including the intellectual expansion and autonomy as a key component for social and professional integration, also contribute to the development of skills, values, knowledge and expertise front of the new professional profile for a globalized world [3].

In addition, to understand an interdisciplinary fashion design project, the first step is to understand that the disciplines should be taught in an integrated manner. The globalized world requires that education manifest societal needs to break with traditional models of education. Although a number of parallel topics are addressed, the disciplines continue with its individuality and integrate each other respecting the specificities of each one. Thus, the interdisciplinary practice encourages students to adopt a holistic view in various study subjects.

There are several examples demonstrating the effective results of this approach, including the emphasis that this practice is in-line with the best practices of education because it highlights collaboration and teamwork, enabling students to be an active agents, able to plan efforts and taking part of user-centered design needs responsibility, therefore making decisions relevant to facts of today needs.

2.1 The Inclusive Fashion Design Project

Student challenged when the course starts by asking them to develop an inclusive fashion collection based on skills learned during the semester from the following disciplines: Ergonomics Applied to Fashion Design, Research Methodology, Textile Technology, Fashion Design, Three-dimensional Modeling; Art History and Aesthetics for costume (see Table 1). The evaluation process of this curriculum does not end only in the integration projects; other activities of each discipline

Table 1 Description of the first module in the fashion design disciplines in accordance with the specific objectives of student projects

General goal	
To plan an inclusive fashion collection with historical references	
Specific goals	
Disciplines	*Goals*
Art history and aesthetics for costume	Contribute to fashion design from a historic context, as well as provides aesthetic elements to create a collection
Ergonomics applied to fashion design	Provide tools for planning and development of an inclusive fashion collection. This collection should meet special needs of a particular disability
Research methodology	Provides background for academic writing project
Fashion design	Support the development of sketches of an inclusive fashion collection using the drawing tools from fashion illustration
Three-dimensional modeling	Help build modeling adapted to the garment needs
Textile technology	Provide tools for identifying appropriate fabrics for special clothing needs

contribute further concepts in the evaluation of the student. The first project is part of the evaluation process and is configured as the culmination of the knowledge of the first module.

The integrated interdisciplinary practice in the curriculum proposes applicability of the knowledge gained in situations that stimulate professional practice. It is a systematization of the concepts studied by developing skills gained during the semester. Reports made by a group of four faculties and a coordinator, shows project stages, the relation among the disciplines, the evaluation process, the requirements to start the student teams and the appointment of head professor, in addition to the project objectives. The leading professor is the one who will follow the project development and does not focus on the specific objectives of the project, as this part is the responsibility of each discipline professor. The lead professor monitors, with the group, all deadlines and steps. Students work in teams of 5 members, which is also one of the project's purposes: to develop critical and mature sense on working groups.

The basis provided by each discipline goes in different times according to each project needs and synchronized among faculty members. Scheduled activities begin with ergonomics applied to fashion design and art history and aesthetics for costume disciplines.

The discipline in Ergonomics starts with initial discussions of anthropometry, usability and inclusion. Bases for students expand the look beyond the traditional fashion, as well as awaken the critical sense about the differences sizes about human bodies. In Art History and Aesthetics for costume, students realize that across the aesthetic panorama, references that can be used in innovative manner. These two disciplines help teams deciding their choices and theme for research. Students are asked to choose the disability that want to attend as well as the historical reference that will be used.

The theme for each student team project is unique since it must provide a component of knowledge shared at the end of the project. In the final presentation, each teams exposes for faculties and other classmates, the main features and design solutions found for disability. In this way reporting the knowledge about disability is enlarged when there is no repetition.

Continuing the project, the research methodology in the discipline presented to the students includes, research objective, how it was conducted, organization and use data. This integration of the three disciplines provides conditions for students to present a pre-project for reviews.

The pre-project is a paper where each team of students explaining referenced data about the disability, inclusive fashion and the historical/aesthetic reference of the collection. Next to the paper, they also present five sketches for party's clothes according to disability in the study.

The second stage of the project is to model one of the five sketches presented in the pre-project that is selected for each time in accordance with the Three-dimensional Modeling professor. This stage also corresponds to the evaluation process of the discipline. While students are modeling, they also define the best fabric that can be used for the selected sketch. Inclusive fashion cannot be treated as segregating, therefore designers encourage students to search for optimal fabrics that fit the design, and similar aesthetic to the traditional fashion, so that the disabled, or person with special needs feels s/he is part of the society. The choice of fabric occurs in the Textile Technology discipline, which provides students with knowledge of fabrics, maintenance, sewing and global impact.

In addition to this phase, fashion design course help students to develop the drawing sketches skill using techniques such as light, shadow and volume to give quality to the final design. For the second phase of the project students have to present 25 sketches, expanding the collection to other segments, which are: 5 to fashion party, 5 to swimwear, 5 to casual wear, 5 to fashion fitness and 5 to underwear. However, these other segments are not modeled, only one of the fashion party sketch.

All sketches submitted must meet, not only the disability studied, as well as people without disabilities, since the main goal is to bring, to value and include people from a design for all (Fig. 1).

At the end of the project, student's exhibit for a faculty committee the completed project by images, a model, a paper and a sketches notebook with the collections and textile, therefore fully integrating the disciplines of the first module (see Figs. 2 and 3).

Fig. 1 Students presenting the final project for faculties and classmates

Fig. 2 Models developed by students with Renaissance references for the Visually Impaired. The fabric textures were chosen to help the user notice the right way to dress from the tactile sense

Fig. 3 Model developed by students for the Visually Impaired

2.2 *Summary of Project Results*

Along the project development process the lead professor encourages students to reflect that the collection must meet the special needs studied and allow the use for public. Frequently, it has noticed that the garment adequacy to disability are quite specific and thereby not interfere in the final aesthetic, aiming to be as common as any other apparel without showing the especial need. Thus, switching the zipper location, or choosing a stretch fabrics to facilitate dressing/undressing, or an internal safety button, are the resources can be adopted.

In this process, ergonomics plays an important role in helping these design solutions for inclusive fashion. Among these, we can highlight:

- Assist in reading the body disability from an analysis and approximation of the differences from normality;
- Develop techniques that result in healthy solutions to both physical and psychological;
- Different particularities of the body should be part of the action of dressing and be studied ergonomically according to principles of usability.

As a result, the design developed by the students aims to present combinations to the body as closely as possible the natural, offering a choice of comfort and well-being to users without discriminating them.

The model shown in Fig. 3, for example, was developed for a visually impaired person. As a solution, the short party dress enables easier and safer movements and the choice of fabric with texture stimulates the tactile sense to identify clothing components in dress.

The model of Fig. 4 was developed for women who have passed through breast removal surgery. As a solution, the skirt quite colorful causes greater attention to the hips while the area of the breasts is covered by the body in black.

Fig. 4 Model developed by students for women using breast prosthesis

3 Conclusions

This paper summarizes the fashion design course modules and integration projects presented by students, who carries the interdisciplinary practice as team of students, while applying the knowledge of the disciplines in the final product. An interdisciplinary approach in fashion design, implemented over the course of three years, demonstrate the importance to arouse students' interest in people with special needs and disabilities, who are often forgotten by consumer fashion design standards and trends, therefore the paper aims at presenting creative solutions to provide safe and comfortable clothes without further constraining movement, comfort social isolation or disability.

With a similar focus, the content of several disciplines is presented in a more dynamic and relevant to reality, encouraging students understand how they can apply the content studied by professional fashion designers best practice.

In conclusion, projects developed by SENAC-PE college aims to contribute to the recognition of the need to intensify research on inclusive fashion design regarding the needs for comfortable and trendy design for people with special needs. As Grave [4] indicated, we are living in a time when everyone, in every way, should be aware of our civil, societal and cultural rights, and know our duties to society.

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The Importance of Ergonomic Design in the Inclusion of Women with Mastectomies with Lymphedema

Maria Grave, Miguel Carvalho and Fernando Ferreira

Abstract This work added the design to ergonomics in order to promote a facilitator of social inclusion of women who underwent mastectomy with lymph squeal. The research started with a physical and/or psychological impairment acquired by a woman subjected not only to the surgical removal of a breast cancer, but of the entire breast with lymphatic sequel, considering its unilateral or bilateral variation. Contemplating the limitations, needs and functionality required by the user, it was studied the perimeter, topography, interference of the physical type and the shape of the breast, the distance between the breasts, its diameter and folds, as well as the characteristics of the affected limb. The research took place in a group of 60 women (patients of two oncological clinics of São Paulo) with upper limb lymphedema resulting from a mastectomy. The multidisciplinary methodology prioritized comfort, usability, aesthetic and therapeutic functionality in order to collaborate with the inclusive therapy of these women in society.

Keywords Participatory ergonomics · Therapeutic engineering · Integrated design

1 Introduction

Design is an active process of innovation and it is humanized by integrating individual/comfort and, for the composition of product requirements, it is supported on the ergonomics bases. For COUTO, 1995 "Ergonomics is a set of science and technology looking for a comfortable and productive fit between men and his work, basically seeking to adapt working conditions to the characteristics of the human

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being." Based on the Gestalt theory, we seek to develop in the product a spontaneous language with balance, in order to distribute well its function: "physiological forces corresponding to the nervous system are distributed in such a way that are compensated between them" [1], the visual harmony and clarity, providing an immediate understanding.

In this interaction, we seek ways within the mastectomy victim's needs with lymphedema to develop a product that, besides the inclusion, can act in their therapy.

Mastectomized women with lymphatic sequel become victim for a second time, as mastectomy requires the use of prosthetics and/or orthotics, since reconstructive surgery repair is still a distant process for most of them. The lymphedema (accumulation of lymph in the upper limb) affects their limb, largely affecting her capacity to perform simple daily tasks like picking up a piece of cutlery to bring food to the mouth. Victim of a stigma, women with mastectomies with lymphatic sequel are largely accompanied by health professionals and under constant medication.

Referring cancer as a growing evil, World Health Organization (WHO) reports statistical indicators showing that 12 % of the deaths in the world today are caused by cancer in all its manifestations—representing about six million people. In Lyon, France, the "International Prevention Research Institute" presented in the "World Breast Cancer Report 2012" the female cancer with an annual growth of 3.1 %, being the breast cancer the most responsible for this increase. Considering their survival before the mastectomy, another question presented is that between 30 and 40 % of the women with mastectomies, can develop lymphedema up to five years after mastectomy Fig. 1.

Within a pluralistic line of research, we have worked the complexity of the details, in order to, with qualitative and quantitative comparative analysis, be able to evaluate subjective issues with the support of a questionnaire survey and observing the results of the design of the device created for them in a single piece, named Device for Mastectomized Women with Lymphatic Sequels—DMWLS—with an inclusive ergonomic design, thus expanding the range of therapeutic fashion products.

Fig. 1 Mastectomy—Lynphedema. *Source* Authors

2 Literature Review

Women have their body more affected, and graced, by generating life, but at the same time they are victims of the concept of beauty, imposed by the society to which they belong. According to Abagnano [2] "beauty is a manifestation of good" and following the cultural changes in the quest to be beautiful, they change their body. When, tragically, the woman who always saw her body sees it now victimized by cancer, she weakens. Mastectomy interferes not only with her physical aspects but also with her psychological. She begins to use a breast prosthesis, becoming stigmatized and suffering psychological changes, such as changes in her sexuality, sensuality, aesthetics, daily activities, leisure, pain, suffering, being more exposed to risks, concerns with personal care such as how to do nails, causing difficulty in accepting the new situation, driving her to isolation, anger against herself and against the world, insecurity, resignation [2]. Facing such suffering, she still lives at a constant risk to develop a sequel: lymphedema.

Lymphedema is a postsurgical edema that if treated immediately to surgery tends to regress. Lymphedema is the result of an excess of a highly protein fluid in the interstitial, called "lymph" or interstitial fluid, caused by the need of emptying the axillary lymphatic vessels [3]. It affects the upper limbs and may be unilateral or bilateral. The member swells toward the trunk, presenting a sensation of weight, skin becomes shiny and smooth—similar to an orange peel and, if pressed, shows up thick, with excess protein and keratin.

Considering inclusion as a high point of our society and before "The Universal Declaration of the Human Rights", proclaiming in its Article 3 (a) (UN): "Respect for inherent dignity, individual autonomy including the freedom to make one's own choices, and independence of persons" [4], professional designers are responsible to research and participate in inclusion, developing means that reintegrate the disabled person into society.

In this quest to meet the public of women who underwent a mastectomy with lymph sequels, we seek to give the design an inclusive and communicative language between the user and the object in the interface, working on concepts and enabling a link between conception and product development [5].

There is also a comprehensive peeve involving the designer, related to ergonomics stating: "Design is one of the methods of forming matter". This is directly related to the comfort, inherent to convenience, practicality and warmth that the product should provide, factors directly related to the thermo physiologic comfort (which allows to harmonize the thermal environment between body and space), psychological comfort (which enables and induces pleasure), sensorial comfort (related to the feeling provided by the touch) and the ergonomic comfort (respecting the biomechanics, the physiological needs of movement), have been strongly considered in this study, characterizing the product as a supplementary therapeutic device [6].

The factors that most influenced the development of design were:

1. Topography related to the pathology: to detail the body characteristics and the pathology;
2. Anthropometry: to know the physical body measurements, determine the size, balance and relate dimensions to the needs for usability that their clothes require, considering the proportions related to the anatomical and physiological state of the pathology;
3. Goniometry: to measure the opening angles required for movement;
4. Anatomical changes: to know the healthy body and the changes that the disease imposes;
5. Physiology: to meet the specific needs of the pathological body;
6. Psychomotor needs: involuntary movements with or without physical changes;
7. Vulnerability to cold and heat: to know the natural temperature corresponding to the pathology;
8. Medications: external or internal application of drugs;
9. Supplementary collectors: use of collecting bags.

2.1 Ergonomic Design Applied to Inclusive Products

In 1970, at the University of Hiroshima, when evaluating products usability, Professor Kansei mentioned a very important psychological factor of the individual, pointing out that the interaction of the product with the body must meet both the physical and the psychological, and with seduction, meet the scope in its function [7], so that the product should conform to an ergonomic approach, fulfilling a facilitating role in the usability, comfort, aesthetics and physical protection, also interacting in the tasks of dressing and undressing, as well as in the daily tasks of the mastectomized woman with lymphatic sequel. Thus, the product must meet the needs of these women and be supported by the OIKOS Theory, focused in integrating the product management in the environment, with a global approach, drawing attention to a new vision for the social economy. Therefore, the designer must subjectively apply questions that allow him to qualify the usability, comfort in all its variables and functionality.

In the search for efficiency in this research project, the designer divided the requirements in:

(1) Features involving the product:

   (a) Ergonomic design applied to clothing, performing two functions in one garment;
   (b) Use of textile technology to increase the value of the product (raw material, importance of color and closing system);

(2) Features that subjectively involve the ergonomics, like the physical aesthetics, lack of courage to get ready, empty feeling in the body, sense of helplessness,

weakness towards her sexuality, the feeling of being a victim of stigma, loss of sensuality;

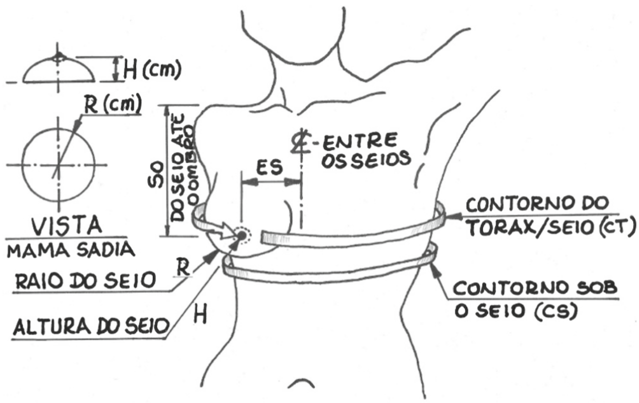
(3) Features that objectively involve the ergonomics, like the change in the volume of the affected upper limb, fear to move the affected limb, consider the use of drains and existence of surgery stitches; need to exercise the affected limb.

2.2 *Methodology Applied to the Product*

The research begun with the study of the healthy breast to assess the needs that will apply to the prosthesis (external), their size, shape, distances, in order to align it to the projection of the breast. Figure 2 represents the obtained measurements.

In a second stage, for the development of the complementary device, were used detailed measurements for the thorax, arm, hand and fingers, presented in Table 1 and represented in Fig. 3.

For the design of the bra, the measurements were obtained in the defined reference points: bust contour/contour of the chest under the bust, breast height, body height, and the height under the arm.



Legend:

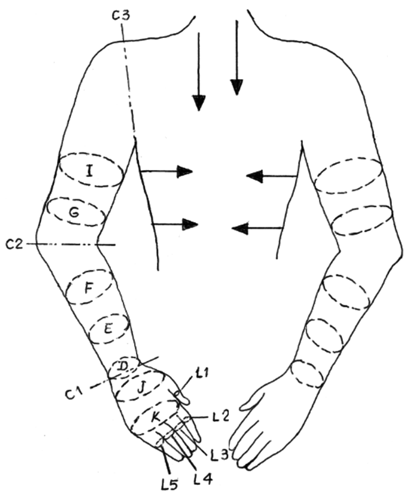
H	- Breast height;
R	- Breast radius;
ES	- 1/2 Distance between breasts;
CT	- Contour of the chest/breast;
CS	- Under the breast contour;
SO	- Distance from breast to the shoulder.

Fig. 2 Basic information to obtain the measurements from the healthy breast. *Source* Authors

Table 1 Reference points for measurements

Body part					Garment
Thorax-breast					Top-bra
Arm					Sleeve
Hand					Gloves
Letter applied to height					Location
C1					Wrist joint
C2					Elbow joint line
C3					Root of the arm/shoulder girth (joint)
Leaving from C1					Fist/contour
D					Handle contour
E					5 cm above D
F					15 cm above D
G					5 cm above C2
I					15 cm above C2
Body part					Hand
J					Outline palmar (3 cm bellow C1)
K					Contour of the region based on the metacar-pophalangeal folds
L					Toe height
L1	L2	L3	L4	L5	Fingers contour
Thumb	Index	Middle	Ring	Pinky	
C1/K					Hand height

Fig. 3 Positions in the body of each obtained measurement. *Source* Authors



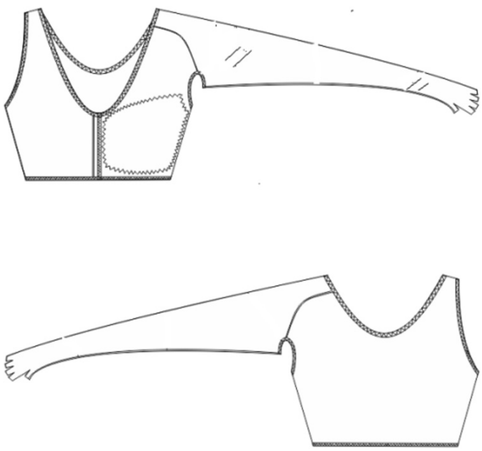


Fig. 4 Device for Mastectomized Women with Lymphatic Sequels”—DMWLS. *Source* Authors

The fundamental design allowed creating a device respecting the entire perimeter and periphery respecting the therapeutic changes. The front and back view of the prototype is represented in Fig. 4.

3 Method and Implementation

The research included both quantitative and qualitative assessments based on a multidisciplinary pluralistic methodology. The study involved 60 women aged between 25 and 70 years old, divided into groups of 3–20 women each, characterized as A, B and C* and fulfilling a 180 calendar days with 3 parallel changes every 60 days. A questionnaire was applied in the end of each change, supported by frequent meetings throughout the semester: Moment one (1) after 30 days; Moment two (2) after 45 days; Moment three (3) after 60 days; Moment four (4) after 180 days.

To evaluate the effect of different raw materials, two types of knitting material (Jersey structure) were used in the construction of the prototypes tested. One using a technical polyamide—Emana®, produced by Solvay-Rhodia, and the other using a standard polyamide from the same producer. To evaluate the effect of the proposed design, a third product was used in the testing. This product represents a commercial garment available in the market for these women. The devices were codified as “T”—Technology; “N”—Standard; and “C”—Commercial.

The survey was able to assess the inclusive-experimental design supported by the statistical analysis of variance—*ANOVA*, together with the *Tukey Test* and the *Fisher Test* [8]. Twenty questions were applied as follows: two questions devoted to aesthetics, eight to usability, four to the therapeutic functionality, and four dedicated to the sensorial and tactile comfort, all requiring subjective responses (Yes or No). Questions 4 and 7 slightly reversed the results.

The statistical analysis was related to the usability, comfort (aesthetic, sensorial, physiological and ergonomics) as well as to functionality.

4 Results and Discussion

Figure 5 shows, clearly, the percentage determined by the subjective "Yes" or "No" obtained for each of the twenty questions.

Usability
The results of the questions regarding the usability of the DMWLS "T", "N" and "C" are represented in Table 2.

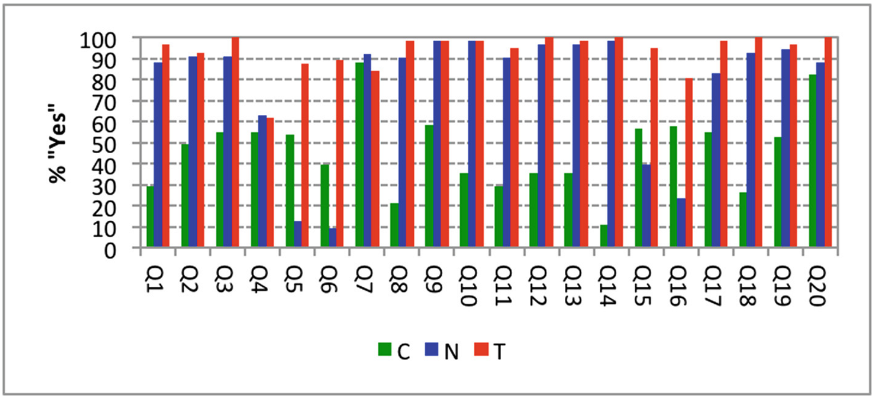


Fig. 5 Percentage of positive responses ("Yes")

Table 2 Usability evaluation

Questions		*p*-value			
		General	C × N	C × T	N × T
2	The product is practical and easy to wear?	<0.0001	<0.0001	<0.0001	*0.7398*
3	The product is practical and easy to remove?	<0.0001	<0.0001	<0.0001	*0.0258*
4	With the use of the product did you have difficulty doing daily tasks?	*<0.6416*	–	–	–
7	Did you have troubles positioning the breast implant?	*<0.4275*	–	–	–
8	Did you like the type of closure?	<0.0001	<0.0001	<0.0001	*0.1589*
9	Did you like the type of sleeve?	<0.0001	<0.0001	<0.0001	*0.9999*
10	Did you like the type of opening under your arm?	<0.0001	<0.0001	<0.0001	*0.9999*
13	After washing, did the product dry fast?	<0.0001	<0.0001	<0.0001	*0.9999*

Statistical analysis showed no significant difference between the “T” devices, “N” and “C” in questions 4 (p-value = 0.6416) and 7 (p-value = 0.4275), related to the possible restrictions to movement assigned to the device when performing daily tasks and their capacity to perform the adjustment of the external prosthetic device. This means that these questions are already satisfactorily catered by existing devices in the market. The design proposed in this study did not provide additional benefits that could be perceived by the volunteers regarding these questions.

As for the other usability questions (dressing and undressing, maintenance, mobility) we can see that the new design (equal in the DMWLS “N” and “T”) was perceived by the volunteers with the most outstanding acceptance in comparison to the design of the device commercially available (DMWLS type “C”). The acceptance rate for the created design ranged from 90.7 % to 100 %, while the DMWLS “C” had acceptable levels between 20.9 % and 58.2 % for the same categories.

It is interesting to note that only in Question 3 (regarding how easy is the removal of the device) the devices “T” and “N” were perceived as different (p-value = 0.0258), with a 100 % acceptance rate for the device “T”.

Aesthetical comfort

Questions 11 and 19 addressed the aspects of psychological and aesthetic comfort. Table 3 shows the results.

It is possible to observe that devices “T” and “N” statistically differ from device “C” (p-value < 0.0001), but no differences between them. The acceptance rates of these devices for the evaluated aspects ranged from 90.6 to 96.5 %, whereas for device “C” the acceptance rate was 28.9 % (Questions 11) and 52.7 % (Question 19). The design created offered a differential in the of psychological and aesthetic comfort aspects, being much better valued than the “C” device.

Sensorial comfort (physical and physiological)

The statistical results for questions 12, 14, 17 and 18 related to the perceived sensorial comfort, especially by the tactile comfort, are presented in Table 4.

Table 3 Aesthetical comfort evaluation

Questions		p-value			
		General	C × N	C × T	N × T
11	Do you enjoy the device’s neck height?	<0.0001	<0.0001	<0.0001	*0.4814*
19	Did you like the style of the device?	<0.0001	<0.0001	<0.0001	*0.6733*

Table 4 Sensorial comfort evaluation

Questions		*p*-value			
		General	C × N	C × T	N × T
12	The product is comfortable?	<0.0001	<0.0001	<0.0001	*0.4954*
14	The product is soft?	<0.0001	<0.0001	<0.0001	*0.4956*
17	The thickness of the seams is good?	<0.0001	<0.0027	<0.0001	0.0071
18	Did you like the thickness of the material?	<0.0001	<0.0001	<0.0001	*0.0549*

Statistical analysis shows that the perceived tactile sensorial comfort was significantly different between device "C" and devices "N" and "T" (p-value < 0.005). The acceptance of the new design ("T" and "N") obtained an acceptance from 83.0 to 100 % whilst device "C" obtained 10.9–51.1 %. It is relevant to mention that device "T" got 100 % acceptance for questions 12, 14 and 18 and 98.2 % acceptance for question 17.

Devices "N" and "T" were perceived to be different only in question 17.

Therapeutic Functionality

The effect of the therapeutic functionality was assessed by questions 5, 6, 15 and 16. The results of the statistical analysis are shown in Table 5.

The perception of the effectiveness of the DMWLS in relation to the reduction of "pain" and "swelling" (questions 6 and 5) was significantly different (p-value < 0.0001) between the devices. Device "T" showed the highest rates, 87.3 % ("pain") and 88.9 % ("swelling") of positive responses, followed by device "C" with 53.7 and 39.6 % respectively), while the rates obtained for device "N" were more modest, with 12.7 and 9.4 %, respectively This result is attributed to the bio stimulation properties of the *Emana*® yarn used in the production of device "T"—the only difference between devices "N" and "T".

The results of the evaluation of the proper compression and elasticity (questions 15 and 16) also showed significant difference between devices. A higher degree of acceptance was found for device "T" with 94.7 and 80.4 %, respectively. Device

Table 5 Evaluation of the therapeutic functionality

Questions		*p*-value			
		General	C × N	C × T	N × T
5	Did you feel improvements in the swelling?	<0.0001	<0.0001	<0.0001	0.001
6	Did you feel less pain when using the product?	<0.0001	<0.0005	<0.0001	0.001
15	Is elasticity good?	<0.0001	*<0.0856*	<0.0001	0.001
16	Is compression enough?	<0.0001	<0.0003	<0.0142	0.001

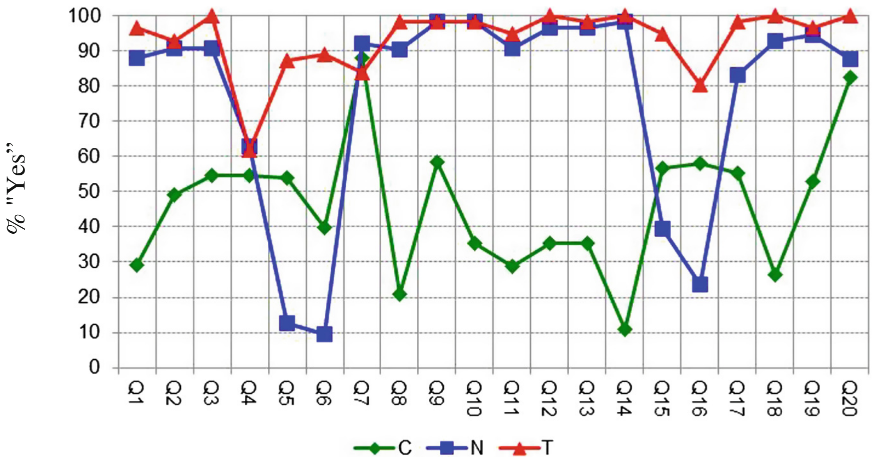


Fig. 6 Acceptance of the DMWLS "T", "N" and "C"

"C" had 56.6 and 57.9 % and device "N" 39.3 and 23.6 %, respectively. Considering that the compression of the device "C" is 18–24 mmHg, and devices "N" and "T" have compression values of 14–22 mmHg, it was surprising that device "T" has been perceived as the one with more appropriate compression and greater acceptance, as presented in Fig. 6 in the question of acceptance of the DMWLS.

It was possible to observe that there was no significant interference regarding the design of devices "N" and "T". The result of the perceived benefit comes from the use of the technological yarn *Emana*® which has benefit the therapeutic action, acting as an adjuvant for pain relief and swelling.

5 Conclusions

This research has shown the need of the market to introduce new products, the importance of having available in the stores products respecting the needs of comfort and protection of the mastectomized women with lymphatic sequels, with seduction, in order to recover their self-esteem within the individual inclusion process.

Despite the advance of research in the various areas the fear and shock of becoming a victim of breast cancer is still present. Also does not eliminate the stigma caused by the extirpation of their body, and much less offers lymphedema cure.

However, the significant results of this research sparked arguments between the physical and the psychological, which when administered by the mental, awarded the success of the *DMWLS—Device for Mastectomized Women with Lymphatic*

Sequels regarding the physiological, psych affective, sociocultural and mainly cognitive aspects, linked to the women's relationship with themselves, and the women with their environment.

The success of the design was perceived to result from its capacity to contribute to the safety, practicality in a single garment, considering the users needs in terms of psychological and physiological comfort, allowing them the possibility to stimulate the healthy of their body.

It was also possible to identify that the technological material used in the development of the device has contributed to their satisfaction in the large majority of questions, as it increased their perception of comfort.

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WearAbility

Gianni Montagna and Cristina Carvalho

Abstract This project aims to research and consolidate a specific methodology to increase or decrease of wearability (widths/ease between the body and the garment) and relative comfort, in woven and knitted garments, in a proportional and balanced manner, allowing performing this operation in a quick and accurate way. In order to allow a larger application of the system some boundaries must be observed. The system has to be suitable for industry and designer scale production and have to be universal and adaptable to women and men products. The system has to permit different levels of amplitudes and have to permit the maintenance of the proportions and characteristics of the basic block. The development of the basic principles of the system will be the next step and the application to different structures of basic blocks will be tested during the entire research.

Keywords Wearability · Garment ease · Pattern making · Garment comfort

1 Introduction

In the garment industry production the need to change the amplitude (ease) of a garment is an everyday work that in needed in order to achieve high standard required with the developing of new clothes and garments.

The adaptation of the garment amplitude by the patternmaker to the need of the designer is a technical task that many times is left to the improvisation of the patternmaker and to his/her experience. As referred by Wang [1] two different kinds of ease applied to a garment could be distinguished: wearing ease and design ease. As wearing ease could be intended as the necessary ease to allow the person to wear and move inside the garment. Wang [1] and MacDonald [2] continues saying that

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users need to be able to bend, breath, seat, rise arms and walk without the garment being over pulled, pinched, banded, stretched or strained beyond a natural relaxed position. For design ease could be identify the ease used by design to assign the correct styling and image to the garment. Amaden-Crawford, [3] refers that proper fit improve the appearance of comfort and is naturally proportionate to the figure, with appropriate amounts of ease for the achievement of a given fashion or garment style. Joseph-Armstrong [4] proposes some principles to identity ease allowances (ease, balance, grain, line, and set) were used to analyse the finished garments. Wang [1] classify design ease into 5 different types: close fitting, fitted, semi-fitted, loose fitting and oversized. Other important variables for correct ease garment fitting is the use of specific material (textile substrate) and the garment construction methodology, that, due to the type of sewing machinery used for production and type of sew used for joining garment different parts could interfere directly on structure and hardness of the final garment.

The need for a methodology in order to create a routine and to avoid possible errors is required. Young patternmakers are probably, the most interested target for this kind of methodologies, allowing to perform patterns alterations/adaptations in a quick and accurate way, increasing or decreasing wearability (widths/ease between the body and the garment) and relative comfort, in woven and knitted garments, in a proportional and balanced manner.

It is intended to develop a universal system to increase or decrease of garment amplitude (widths/ease) to be applied in different cases. This universality comes from the fact that the system should be possible to apply to quite the totality of the garments of the same typology (shirts, jackets, overcoats, vests, etc.) indifferently they are for man, woman or child. The system has to be universal with respect to the textile material involved into the manufacturing and liable to be use with orthogonal textiles as well as knits and non-woven. The methodology has to be useful for both patternmaking and draping technique and adaptable apart from garment construction methodology or pattern drafting principles and measurements, respecting and ensuring to preserve the basic and initial characteristics of the basic block. At the same time the system aim to improve better movement of the user's inside the garment, despite the garment typology or the garment wearer physical characteristics.

2 State of the Art

The development of drafts for cutting tissue is an important task that has technical features and key creative for the industry of clothes and fashion. Since the method presented by Juan de Alcega in 1589 [5], which was considered the first cutting method, many others have followed. Cutting methods developed since then, up to our days, had their development bases in many different elements. Since the methods of directly measuring the proportion methods, studies have undergone triangular methods, such as Klemm 1890, or ring system “The Tolerable Good Tailor” 1880, or systems in which the measurement unit was hand tailor himself [6].

Aldrich [7] in his “Tailors, Cutting Manuals and the Growing Provision of Popular Clothing” refers that only few garments drafting books written before the nineteenth century for dressmakers or tailors have survived. But it is clear, continue Aldrich, that cutting systems used by dressmakers and tailors were simple point to point instructions which enable them to cut basic garments or a fashionable coat shape.

The most amazing number of different tailor’s drafting systems emerged in the years between 1800 and 1850 [7]. Most of them were divisional systems: which divide major measurements proportionally; direct measurements systems: which identify most points by body measurements; combination systems: which are a mixture of the two. Wampen’s System was created by Dr. Hanry Wampen in Germany and was the first to analyse human surface anatomy. First published in 1860s his system is the first that proves that anthropometry could be translated into terms of garment cutting [8]. Wampen created a great number of models that give access to the creation of his garment pattern system that were well accurate and permitted an effective and efficient garment production, even apply the idea of the future mass production for ready-made market. Doyle [8] continues saying that Wampen laid out a manner of measuring the human form that affected the drafting systems that were to follow and had an immense influence on the clothing factory systems that would follow in the next century.

Today the development of new drafts building systems almost disappeared and in most cases are used systems of the 70s, where it is possible to achieve high quality and great technical levels.

If the last 400 years will lead several new methods for projecting two-dimensionally as a three-dimensional body, it doesn’t happened with the possibility, these different methods, applied bigger amplitude to the body to enable the user to feel more comfortable and could move better inside the garment. In this regard, Hulme [9] reported that if an easier garment is needed it can be produced in only one way—namely, to increase the breast girth (and, of course, the waist and hips) by the amount of the ease required […]. The possibility to adapt increasing or decreasing more or less amplitude to a specific garment is an important issue that deserve special attention in order to maximize comfort for the users wearing a cloth.

Investigation on ease allowance in patternmaking has to be distinguished on some points. First of all a difference have to be made between the upper part of the body and the lower part of the body due to the fact that the use of the garment and the movements made by the body, including arms and legs, are fundamentally different and with different purposes. Secondly, the garments used in the upper and lower part of the body are very different in use and structure and in the way they uses their verticality.

The garment-sizing system tabulates the dimensions of the garments that will fit the bodies in the body-sizing system after ease amounts have been set by the designer [10]. Because of the different markets, products and user´s age, production and designers needs diverge constantly and the creation of a common path it is impossible and even undesirable. Ease allowances are, in most cases, part of the construction and communication of the brand values and image. Ease allowances vary between manufacturers who make similar garments and this is due to the fact that manufacturers have freedom in deciding there ease allowances [11]. Watkins [12] refers ease as one of the most important factors for the designer to explore is movement capacity into a garment. As referred by Petrova [10] garment fit depends on the amount of ease added above and beyond the body measurements for comfort and style […].

3 Methodology

The present paper is part of a research project, being developed in different stages and applying distinct methods. Several garment drafting systems will be analysed (directs, semi-directs, proportional, etc.) than a record with the methodology parameters and limits will be set down. After the methodology concept set up a method for the application of the ease to the different parts of the pattern will be created. Active methodology will be applied for the application of the system to different cases that will be tested and validated in different garment typologies.

This paper is the first paper where a conceptual methodology will be set down and on a theoretical model.

4 Development and discussion

Having regard to the introduction to the problem of the need for a system for increasing and decreasing garment ease that could be simple and effective, we will list some characteristics which we believe are necessary and a gain for a system for the development and adjustment of the ease allowance in garments Table 1:

The list of the characteristics listed above is considered as a primary and basic feature a dynamic and useful system has to propose and explore. The suitability of the system for industry and designer scale garment production is important because the methodology action over the main basic block without altering or modify the basic features of the pattern draft. In order to develop a universal system, no matter what the basic block construction system used to develop the garment structure, the proposal of an independent ease alteration system that works on the principal body assets is a must have. Taking this characteristic as a main specific issue, the system and its conceptual theory could be apply to both men and women garment patterns without altering its principles and practice, even if the garment is intended for indoor or outdoor use, or even if the garment is considered anatomical or heavy constructed. Even if patterns basic blocks are specific for men and women and gather exact distinctive characteristics, main body reference points are identified on the garment draft and are not changed or modify in any way, the methodology

Table 1 Table of the characteristics for the WearAbility ease system

	System characteristics
1.	System must be suitable for industry and designer scale production;
2.	System have to be independent from the basic block construction instruction and have to be adaptable anytime;
3.	Must be universal and adaptable to women and men products;
4.	Has to be easy to apply to the patterns
5.	Has to permit different levels of amplitudes
6.	Must take into account the proportions of the basic block
7.	The system will be useful for the production of all kinds of garments, including outerwear
8.	System has to be useful for woven textiles and knits
9.	The system must permit the positive and/or negative application of the ease to the garment
10.	System principles have to be the same for man and woman
11.	System has to improve comfort
12.	System has to improve and facilitate movements

could be used for men and women being very easy to use and to apply. Its application, being proportional on the different points of the body have to permit different levels of amplitude regarding the kind of garment have to be made. At least but not last, the system have to be convenient for use with any textile substrate, including knits, and have to be suitable for positive and negative ease application to the garment.

It is important to refer that some confusion exists between ease allowance and pattern grading: It must be remembered that to increase the wearability of the piece (ease allowance) is assumed that the body to wear will be same and that this change will be implemented to allow a greater range of the garment. In this case the garment modify their width measures the workpiece, leaving the height unchanged. With regard to the development of the sizes (pattern grading) should be noted that this modification is applied to allow the same garment to be use in bodies with different measures (size) than the original, modifying, in this case, height measurements as well as widths. Even though this increase in size can take place occasionally, this should not be used as a way to increase the width of the garment, as the piece will be bigger but fail to adjust properly to the user's body.

Quantity of ease to apply to the garment is depending from the volume, aesthetics and requirements of use of the garments itself. Although the methodology used to apply ease allowance to the garment, it is important to understand where, into the patternmaking methodology, ease allowance is introduced or modified during the patternmaking garment development (Fig. 1).

The ease variation from one garment style to another may partially explain why garment designated with the same size may have different dimensions [10].

Differences have to be placed between garment fit and garment ease. Garment fit refers especially to the way the garment fit around the body and the way the different parts of the body (garment construction sectors) works together to respect

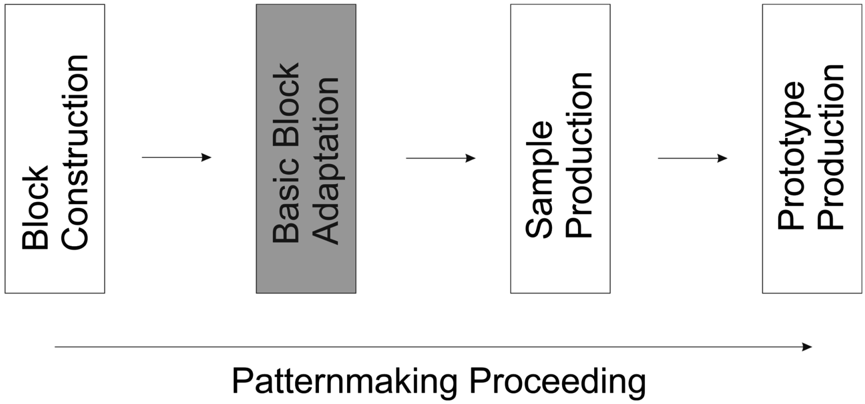

Fig. 1 Theoretical positioning of the WearAbility ease methodology inside the professional working patternmaking proceeding

body proportions and designer style line. Great fit could be achieved on the garment even if the ease is not considered balanced and adequate in terms of quantity. Garment ease refers to the ease applied to the garment (amplitude). When a great amount of amplitude is applied to the garment it doesn't mean that garment verticality and movement is balanced and granted for fit, especially is ease distribution is not proportional and equilibrate around the garment.

For the development of this project several garment drafting systems have been analysed and studied in order to understand in which manner they included ease allowance measurements during garment drafting construction and the level of intervention the patternmaker could apply on the system. The garment drafting systems analysed for this project are: The Science of Pattern Construction for garment Makers [13], Estetica e tecnica dell'abbigliamento maschile [14], The Modern Tailor, Outfitter and Clothier [15], The Theory of Garment-Pattern Making [9], Cappotti, Giacconi, Blusoni [16], Enciclopedia la Moda Maschile [6], Método de corte para sastres Garden Roux [17], Modern sizing and pattern making for women's and children's garments [18], Modelli base dell'abbigliamento [19], Methode de tracé de modèle, vêtements masculins sportswear [20], Pattern Cutting and Making Up [21], Pattern Cutting for Women's Outerwear [22], Pattern Cutting for Women's Tailored Jackets: Classic and Contemporary [23], Pattern Cutting for Lingerie, Beachwear and Leisurewear [24], Pratical Guide to Patternmaking for Fashion Designers [25], Jackets and Vests [26], Patronaje de Moda [27].

After the analyses of the garment drafting systems listed above it is to refer that all the systems, independently if they are direct drafting systems, proportional drafting systems, semi-direct drafting systems, or others, the inclusion of ease allowance into the garment drafting is part of the garment construction system and is not seen as a potential methodology that could work in an independent and autonomous manner. Exception is made for the Sergio Testi garment drafting methodology that proposes a method to modify and adapt upper garment ease for different cases [19]. Furthermore, quantity of ease applied to the garment is fix end could not be decided by the patternmaker in the moment when is planning the realization of a basic block or prototyping. Wang [1] refers that: "Since the distribution of ease in the garment is uneven and nonlinear, it is mainly determined by the experience and judgement of pattern maker.

Taking into account the method proposed by Sergio Testi [19] an adapted methodology is proposed in order to smooth the difficulties in applying different ease quantity to different upper body garments Fig. 2.

The WearAbility proposed methodology is applied in the same way to the back and to the front of the upper body garment and allow to apply different amplitudes depending from the needs of each garment. The proposed methodology aim to develop the upper side of the body and a methodology for the lower part of the body will be presented on a next research paper.

The presented methodology which is based on some aspects of the methodology presented by Testi [19], it is considered to be very dynamic and could be implemented in different types of upper body parts patterns drafts. The system is based on a standard application of specific values for each pattern drafting point that permit balanced dissemination of ease all over the garment. The ease values distribution will be apply as following:

The ease allowance values presented in table 2 are intended to be used for one level of the methodology being that the methodology proposes the application of multiple levels in order to achieve to achieve the width value required to develop the pattern draft of a specific garment, respecting garment drafting different construction sectors. Thus, taking into account that to each garment a different width may be applied, we may apply more or less ease allowances levels in order to succeed, in a balanced way, garments with different amplitude characteristics. For

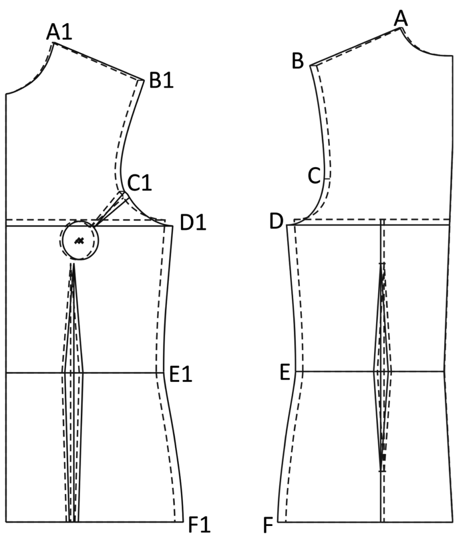

Fig. 2 WearAbility methodology applied to the *upper* body basic block

Table 2 Ease allowance values and distribution

Drafting point	Point identification	Value
A and A1	Neck-shoulder	3 mm
B and B1	Shoulder-arm	7 mm
C and C1	Arm notch	Same points B and B1
D and D1	Arm-chest	10 mm
E and E1	Waist	Same points C and C1
F and F1	Hips	Same points C and C1

the realization of a fit shirt one or two ease levels could be applied to the draft and for an outdoor garment may have to apply four or more levels.

For the decision of how many ease levels to apply to the garment that is being developed, there are other factors to take into account: thickness of the material used for the realization of the garment and their construction structure are some of them. The interior construction of the garment must be taken into account for the thickness of the finished piece which can be influencing by lining and interlining materials and also by the more or less heavy sewing techniques which can interfere with the workpiece stiffness and influence their falling.

The presented methodology allows each point of the pattern presented to expand the piece to be used independently, allowing the application of different values levels as an autonomously manner. For example, three levels can be applied across the all garment, but not to the shoulder width point if necessary to keep it small.

Application of this methodology to increase wearabilty (ease) to garments may be used for negative ease application. This is the case of knitted garments made by ribbs and that, because of the elastic material; they need to reduce its ease in a proportional manner.

5 Conclusions

Wearing ease and design ease are two different aspects of the same issue. When wearing ease is present and balanced, allowing the user to move freely inside of the garment without limiting user's movements and without causing any kind of discomfort, the attention of ease moves to the design aspect of the garment, taking into account that addressed the practical issues related to the use and comfort of the garment, any ease applied to the garment must be intended as a characteristic style.

The proposed system has been tested in patternmaking and very good results have been achieved. The methodology presented and its concepts can be applied to all garments of clothing for the upper side of the body which makes it proves very useful.

The points given for the application of the level values must be considered independent and to each point can be assigned a different number of levels, increasing the capacity of the system to adapt to the needs of its user. The system allows intervening in change in ease of the different sectors that make up the garment draft, thereby ensuring a wider distribution control capacity of the overall width of the vestment.

Its application can be considered universal and adaptation of the applied values, the system can be used for women's clothing, men and children.

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Fashion Design and Life Experience: Reduced Mobility in Ageing

Cristina Carvalho, Gianni Montagna and Carla Morais

Abstract Osteoarthritis is multiple and rheumatic disease is by far the most common. It is a degenerative disease that nature involves the entire joint: the cartilage wears away and the bone that grows and becomes denser. Of all the pathologies that affect individuals from forty years of life osteoarthritis is undoubtedly the most common and it is estimated to occur in about 90 % of the adult population. Osteoarthritis is a functionally disabling disease especially in daily activities that require greater range of motion of the members. The aim of this research enfold inclusive design of clothing and ergonomics, the impact of extrinsic factors that may contribute to the increase in garment comfort for individuals with specific diseases and can identify critical values such as pressure in different anatomical sites at risk, assess the impact of textile contact surface, patient modes easily use the proposed clothing, even when it reveals low capacity for mobility. This research aims to develop and application of appropriate clothing solutions to the specific needs of elderly or patients with osteoarthritis.

Keywords Osteoarthritis · Inclusive design · Garment comfort · Ergonomic garment

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1 Introduction

Osteoarthritis normally presents a loss of sensitivity in the regions of the body that contact with clothes, reduction of the autonomy of the ill person and the garments he uses, modifications of the muscle-skeleton position that make them more fragile and vulnerable to bone fractures, loss of force and flexibility in the muscles and in the joints [1].

Of all the pathologies that occur on individuals with more than forty years old, osteoarthritis is without a doubt the most common, it is esteemed that it may occur in about 90 % of the adult population; osteoarthritis is a frequent rheumatic illness and results on the gradual degradation of the cartilage and the bone. Osteoarthritis of the hip and of the knee they are most frequent, although, it can affect any joint [2]. Osteoarthritis is an incapable functionally illness mainly in daily activities that demand greater amplitude of movement of the members [3]. The main symptoms of osteoarthritis are pain, rigidity, movements' limitation and, in more advanced phases, bone deformations, as we can see in Fig. 1.

An anticipated identification of the people at risk is the adoption of preventive strategies is one of the priorities of this project. We have some questions that we would like to answer:

Which is the level of pressure and/or at the end of how much time the clothes adapted to these users do not provoke discomfort, increase motor incapacity avoids the possibility to hurt the body?

In what level other extrinsic local factors, as temperature or moistness, contribute for the occurrence of muscle-skeleton damages?

Which characteristics the garment must have to assure excellent conditions of comfort for these patients?

Which design and ergonomics level of requirements must be contemplated?

The present work wants to investigate, from the point of view of clothes inclusive design and ergonomics, the impact of the extrinsic factors that can contribute for the increase of comfort on clothes for aged people with these specific pathologies, being able to identify the critical values as the pressure in different anatomical points at risk, to evaluate the impact of the textile surface contact, ways

Fig. 1 Example of osteoarthritis in knee and in hands

for the patient to easily use proposed clothes, even when he reveals low mobility capacity [4].

Through the incorporation of sensors, we intend to identify values (pressure, temperature, moistness, etc.) corresponding to comfort/discomfort levels and establish relations between its magnitude and duration, and the motor reactions of healthy people.

These values will be used to define a protocol of data acquisition versus eventual alert and/or intelligent automatic actuation to obtain the same results that healthy users reach without any limitations [5].

The osteoarthritis treatment represents enormous costs in financial and human terms. According to the United Nations the aged population in the 90s was quantified in 330 million, in 2050, they foresee that it will rise to 1 billion and 500 million. In resume, in a space of 50 years this number will quintuple. In Portugal, in 1992 the incumbency of the Health National Service (SNS) was of 77.5 million euros, on the consumption of anti-inflammatory steroids for the treatment of these pathologies, therefore, supporting 69 % of global the pharmacological expenditure. Currently the costs associated to osteoarthritis represent about 2 % of the GIP in developed countries. As a result we are dealing with a pathology with high social and economic impact, not only for its secondary costs, as well as for its repercussions in the labour sphere, but also for the necessary support resources and treatment of sick people [6].

This multidiscipline project, will allow the involved investigators, doctors, nurses, patients, users and pupils the interchange of knowledge and an elevated sensitization for the daily motor difficulties of this aged/patient, where it is also included other individuals with motor limitations, as it is the case of people in post traumatic rehabilitation [7].

2 Literature Review

Osteoarthritis is multiple and rheumatic disease is by far the most common. It is a degenerative disease that nature involves all the joint: the cartilage wears away and the bone that grows and becomes more dense. In this degenerative process occurring more or less important phenomena of joint inflammation causing pain, stiffness, swelling of the joint, limited range of motion to the deformation [8]. There joints that is more common emergence of the disease: the knees, hands, hips, spine and feet.

It is very important, to built a system in the field of e-textiles and clothing applied to public health issues, safety and comfort.

It is also necessary to promote the national and international textile garment industry introducing new skills and knowledge in this area, e-textiles and clothing as valued products applying inclusive design as a tool [9].

Develop new approaches for producing “smart garments”, or e-textiles which can involve modifications in its fibres/yarns or surfaces production; appeal to biochemistry engineering/ biotechnology and textile technologies and inclusive design, seems to be adequate to a researcher interested in the area of interactive textiles with new concepts and scientific technologies. This is a very stimulating area of research and very useful to the potential user.

Electronic wearable solutions are presently a major area under research and textile development. Several solutions were proposed in these past few years, comprehending different fields, namely in multimedia and health, where critical ages need to be monitored—babies, ill persons or elderly persons [10].

Inclusive design and development of new concepts on clothing prototypes related with maximum comfort, and comprehension of the best combination of textile material with embedded microelectronics for signal acquisition and data transmission;

Using seamless knit technology is a specific feature that provide a production of a knit garments with reduced making-up processes, shorter throughput times and even greater pattern variety—to produce Knit and Wear garments fast and economical [11]. This minimum number seam garment production technique is a great value for motor impairment persons that usually are victims of osteoarthritis, because of the absence of any bulky jointure between fabrics and absence of sewing yarns results in no chafing or rubbing against the body [12].

The clothing industry needs to develop products with new technologies for embedding micro-sized sensors and actuators in textiles substrates/surfaces; micro sensors for biological and biomechanical measurements, such as temperature, humidity, pressure/compression; universal electronic systems for power supply, data acquisition, processing, management, and communication working for both environments and embedded on textile substrates [13]. There are several biotech and nanotechnology solutions can also be embedded on textile substrates and improve special functions, as for example bioactive properties, on garment [14].

Ergonomic and sensor characteristics should be designed, produced and tested, in order to validate the proposed garment solutions [15].

The development of special garment for elder people with motor diseases can present several noticeable repercussions in National and International Communities, as well as to the promotion of comfort, safety and improve the rehabilitation processes through the clothing [16].

The development of special clothes that will be used by elder people with motor impairment as osteoarthritis (OA), at the same time can give them comfort and even prevent risks on their health. Improved technology can be produced allowing the most innovative monitoring, ambulatory registration, real-time visualization and post-motor activity display of both physiological and biomechanical relevant data (heart-rate, respiratory frequency, sweat, etc.) with a view to further improve the performance of clothing [17]. Growing in complexity, but keeping in the same research line, it is expectable to accomplish the development of the prototype clothing with same or different type of parameters, thinking also on motor limitations of as well as other more complex rehabilitation processes [18]. In all cases, important repercussions are expected for users, garment designers, scientific community and production textile and garment industries, allowing an increased comfort and safety in physical activity, an augmented objectivity—and efficiency—of the elder people use/dressing process, and an easy data collection for scientific research in neuro-physiology and biomechanics sciences [19].

On the other hand the technologies that will be used and know-how gained can be of significant importance for our garment/textile industry [20]. Since this kind of research is quite expensive for companies, universities and research units can partially support the industries by providing this know-how.

3 Methodology

To develop a system in the field of e-textiles and clothing applied to public health issues, safety and comfort.

- Promote a positive impact in the national and International textile garment industry introducing new Skills and knowledge in this area e-textiles and clothing as valued products;
- Develop new approaches for producing “smart garments”, or e-textiles which can involve modifications in its fibres/yarns or surfaces production;
- The researcher group intends also to propose new garment shapes and a easier use of garments, developing new textile surfaces with sensors, particularly at micro scale and if possible for smaller scales. The objective is to be involved in textile, biotechnology, nanotechnology and electronic researchers;
- To develop garment textile prototypes for elder people, quantification of several biological and mechanical parameters, critical for use and dress performance and health purposes, is crucial. The main ideas to overcome and address the several criteria and technological parameters are;
- New design and development of new concepts on clothing prototypes related with maximum comfort, and comprehension of the best combination of textile material with embedded microelectronics for signal acquisition and data transmission;
- Seamless Stoll® Knit and Wear-Class knit technology is a specific feature that provide a production of a knit garments with reduced making-up processes, shorter throughput times and even greater pattern variety—to produce Knit and Wear garments fast and economical;
- This minimum number seam garment production technique is a great value for motor impairment persons that usually are victims of osteoarthritis, because of the absence of any bulky jointure between fabrics and absence of sewing yarns results in no chafing or rubbing against the body;
- New technologies for embedding micro-sized sensors and actuators in textiles substrates/surfaces;
- Proposal of new micro sensors for biological and biomechanical measurements, such as temperature, humidity, pressure/compression;

- Universal electronic systems for power supply, data acquisition, processing, management, and communication working for both environments and embedded on textile substrates;
- Several biotech and nanotechnology solutions can also be embedded on textile substrates and improve special functions, as for example bioactive properties, on garment;
- Ergonomic and sensor characteristics will be drawn, produced and tested, in order to validate the proposed solutions;
- Validation of garment prototypes based on the team's previous experience and research;

The development of special garment for elder people with motor diseases can present several noticeable repercussions in National and International Communities, as well as to the promotion of comfort, safety and improve the rehabilitation processes through the clothing.

4 Tasks Description and Expected Results

First task has the objective of coordinates the researching group in the way to optimize time and resources. Special contact with final users and dedicated associations will be promoted during this task with the aim to collect data and specific needs of this specific target. The information of a specific questionnaire driven to older people will be resumed and organized in proper worksheets. The collected information will be adopted by the investigation group as a basic tool and used to better understand needs and design better solutions. Since the beginning till the conclusion of the investigation, monthly meetings will be promoted between the group members with the aim of sharing ideas, interim results and to drive specific methodologies in a better and coordinated way.

Further and specific concepts will be explored into this task. The definitive way to try to solve the problem will be chosen. Interacting between all members will be crucial at this time. All the elements regarding the problem will be analysed and all the specification must be produced by the group for all the tasks. Materials will be chosen and the acting line traced. Technical limitation must be valuated and a solution found. Special care will be taken on discussion about garment basic shape design, sensor integration, sensor system specific needs, row material usage, ergonomics, textile structure, and user utilization of garments.

Special attention will be driven to all comfort aspects for people with motor impairment.

Prototyping design will start considering the main problems usually found in osteoarthritis disability as a first step. Different shapes will be designed and a research on appropriate knit structure will be conducted with the aim to take advantage from the basic natural properties the knit fabric could produce: heat, refresh and compression.

The research of a specific pattern for body posture and the creation of a specific measurement chart and specifications will be an important part of the design work.

Specific attention will be paid to the possibility of compensation of different body areas in order to produce heat compensation, usually more pronounced and difficult to obtain in older people or motor impairment persons. In this case, double threads zones will be marked and a used of a specific conductive yarns or micro capsulated rechargeable treads will be used inside the garment.

Ergonomic contribute and evaluation will be a constant support during the design process as a fundamental tool of the design process.

During the development task the sensor system will be developed and tested under different conditions and different signals will be shared and integrated in order to collect specific data. At the same time, garment prototypes will be tested for shapes and comfort with different groups of final users under different conditions.

Produced clothes will be integrated with the smart system and tested in terms of garment material used for production and adopted knit structure. Special attention will be given to sensor positioning inside the garment in order to collect data.

A specific questionnaire directed to final users will be produced for registering goals and disadvantages of the produced prototypes.

As a final step, garments will be tested in terms bio-signal collecting and receiving data under different conditions and with the smart system mostly embedded into the textile substrate. Quality of signal must be good enough to permit a garment reaction to improve user's well being.

Data modelling will be very important in order to resume final user's behaviours and to permit the creation of behaviours' models, needs' patterns and a possible national information database on elder's people to use a reference for future works on this subject.

5 Final Considerations

The proposed project is inspired in all emerging technologies and intends to apply them in a "smart garment" which should allow comfort and well-being to elder or osteoarthritis patient.

The advent of biotechnology and nanotechnology constitutes a big impulse for e-textiles by means of the complete merging of electronics in textile substrates. With the purpose of producing highly advanced equipments, the research of e-textiles with specific properties which can replace some of the actual sensors in use. The major advantage is the fact that textile and electronics are one single material, thus contributing to more comfortable garments for all.

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Open Inclusive Fashion: New Insights for a Co-design Platform

António Lucas Soares, Eric Costa, Solange Mazzaroto, Miguel Carvalho, David Allen, Kathleen Wachowski, Eric Gehl, Veronique Barreau, Deza Nguembock and Fernando Nunes Ferreira

Abstract This paper intends to propose a platform dedicated to a community for inclusive fashion. This platform can innovate in the awareness creation process by involving a wide range of stakeholders through a novel combination of visually-centered networking/collaboration together with a powerful recommendation system

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based on data analytics. This solution can potentially impact positively the well-being of more than 50 million of motor/physical disabled citizens as consumers of fashion products. This can be achieved by bringing together three different networks: (i) fashion consumers, emphasizing consumers with disabilities; (ii) companies from fashion/garment/footwear industry; (iii) social and research organizations supporting disabled people. This will allow to create individual and collective awareness about sustainability at the social level demanding the engagement of groups of citizens and industries in sharing information and knowledge and developing ideas and solutions for people with disabilities facing problems related to fashion, garment and footwear products and services.

Keywords Design for inclusion · Open inclusive fashion · Collaborative awareness · Co-design platform

1 Introduction

According to the European Union Agency for Fundamental Rights [1], some 80 million European Union citizens have a disability, with 70 % of them (almost 60 million) with a motor/physical one. In a social approach, disability is understood as the result of the interaction between the individual's impairment and the barriers created by society (be social, environmental and attitudinal) [2]. In 2010, the European Commission adopted a strategy to break down barriers that prevent disabled people from participating in society [3]. The values of dignity, autonomy, equality and inclusion were defined as key EU principles. With the UN's most recent human rights treaty, the Convention on the Rights of Persons with Disabilities (CRPD), the core concepts of self-determination, participation and inclusion have been expressly linked to people with disabilities [1].

Fashion is part of human life, transversal to all genres, geographies, religions, economies, and ways of life. It induces happiness most of the time, but it can also contribute to forms of delusion and social exclusion. Particularly when considering people with disabilities, fashion cannot be considered a vehicle for inclusion, rather it is the contrary most of the times. Fashion is an industry pushing lifestyles to the consumer, and being pulled by basic to sophisticated consumer needs. Pushing is the prevalence, so the disabled and other minorities seldom have a voice in what concerns to fashion. This creates a kind of "lifestyle exclusion" of a big minority of people. The lack of empathy of society towards disabled's lifestyle represents another barrier for the inclusion of people with disabilities from participating in society. In Europe, millions of people with disabilities experience difficulties with garments and footwear every day, i.e. clothes and shoes do not fit properly or are difficult to wear. Moreover, these consumers seem to be excluded from the fashion industry target markets. This prevents these people from enjoying the well-being that follows from being able to create or choose their own image from a fair amount of choices adapted to their disabilities. In fact, the meagre offer of fashion products and services, the poor knowledge and engagement of the fashion/garment/footwear industries in what concerns to people with disabilities, and the unawareness for the citizens is likely to make this societal problem ongoing.

This paper intends to address this as a sustainability problem at the social level, proposing a platform to empower disabled citizens through participation and interaction. The platform will be dedicated to a community for inclusive fashion aiming to create individual and collective awareness by using state-of-the-art social media technologies together with modern data and information management techniques. This paper is the first formal presentation of the platform, providing its rationale, a brief description of the concept and approach, as well as some of the expected impacts.

2 Rationale for the Collaborative Awareness Platform

The above described social sustainability challenge is addressed by proposing a collaborative awareness platform that will empower disabled citizens, as fashion consumers, through distributed networking and online collaboration. This can represent the first platform and community dedicated to inclusive fashion, and will innovate in the awareness creation process by involving a wide range of stakeholders—disabled consumers, socially responsible companies and disability experts—through a novel combination of visually-centered networking and collaboration together with a powerful recommendation system based on data analytics. Such collaborative platform will create awareness in three complementary ways:

(i) by involving fashion consumers, emphasizing consumers with disabilities, in sharing expectations, ideas and experiences aiming to stimulate the industry offer; using the services of the platform, disabled fashion consumers will be able to communicate visually and interactively fashion concepts, ideas, concerns and collaboratively co-design solution concepts that, eventually, can be developed by interested companies;

(ii) by involving companies from fashion/garment/footwear industry: from one side in learning from a community of consumers with disabilities and, from the other side, in contributing with knowledge about fashion design and production; engaging companies and consumers in a networked dialog for knowledge co-creation will hopefully result in ideas and concepts for the design of adapted fashion products and services;

(iii) by involving social and research organizations supporting disabled people, bringing specialized knowledge on how to engage and empower the disabled citizens as fashion consumers.

The platform's ambitions are to foster the co-design of fashion products and services by a collaborative network of consumers with special needs, companies

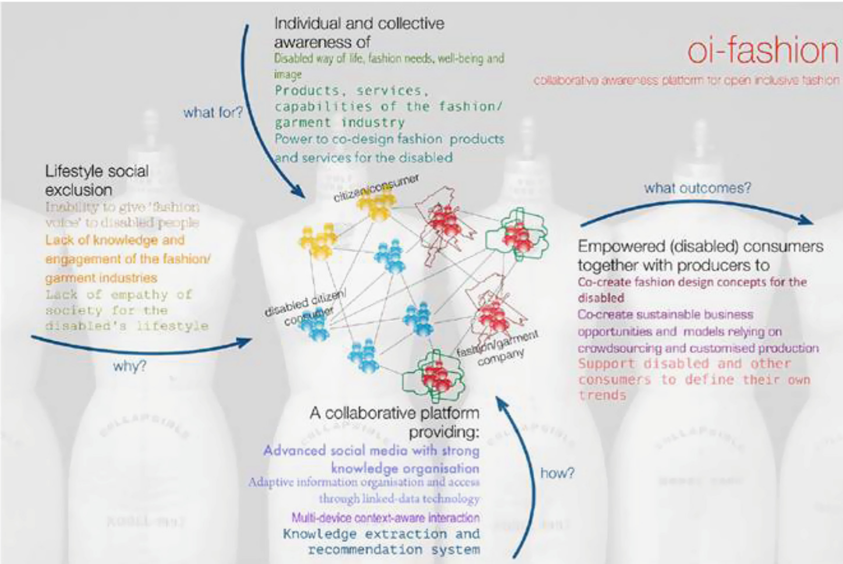

Fig. 1 Rationale for the collaborative awareness platform

belonging to the fashion industry, and multi-disciplinary specialists contributing to an all-inclusive well-being society. Figure 1 presents the platform's rationale: why, what for, how, what outcomes.

3 Concept and Approach for the Collaborative Awareness Platform

This user-driven collaborative platform will empower and foster awareness in the existing community of disabled citizens. This platform is aimed at different types of users: citizens/consumers with disabilities, caring people of disabled people, general citizens/consumers willing to contribute to the well-being of people with disabilities, organizations supporting the disabled and fashion/garment/footwear companies willing to be aware of expectations and needs of consumers with disabilities.

This can integrate several online communities of disabled citizens together with fashion industry companies and disability experts through an innovative combination of a distributed, image-based, social network, an interactive co-design tool of fashion concepts and a recommendation system based on the social-network generated data. The resulting community will raise awareness on the inclusive fashion social sustainability problem through the improved communication and visual oriented collaboration services provided by the platform. This will have a significant impact on the self-esteem and well-being of the disabled citizens and will pave the way for a visible and positive economic impact in a market normally seen as unprofitable.

The platform can take the needs of lifestyle inclusion and self-esteem of people with disability as a starting point and engage them, the general public, socially responsible fashion industry companies and disability experts in a process of developing collaborative fashion concept designs as a lever for awareness creation. Another lever that will contribute to start this initiative is the actual participation of already-existing networks of interest and communities of disabled persons.

Collective awareness (Fig. 2) will be achieved through the dynamics of an online community supported by a social network centered on visual information and by synchronous and asynchronous collaboration with the purpose of co-designing fashion concept designs.

Photographs, sketches, videos and other visual content will be uploaded or created online by the users and can be collaboratively annotated with metadata and superimposed drawings or sketches. Comprehensive individual and group social-network profiles will support the automatic and manual establishment of ties between the users, linking them to the generated visual information. Self-presentation and self-representation are of utmost importance in this type of community. Knowing the history, experiences and expectations of each member increases their credibility and the perceived-value to the community of their contributions.

An application will enable the collaborative creation, edition and discussion of fashion/functional design concepts through both creating stencil based sketches from scratch on a canvas, and superimposing sketches and adding comments, suggestions and other annotations to uploaded visual media content. Examples of

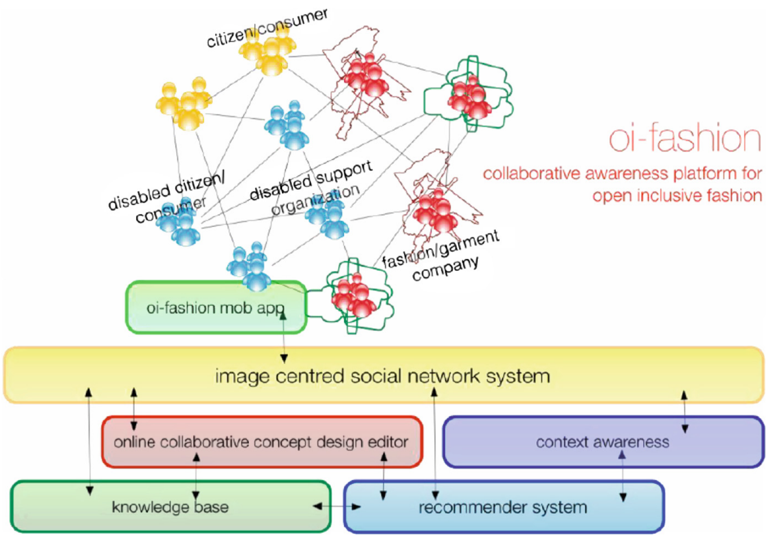

Fig. 2 Overall concept for a collaborative awareness platform

specific collaborative content are fashion designs—fashionable garment and footwear (stylish appearance); functional finishing—garment and footwear that fits the body properly and enhances the wearer's abilities and personal image; sustainable products—garment and footwear made in sustainable ways and with sustainable resources.

The social-network and the collaborative co-design application will be powered by two features: (i) a knowledge base with knowledge extracted from the social network data together with data provided by the fashion/garment/footwear companies and the disabled support organizations; (ii) a recommendation system giving suggestions on fashion and functional design. The recommendation system will rely on analytics techniques applied to the social-network generated data.

The platform will be accessed through a mobile or desktop application where, besides co-designing fashion/functional concepts, the user will do the usual social networking activities such as browsing the images, commenting, interacting with others, creating interests. Mobile application access will be used to create contextual links that can be used for immediate awareness. By using the mobile application, contextual data such as location or proximity to stores and other points of interest will be recorded to be used by the recommendation system.

The stakeholders will be not only industry and academia but also local communities, family members of disabled persons, activists for an all-inclusive society, social entrepreneurs, students, citizens, and civil society organizations. The platform will be unique as it can bring together disabled person with traditional manufacturers in one space, transforming extant business models and creating new models of corporate social responsibility (CSR).

4 Advances Beyond the State-of-the-Art

4.1 Collaborative Awareness

One of the goals of the European Commission is to raise awareness of different societal, economic and sustainability problems among citizens and mobilize different categories for trying to solve these problems. Among all the categories, this platform will be focused on: (i) people with disabilities and mobility impairments, elderly and their caregivers, and parents using strollers for their children; (ii) users of online communities interested in knowing more about their data and in defending their online rights [4]. Virtual communities are considered a source of information as well as a means of social interaction [5]. Schau and Muniz [6] found that participating in a community helps members to gain confidence and validation of self-identity.

Therefore, this collaborative platform intends to create links with the broader consumer community and foster the social and business interest of the fashion industry. To create awareness it will involve a wide range of stakeholders—

disabled consumers, socially responsible companies and disability experts—through a novel combination of visually-centered networking and collaboration together with a powerful recommendation system based on data analytics.

4.2 Communication Channels

Annett-Hitchcock and Xu [5] developed a study entitled "Shopping and virtual communities for consumers with physical disabilities" which was conducted in order to provide some insight into how the Internet can facilitate the sharing of information about fashion products for consumers with disabilities and fill a gap on the development of studies in this area. From the websites found (Apparelyzed; Disabilities-R-Us; Abledbody; Disaboom; New Horizons and Luvwhatyouwear) the Apparelyzed was selected as the biggest one. Researchers selected all posts directly related to clothing, fashion, accessories and shopping. From the data obtained, areas, categories and words that appeared more frequently were analyzed. In general, this study found that there is a gap between retailers and consumers with disabilities. There are limited opportunities for people with disabilities to interact with retailers other than those offering 'specialized' products. A number of small, independent companies serve the needs of this population, with different degrees of emphasis on fashion and function, and mostly online. These authors also concluded that future studies might look at the possibility of online communication channels, exploring marketing, product development and brand recognition on a global level, addressing a variety of disabilities types.

The collaborative awareness platform proposed in the present paper will serve as a communication channel between the disabled and fashion industry. From this integration they will be able to create products about fashion clothing and solutions that meet the specific needs of this population, addressing the suggestions of Annett-Hitchcock and Xu [5].

4.3 Collaborative Design

Understanding the voice of the consumer and how consumers with different needs interact will ultimately enhance product design. People with disabilities traditionally view clothing and fashion as an adaptive art, where it is up to the consumer to find a way to adapt something to suit their needs. Their desire for style and image can even be perceived as stronger than able-bodied consumers, as apparel products are appearance management tools, which could be utilized to downplay visual impact of the disabilities that they may have. A few examples of studies with a specific focus include donning and doffing, fabrication, construction quality, thermal comfort, seamless knitting technology. Unfortunately, this wealth of research has not translated into much improvement in the general availability of clothing and accessories in mainstream retail stores [5].

Therefore, the objective of the platform is to foster the co-design of fashion products and services by a collaborative network of consumers with special needs, companies belonging to the fashion industry, and multi-disciplinary specialists contributing to an all-inclusive well-being society.

4.4 Clothing Acquisition

The acquisition of clothing for people with disabilities and mobility impairments is a process that needs better understanding. Crosier and Handford [7] found that shops are not prepared for accommodate disabled people, turning shopping into a humiliating and negative experience for these consumers. Limited sources are available for these consumers to seek information or advice regarding apparel acquisition. In addition, it is hard to find research that looks at acquisition from the consumer perspective. So, information through word of mouth from peers who have similar backgrounds becomes more important for these consumers. There is a strong potential for virtual communities for consumers with physical disabilities not only to share information, but also to assist in the decision-making process of product purchasing.

This collaborative platform will help the fashion industry to develop clothing for people with disabilities and mobility impairments, while taking into account shared information regarding their specific needs. The people interested in acquiring these clothing will have access to information that would help them during their decision-making process of product purchasing.

5 Expected Impacts

5.1 Primary Impact

This platform will be the first collaborative platform dedicated to disabled fashion and potentially impact positively the well-being of more than 50 million of motor/physical disabled citizens as consumers of fashion products. There is not a real community about fashion and disability EU-wide. People are still surprised that the 2 words ‘aesthetics’ and ‘disability’ could be mixed, even disabled people themselves. According to the European Union Agency for Fundamental Rights [1], some 80 million European Union citizens have a disability, 70 % of them with a motor/physical one. Thus, millions of people with disabilities experience difficulties with garments and footwear every day, i.e. clothes and shoes do not fit properly or are difficult to wear. Moreover, these consumers seem to be excluded from the fashion industry target markets. This prevents these people from enjoying the well-being that follows from being able to choose their own image from a large amount of choices adapted to their disabilities. People, having short-term injuries due to accidents as well as elder people having mobility problems due to their age are in a similar situation (in Europe, people aged over 65 represent 17 % of the total population (89 million in 2008) and are expected to reach 29 % by 2050). The platform can significantly contribute to overcome this situation by involving the community in an active and creative way.

5.2 Secondary Impact

The active participation of numerous branches of the social life in the European society in a common platform will create awareness of the industry towards the disabled community, which will positively influence decision making regarding this market segment. The increasing individualization demands more and more personalized approaches in any kind of services, and especially in the services for disabled people. That is why ideas, experiences and concepts developed together by consumers, enterprises, research centers and specialists stored in the knowledge base of the platform, can create business opportunities that fulfill the disabled consumer needs of a high personalization, what can be applied also for people without disabilities. As the platform will be crowdsourcing ready, there is an enormous potential for the identification of business opportunities and the creation of new business models addressing the new markets fostered by the platform.

The customization need for disabled people is immense and is today covered mainly by very small producers offering marginally very functional and less fashionable products. Retailers as well as brand owners are mainly interested in distributing mass market-oriented products manufactured in low-cost countries, while online shopping cannot currently satisfy this category of consumers since most of the time, online garment, shoes purchases need to be adapted. This results in the production of small quantities and high production costs, making them accessible only to a small portion of this population and not providing enough income to the companies involved in this niche business. The development of an international niche market of adapted, personalized fashion for disabled people is a chance for the European textile, clothing and footwear industry, representing around 1.2 million employees (0.9 Textiles and clothing, 0.3 Footwear and 1.2 Furniture), a chance to minimize the delocalization in cheaper labor countries outside the EU.

By this way, the platform may contribute to empower not only people with mobility impairments to express their wishes and needs but also textile, garment and footwear companies in EU with economical obstacles to develop personalized products for all. In this manner, the big difference between people with and without disabilities will disappear with the time.

6 Conclusion

Although people are becoming more aware of this situation, disabled citizens still experience difficulties with garments and footwear products and services. Their desire for style and image can even be perceived as stronger than able-bodied consumers, as apparel products are appearance management tools, which could be utilized to downplay visual impact of the disabilities that they may have. It is important for the industry to recognize the needs of this market segment, both the special function-related utilitarian need and the image/style related to hedonic need. Disabled people represent a large and untapped market that is far from being fully addressed. Nevertheless, there are now some designers involved in the creation of fashion for people with special needs. However, they are still insufficient to meet the demands of current needs.

Millions of disabled citizens participate today, as fashion consumers, in small/local, more or less dedicated, online communities. They try hard to overcome the lack of awareness and empathy from the fashion industry and other citizens but the outcomes are very limited as their voice is not loud enough due to the low density of their networks. This is a clear, long-lasting social sustainability problem. It is thus a challenge and an opportunity to use the collaborative power of ICT networks to integrate, amplify and metamorphose these small/local communities into a global distributed social-network, beyond the limited Facebook stereotype, fostering not only knowledge networking but, above all, active ways for the involvement and the creation of awareness and empathy. State-of-the-art social media technologies together with modern data and information management techniques can thus be used to develop a collaborative awareness platform that joins the vast but dispersed community of disabled fashion consumers, create links with the broader consumer community and foster the social and business interest of the fashion industry.

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Part VII
Design for Inclusion: The Japanese Perspective

Applicability of HAPTICS for Universal Design: A Study to Develop a New System for Visually Impaired People

Masayoshi Kubo

Abstract Since communication services have become more readily available because of the emergence and spread of advanced mobile devices, such as smartphones, the information lifestyle of consumers has begun changing significantly. However, it is difficult for the visually impaired to operate smartphones equipped with touch-panel graphical user interfaces (GUIs); consequently, the information gap between those with and those without normal eyesight has widened. We developed a new text-entry method and conducted the user survey. We also explored, assessed, and tested a new communication method using vibration. The results from a hearing test we administered showed not only a strong interest in using smartphones, but also a deep anxiety about the inability to use touch panels such as bank ATMs. The newly developed three-point Braille input method showed higher values ($P < 0.05$, $P < 0.01$) for many items, compared with the existing two-point method, and the new method's benefits were confirmed. As newly developed vibration system, it is clarified haptics gives the [short–long] images by changing the component of vibration. Haptics also gives the various pattern of impression such as [weak–strong], [short–long], [decrease–increase] on the visually impaired. In this study, we proposed and evaluated smartphone text-input and vibration sensing for the visually impaired, and found a new direction for text-input systems that would be easy for them to use. We also see a new direction for transmission systems.

Keywords Visually impaired people · Smartphone · Braille text entry · Vibration communication

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1 Background

It has sometimes been said that visually impaired people are informationally disadvantaged because they cannot fully take in visual information. In recent years, the information environment has changed significantly for visually impaired people due to the spread of Braille text display devices1. Information networking through the internet has become indispensable for everyone, including visually impaired people. With the emergence and spread of smartphones, people's lifestyles have changed tremendously. Touch screens enable sensory and intuitive operation of cell phones, accelerating the rapid spread of smartphones, even for new users. On the other hand, the touch screens of smartphones based on GUI operating systems are difficult for visually impaired people, who have difficulty handling visual information, to use, increasing the information gap between visually impaired people and those with normal eyesight. Few studies have been done on the accessibility of touch screens for the visually impaired, so this study seeks to fill that gap.

2 Purpose of the Study

In today's society, visually impaired people are severely handicapped in terms of information acquisition compared to those with normal eyesight. With the development of ITS technology, touch screens have become standard for information and telecommunication devices. This has widened the information gap between visually impaired people and those with normal eyesight.

However, even visually impaired people cannot ignore the convenience of smartphones. Making phones accessible to the visually impaired will solve a number of problems. This study has two main goals:

1. To identify the problems with several text-entry methods and propose an easy-to-use text-entry method to allow visually impaired people to use a touch panel. In what follows, we will refer to this as "the innovation in text entry."
2. To examine the possibility of vibration cues as a method for the visually impaired to use touch screens. In what follows, we refer to this as "the possibility of introducing vibration communication".

3 Method

3.1 Procedure

The innovation in text entry

- Select survey content and survey items derived from previous studies.
- Perform an audio survey and a text-entry evaluation experiment using touch screen devices and several test subjects.
- Propose improvements to the user interfaces based on the survey results.
- Perform a heuristic survey that includes the proposed improvements.

The possibility of introducing vibration communication

- Examine how different test subjects experience different vibration patterns associated with different touch screen gestures. The participants were divided into two groups: young, healthy subjects, and impaired subjects, either visually impaired or deaf.
- Investigate whether the different subject groups feel phone vibration patterns differently.
- Propose appropriate haptic feedback for different situations and gestures.

The study aims to identify the problems of different text-entry methods and to propose an easy-to-use text-entry method that will allow visually impaired people to use a touch panel.

To reach these goals, we sought to verify the universality of tactile feedback. The goal of the survey was to determine whether visually impaired, deaf, or young, healthy cell phone users experience tactile feedback differently, and to identify the vibration parameters that all groups experienced similarly.

Specific components of vibration patterns (amplitude, periods, vibration time, and shape) were taken from previous studies. Seven different vibration patterns were used in this study. The subjects were exposed to tactile feedback in the form of phone vibrations. Analysis of subject responses enabled us to verify the effectiveness of tactile feedback.

3.2 Survey

The innovation in Braille text entry

Implementation period: Dec. 9 to Dec. 20, 2011
Implementation site: Kyoto Lighthouse, which is a facility for visually impaired people
Participants: 20 visually impaired persons
Confirming the possibility of introducing vibration communication
Implementation period: Dec. 19, 2015 to Jan. 21, 2016

Fig. 1 The survey location

Implementation site: Kyoto Institute of Technology, Kyoto Lighthouse, Kyoto Deaf Association
Participants: 19 visually impaired, 20 deaf, and 23 young, healthy people.

3.3 Survey Method

The survey was conducted in a private room. Subjects used a smartphone and were asked to evaluate three prepared text-entry methods and to shake the phone to evaluate vibration patterns. In both cases, testers filled in the subjects' survey answers after reading the questionnaire aloud. For each subject, the total required time was 50 min, and the interviews were recorded on an IC recorder to prevent incomplete forms. The Fig. 1 shows the survey location.

3.4 Survey Equipment

The innovation in text entry

For this study, subjects used the iPhone4, Xperia acro, and GallaxySII2. A landmark designed to inform users of the operation position was installed in each smartphone. The entry methods were illustrated with a plastic position guide and an explanation table in Braille.

Confirming the possibility of introducing vibration communication

Fifteen patterns of finger gestures were selected. For visually impaired subjects, eleven patterns of gestures were selected. For deaf subjects and the young subjects, four patterns of gestures were selected. Table 1 illustrates all the gestures.

The visually impaired used a double tap, swipe left or right, two finger tap, two finger double tap, hold and tap, two finger swipe, three finger double tap, three finger swipe, four finger double tap, and rotate and swipe.

Table 1 Gestures

4 Results

4.1 *The Innovation in Text Entry*

Visually impaired people and text entry

From the verbal survey, the following problems for the visually impaired with portable information devices, text entry, and the like were identified:

- All the test subjects use a cell phone, making it a daily necessity for visually impaired people.
- Most visually impaired people use a Braille information terminal, Plextalk.
- Many visually impaired people are frustrated with their device.

- The auxiliary audio function is slow.
- It is difficult to convert to Kanji.
- It is difficult to operate the device in noisy environments because the auxiliary audio function support is hard to use.

The audio survey revealed that:

95 % of the test subjects were inexperienced with smartphones.
90 % of them stated that they wanted to use a smartphone in the future.

Subjects wanted to use a smartphone because smartphones are convenient, because the subjects want to use a device that many sighted people use, and because subjects were anxious about their inability to use a smartphone.

Evaluation of the entry methods

Test subjects used smartphones to enter text using various methods. The time required for text entry was measured, and each entry method was evaluated.

1. Survey content
    - Subjects entered a sample text using the double hand-tap method, the three-point Braille entry method, or the one-line entry method.
    - The time required for text entry and the number of entry errors were measured in order to obtain a numerical evaluation of each entry method.

Survey hypotheses

We proposed the following hypotheses:

H1 Of the three input methods, the "double hand-tap method," the "three-point Braille entry method," and the "one-line entry method," the three-point Braille entry method is the easiest to use (Fig. 2).
H2 Methods with prompt text entry are also easy to use overall.
H3a The double hand-tap method is easier for users who prefer the toggle method.
H3b The three-point Braille entry method is easier for users who prefer six-point Braille entry.

Survey results

1. The ease of use of touch screen text-entry methods for the visually impaired.

A statistically significant difference in terms ease of use was only found between the one-line entry method and the double hand-tap method ($P < 0.05$). The results

Fig. 2 Entry method evaluation test for example texts

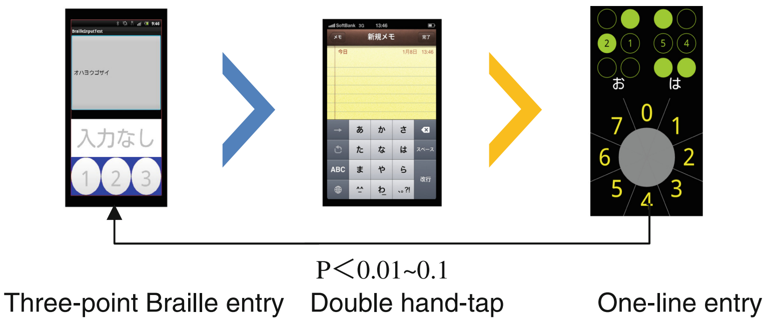
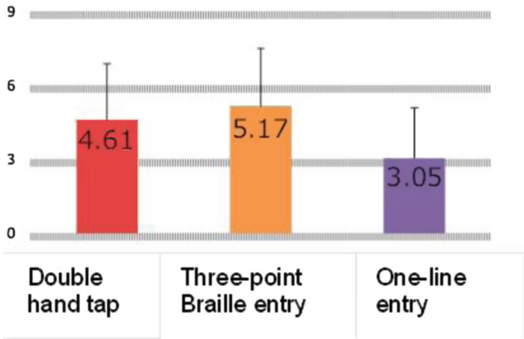


Fig. 3 Comparative evaluation of the text-entry methods

Fig. 4 Entry method evaluation test for example texts



are not absolutely certain, but we found an average evaluation value of 3.6 for the one-line entry method, 4.6 for the double hand-tap method, and 5.2 for the easiest, the three-point Braille entry method. These results confirm Hypothesis 1: visually impaired people feel that three-point Braille entry is the easiest text entry method.

2. The correlation between comprehensive ease of use and the evaluation items (Figs. 3 and 4).

A correlation between the ease of use for the prompt text entry and comprehensive ease of use can be found for three-point Braille entry ($P < 0.05$), but such a correlation cannot be found for the double hand-tap and the one-line entry methods. Therefore, Hypothesis 2, the method for easily performing prompt text entry is also comprehensively easy to use, was partly supported.

3. The relationship between these touch-screen methods and already existing methods in terms of ease of use.

For [Comprehensive ease of use] and [Ease of understanding the operation method], no statistically significant correlation was found between currently existing methods and these touch screen methods. Therefore, Hypothesis 3a, users who prefer the toggle method also prefer the double-tap method, is supported.

Hypothesis 3b, users who prefer the six-point Braille entry method also prefer the three-point Braille entry method, was not supported by our results.

Improvements after the heuristic survey

Based on the results of this survey, we propose the following improvements to the three-point Braille entry method:

1. For the entry cognition method and the audio aid, merely touching the panel should not initiate a command, data entry should be accompanied by vibration, and an audio aid should be activated when a key without an entry is pressed.
2. The screen display should also be altered to accommodate the visually impaired. People with poor vision do not see as well as normally sighted people, but they can still obtain and process some visual information. To better accommodate their needs, smartphones should enhance the contrast by reversing the display of black and white, and enlarge the display of each text string.

Summary

1. The present state of and problems regarding the use of portable information and telecommunication devices by visually impaired people.

This study examined the current use of portable terminals by the visually impaired, which has recently been attracting increased attention. This enables us to identify the current status of this issue and its problems. For visually impaired smartphone users,

- Functionality is limited, and many people carry multiple devices.
- Because cell phones use audio information, they cannot be operated in a noisy place or in a place where noise or talking is limited.
- Audio entry is often inaccurate, and many users are uncomfortable using audio entry when they are around other people.

Furthermore, there are several operational problems:

- Cell phone audio aids often have a time lag, causing confusion.
- Kanji conversion is difficult.

This study confirms the efficacy of the three-point entry method: one-line entry is less efficient than double hand-tap entry, which is less efficient than three-point Braille entry.

Future problems and prospects

This study describes the current situation for visually impaired people who use information and telecommunication devices. It also investigated the usability of smartphones, examined text entry methods for touch screen operation, described some problems, and made proposals for improvements.

An advantage of smartphones is that users can select their favorite of multiple methods and use it as an application. In addition, the three-point Braille entry method is considered to be helpful for learning Braille, and it would be very useful if it could help to increase the percentage of the population who can use Braille.

However, smartphones are not only used for text entry. The assignment of functions to gestures is considered to be effective. Nevertheless, there are problems with this method as well, such as developing guidelines for creating applications that even the visually impaired can use.

4.2 Confirming the Possibility of Introducing Vibration Communication

The statistical significance of the elements

Tables 2, 3, 4 and 5 show the results for young subjects, 19 visually impaired subjects, 20 deaf subjects, and 23 young, healthy subjects using tap entry. These tables reflect the influence of vibration parameters on image word pairs. For the first word pair in particular, more than two vibration parameters often had an effect. For example, for the word pair [weak–strong], four vibration parameters, amplitude, period, length of vibration time, and shape, affected the image word pair. Thus, the statistical significance of each element of a vibration pattern was identified for each subject and gesture.

Table 2 Statistical significance on double tap gesture (visually impaired)

Image words	Amplitude	Periods	Vib. time	Shape
Weak–strong	*(0.03)	**(0.00)		**(0.00)
Short–long	*(0.02)			**(0.00)
Decrease–increase	**(0 00)			**(0.00)
Closed–open				
Receed–advanced	*(0 03)			**(0.00)

**p < 0.01, *p < 0.05

Table 3 Statistical significance on hold and tap gesture (visually impaired)

Image words	Amplitude	Periods	Vib. time	Shape
Weak–strong		**(0.00)	*(0 03)	**(0.00)
Short–long		**(0.00)	**(0.00)	**(0.01)
Decrease–increase		*(0 03)		
Closed–open				*(0.013)
Receed–advanced		**(0 00)		**(0.00)

**p < 0.01, *p < 0.05

Table 4 Statistical significance on single tap gesture (deaf)

Image words	Amplitude	Periods	Vib. time	Shape
Weak–strong	*(0.01)			**(0.00)
Short–long	*(0.04)	**(0.00)		**(0.00)
Decrease–increase				**(0.00)
Closed–open				*(0.04)
Receed–advanced				**(0.00)

**$p < 0.01$, *$p < 0.05$

Table 5 Statistical significance on single tap gesture (young)

Image words	Amplitude	Periods	Vib. time	Shape
Weak–strong	**(0.00)		*(0.02)	**(0.00)
Short–long	**(0.00)	**(0.00)	**(0.00)	**(0.00)
Decrease–increase	**(0.00)		**(0.00)	**(0.00)
Closed–open	**(0.00)	**(0.00)	*(0.02)	*(0.00)
Receed–advanced	**(0.00)	**(0.00)		**(0.00)

**$p < 0.01$, *$p < 0.05$

Tactile feedback recommendation

Table 6 shows the basic parameters with statistical significance in determining how the subjects experienced a vibration. The red figures in the reference model represent the constituent elements of the vibration that affected each of the three groups of subjects when the vibration parameters were changed. The bright blue figures represent the constituent elements of the vibration that affected the visually impaired and deaf subjects; bright green figures represent elements that affected visually impaired and healthy subjects; bright yellow figures represent elements that affected deaf and healthy subjects; light blue figures represent elements that affected only the visually impaired subjects; light green figures represent elements that only affected deaf subjects; light blue figures represent elements that affected only the young subjects. With the tap, owing to the program setup, the vibration was felt almost entirely with the palm of the hand. However, for the 40 entries, it was possible to determine the constituent elements of a vibration that all the subject groups experienced similarly. It is assumed that, even with the upward swipe, a wider variety of impressions can be generated from the vibration that occurs when the gesture finishes.

Discussion

For all seven gestures, if the amplitude or time of vibration is increased, subjects described the vibration as “increasing,” “long,” or “strong.” Moreover, if the amplitude or time of vibration is reduced, the opposite impression is given. This was true for both elderly and healthy subjects. If these words are compared to the other image word pairs, it can be seen that they are words for which it is easy to create a quantitative image. Thus, if one is performing an operation that can be expressed numerically, such as something related to size, it is possible to replace

Table 6 Tactile feedback recommendation list on gesture meaning "decision"

image words	amplitude	periods	vib. time	shape
weak	small	60	short	GW·GS·T
short	small	60	short	GW·GS·T
decrease	small	60	short	GW·GS·T
close	small	60	short	T
receed	small	60	—	GW·GS·T

image words	amplitude	periods	vib. time	shape
strong	big	10	long	S
long	big	10	long	S
increase	big	10	long	GS·S
closed	big	10	long	GS
advanced	big	10	—	S

red : all subjects,
blue : visually impaired, and deaf, green : deaf and younger,
yellow : deaf and younger
light blue : visually impaired, light green : deaf, light yello : younger

small : 4000 / big :6000,short : 160ms / long:320ms

GW : Gradually Weak, GS:Gradually Strong
T:Triangle, S:Squeare

hyphen (—) :any

one gesture with another. Next, we look at overall trends. The overall amount of vibration that the user can feel, called the vibration parameter area. This area can be calculated from the four parameters that determine the haptic feedback. It has a direct relationship with amplitude and time of vibration. If these parameters are increased, the vibration parameter area also increases. On the other hand, the vibration parameter area has an inverse relationship with period and the starting or finishing time of the vibration (i.e., shape). If these parameters increase, the vibration parameter area decreases.

Tables 2, 3, 4, 5 and 6 shows the information regarding haptic feedback in response to the seven types of gestures. Except for healthy people performing a single tap, the following points hold true:

1. Parameters that increase the vibration parameter area are linked to positive haptic feedback.
2. Parameters that reduce the vibration parameter area are linked to negative haptic feedback.

The "positive" items in (1) and (2) are those that received a score of close to +3 at the time of evaluation, whereas the "negative" ones are those that received a score close to 0.

Conclusion

Result (1) For both young, healthy people and elderly people, when vibrations accompany the operation of touch screens, users receive different impressions when the constituent elements of those vibrations are changed.

Result (2) For both groups, particular shared impressions existed when the subjects were exposed to the haptic stimulation that accompanied seven different gestures used to operate a touch screen. In addition, to ensure that the appropriate haptic feedback for each gesture could be easily selected, a table illustrating "haptic feedback in response to gestures" was created and divided into each of the seven gestures. This table illustrates the commonality between both subject groups for each of the different gestures.

5 Final Statement

In this study, in order to improve the touch panel and other operations of smartphones for the use of visually impaired people and expand their use of the smartphones, we developed a Braille entry method for touch screens and explored the usability of a new communication method using vibration. We demonstrated the efficacy of three-point Braille entry and the effectiveness of vibration communication in both normal and emergency-alert/urgency communication.

These systems enable us to find contact points for visually impaired people, who have rarely been able to use smartphones. Using these contact points as starting points, we can also promote with the use of smartphones among the visually impaired, as well as the use of applications that they may currently use on a personal computer. By attempting to modify smartphones for the visually impaired, which is a rarely-addressed subject, and by initiating an active approach, we hope to stimulate further developments to overcome the challenges that stand between information technology and the visually impaired.

Panasonic Group’s Universal Design Measures

Yoko Nakao

Abstract Panasonic Group has been supplying products and services based on the company’s Universal Design Policy of providing greater consideration to more people through its products and services, and thereby realizing a lively, comfortable and richer lifestyle. In Japan, a country which is confronted with numerous issues such as a declining birthrate and an aging population, as well as frequent earthquakes and other natural disasters, Panasonic Group has been proposing solutions that give full attention to people’s needs and lifestyles. The J Concept Product Series features a range of consumer electronics that cater to the needs of an aging population. Based on a new concept determined through repeated surveys of people in their 50s and 60s, and therefore with much life experience, the products integrate superior design and ease of use suited to Japanese lifestyles. Emergency goods are not always able to be found immediately or may not be in a usable condition when disaster strikes. Therefore, the Everyday Convenience X Being Prepared for the Unexpected Series of products has been designed for handy use in everyday life and during disasters. These products are highly evaluated as they directly address issues faced by consumers in their daily lives. Going forward, Panasonic Corporation will continue to provide products and services that meet the needs of ever more people.

Keywords Universal design · Inclusive design · Design for all · Panasonic · Aging population

1 Introduction

Panasonic Group has been supplying products and services based on the company’s Universal Design Policy of providing greater consideration to more people through its products and services, and thereby realizing a lively, comfortable and richer lifestyle. This concept dates all the way back to the message of “having a funda-

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mental desire to bring joy to consumers by making products full of goodwill, warmth and grace" issued by our founder, Konosuke Matsushita, in the year 1942, when Japan was starved of commodities and only poor quality goods could be found. Our employees believe that universal design is part of the DNA of Panasonic.

In Japan, a country which is confronted with numerous issues such as a declining birthrate and an aging population, as well as frequent earthquakes and other natural disasters, Panasonic Group has been proposing solutions that give full attention to people's needs and lifestyles. Two prime examples of this are introduced here. The first is the J Concept Product Series, a range of consumer electronics catering to the needs of an aging population through a new concept determined via repeated surveys of people in their 50s and 60s, and therefore with much life experience, to integrate superior design and ease of use suited to Japanese lifestyles. The second is the Everyday Convenience X Being Prepared for the Unexpected Series of products, designed for handy use in everyday life and during natural disasters such as earthquakes.

2 The J Concept Series

Panasonic's J Concept is a new consumer electronics series made possible by the painstaking attention to detail and faultless manufacturing refined by Panasonic over our many long years in the white goods business, combining the elements of simplicity (eliminating extra functions infrequently used while retaining core functions to the full) in a compact size with stylish designs blending into Japanese homes (Fig. 1).

Fig. 1 The J concept series

2.1 Background to the Development

To explain the background that led up to the development of this series, up until now Japanese consumer electronics have evolved to incorporate multiple advanced functions, yet the customers could not fully utilize all of these functions, and neither are such products really suited to elderly customers, despite the fact that people aged 65 or older now make up a quarter of the Japanese population, as the aging society truly comes into being.

This was the trigger for several business divisions and departments to come together in a single project with the desire to genuinely focus on the elderly, search out their actual needs, and create products to solve these problems.

Two years were spent in repeated surveys and verification, hearings with experts, analysis, idea discussions and prototype development, to result in totally revolutionary consumer electronics condensing Panasonic's expertise and technology with a thorough focus on user friendliness, functionality and design. We performed 30 surveys and over to reach 30,000 customers or more.

Having questioned so many elderly people, we found that what they want is to remain active, to look after the house and enjoy hobbies and take care of things for themselves up to any age, as evinced by comments such as "I want to do the vacuuming properly myself," "I want to enjoy cooking every day," and "I want to watch videos my grandchild send me." What we learned from specialists on aging was that, with the onset of old age, our motor functions, senses and cognitive functions gradually decline, so to offset this with consumer electronics, we need to take into account lower muscle strength, sight, hearing and perception, to make them (1) easy to use, and (2) simple to see and understand. We also took into account the fact that the elderly generation in Japan nowadays have a wide life experience and tend to view and consider things with an objective and critical outlook, so that they do not want items that look plain or unsightly, even if they are user friendly, and dislike cheap-looking items even if they have simplicity. The next step was to endeavor to create consumer electronics that would combine all the elements so far.

The J Concept Series currently extends to vacuum cleaners, washing machines, refrigerators, rice cookers, steam microwave ovens, and air conditioners. Here the specific points are explained in order.

2.2 Introducing Examples

2.2.1 Vacuum Cleaners

One thing we learned from our surveys is that for vacuum cleaners the key point is weight; the lighter they are, the better, because a heavy vacuum cleaner makes the whole process tiresome (Fig. 2). So we aimed to make a vacuum cleaner designed specifically to be light, and using the paper-bag system quite popular amongst elderly Japanese people.

How many kilograms would an elderly person feel to be light? Having gained a ranking of 3, 2.8, 2.4, 2.2 and 2.0 kg from elderly people, we found that a weight of 2.2 kg or lower was perceived to be light. We had found our target value, but standard vacuum cleaners at that time weighed 4.1 kg, meaning we had to undertake some drastic changes to achieve lightness. So, we designed a new outer material and a new lightweight motor, rearranged the layout and made other sweeping changes, to cut the weight by 51 %, to achieve the world's lightest figure of 2.0 kg for the vacuum cleaner itself. For household floor-type vacuum cleaners, as of January 1, 2016 (Fig. 3).

In particular, for the outer body we used a unique material adopting PP fiber-reinforced plastic (PPFRP), the first use in an appliance for a stylish and tough

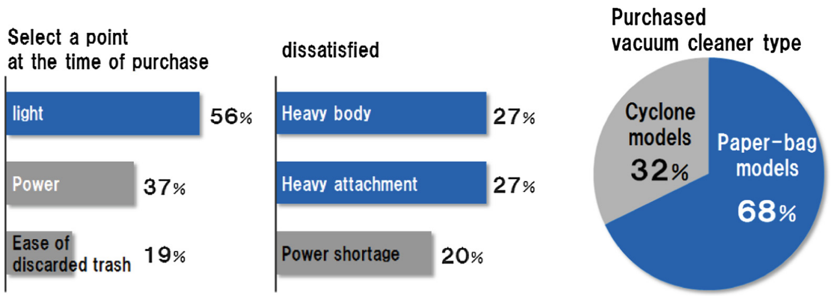

Fig. 2 Vacuum cleaner purchasing and usage among people aged 60 or older. Research by Panasonic; 2012 online survey (n = 468). **a** People want light, easy to use models. **b** Paper-bag models are extremely popular

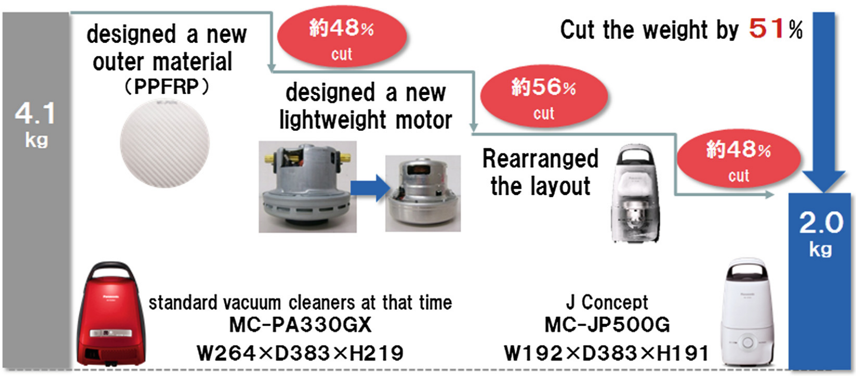

Fig. 3 Cut the weight by 51 %

design. Through trial and error, we maintained the toughness while halving the thickness compared to our previous products, helping to lighten the vacuum cleaner.

Even though the product is so much lighter, we haven't skimped on any features for ease of use. These include a large handle placed precisely for better carrying, house dust sensors that light up to show you when dirt and house dust are being sucked up, LED navigation lights to easily spot dirt (Fig. 4), a narrow nozzle that can be removed with a single touch of the foot alone, without having to bend down, and more (Fig. 5).

What's more, on some models the neck swivels freely enabling it to reach high and narrow places easily, and are equipped with a lightweight long nozzle with LED lights for safely cleaning dark places (Fig. 6). This lets you clean wherever you want to, not just the floors but also ceilings, on top of curtain rails, and so on (Fig. 6).

This vacuum cleaner was created with a focus on elderly people, but its sheer lightness has made it highly popular among people of all ages, making it a hit product frequently asked for in particular by buyers.

2.2.2 Washing Machines

Next we consider our washing machines. As many people report that getting clothes out of the washing machines is a hassle, we used a vertical washing machine design as preferred by elderly Japanese people, and carried out exhaustive tests of the

Fig. 4 House dust sensors and LED navigation light

Fig. 5 Single touch narrow nozzle

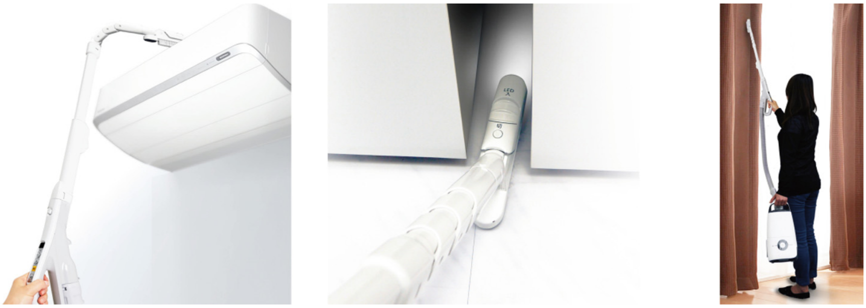

Fig. 6 Freely swiveling neck and a lightweight long nozzle with an onboard light for cleaning in confined spaces

frontal height and easy reach depth of the tub, based on the physique of women aged 65 or older. We built up a basic framework that not only lightened the burden of getting clothes out but also made it easier to keep the machine clean (Fig. 7). Testing using the average physique of a Japanese woman aged 65–74. In addition, by adopting a slimmer balancer on top of the tub we widened the diameter of the door, making it easier to take the laundry out and to easily accommodate even big items like double-sized blankets (Fig. 8).

Moreover, it is equipped with an untangling function where the pulsator rotates in short steps after dewatering to shake off clothes sticking to the sides of the tub, disentangling them to make them easier to remove. More support is given to user friendliness in terms of the functions.

Fig. 7 New basic framework

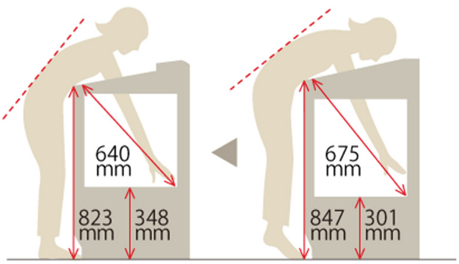

Fig. 8 Door extended by approximately 14 %

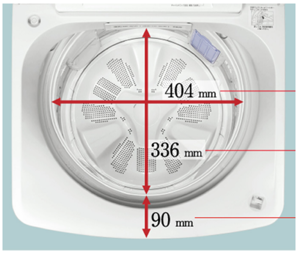

Fig. 9 White touchscreen LCD and direct course button for ease of use on a large, easy-viewing screen

Fig. 10 Refrigerator with special attention paid to the ease of putting food in or out

Elderly users are taken into account for the ease of using the controls. By adopting the industry's largest white touchscreen LCD, it allows intuitive control requiring only light touches, with a display highlighting only the necessary information. Every effort is made to ensure straightforward operation, for example, buttons to directly choose the four courses and a large time remaining display (Fig. 9).

2.2.3 Refrigerators

Our multi-door refrigerators, a type popular in Japan, minimize strain on the arms and elbows, setting the height between the refrigerator compartment and vegetable compartment most often used by the target group at 88 cm from ground level, just right for Japanese women to use, according to data on the elbow height of women aged 50–79.[1] The bottom two-stage drawers open up 100 % to reveal themselves, making it not only easier to take items out but also to prevent people forgetting to use items (Fig. 10).

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[1]Research Institute of Human Engineering for Quality Life: *Japanese Body Size Data Book 2004–2006*

2.2.4 Microwave Ovens

These ovens offer microwave cooking, conventional cooking and steam cooking functions, making them safer than open flame cooking and enabling handier cooking and more varied dishes. They contain 50 preset recipes of popular Japanese dishes for easily making grilled, stewed, steamed and fried dishes, giving consideration to supporting health in everyday life. The color touch panel contains illustrations and photos for ease of understanding and allows simple switching between screens, so that anyone can use it without becoming confused (Fig. 11).

2.2.5 Rice Cookers

Whereas with previous rice cookers it was difficult to cook small amounts with a nice flavor, the variable pressure Odori-daki function makes it possible to achieve a delicious result. The compact body including the pot is easy to handle, and the full dot LCD displays large fonts that give consideration to being easy to read (Fig. 12).

2.2.6 Air Conditioners

To deal with Japan's hot summers and cold winters with temperature variations of 30 °C or more, these air conditioners utilize big flaps in a new form to ensure they

Fig. 11 Microwave oven with 50 preset recipes of Japanese dishes to enjoy healthy food

Fig. 12 Rice cooker able to cook even small amounts with a delicious flavor

give a gentle breeze not directly blowing onto the body in summertime, and bring warm winds of 35 °C all the way to the feet in wintertime (Fig. 13). This is due to the attention paid to the fact made clear by the surveys that many people are dissatisfied with air conditioners used for heating because they fail to heat all the way to the feet (Fig. 14). Multiple sensors monitor conditions in the room, with a room overwatch function to automatically start operation in high temperatures or humidity during the summertime, carefully serving all users from elderly persons down to small children. It contains a filter-cleaning robot to eliminate the need for cleaning, while the remote control has color-coded buttons and an easy-viewing LCD for ease of use.

2.2.7 Unified Design Concepts

The J Concept Series has a unified design concept incorporating the essence of Japan. The simple overall forms that blend into everyday environments (Fig. 15)

Fig. 13 The new form enables cool breezes reach the ceiling in summer and warms air down to foot level in winter

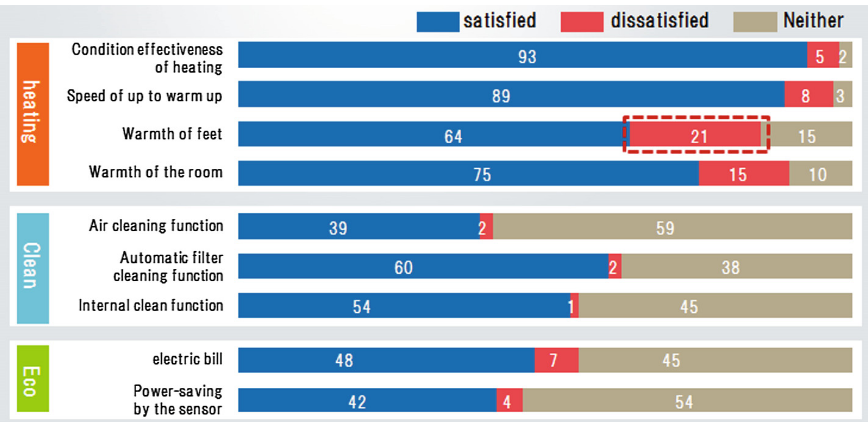

Fig. 14 Satisfaction with air conditioners. Research by Panasonic (n = 1168)

Fig. 15 Forms blending into everyday environments

Fig. 16 Simple yet ingenious designs incorporating Japanese traditional taste

and the front surface having subtle patterns with essential Japanese designs create a tasteful yet unimposing design (Fig. 16).

3 Everyday Convenience X Being Prepared for the Unexpected Series

Next we look at the Everyday Convenience X Being Prepared for the Unexpected Series of products, designed for handy use in everyday life and during natural disasters such as earthquakes.

3.1 Background to the Development

In 2011 Japan suffered unprecedented losses in the Great East Japan Earthquake. This has led to a greater awareness toward safety and security among consumers and increasing numbers of people concerned with readiness for disaster. In data obtained through a Panasonic survey in April 2011, respondents answering that they use flashlights and emergency torches rose from 65 to 83 %, while as many as 79 % replied that they kept a stock of dry-cell and rechargeable batteries on hand. The survey also indicated for post-earthquake purchases a demand for products that could be used in everyday life but also function when a disaster occurred over those for use in a disaster only (Figs. 17, 18).

In many cases when we try to use items kept in case of a disaster, we forget where we have put them or find that the batteries are no longer working. To solve this problem, Panasonic planned a series of products called Everyday Convenience X Being Prepared for the Unexpected, as products that can be used in everyday life yet also be put to use in optimal condition in a disaster at any time. The series also promotes a new lifestyle raising environmental awareness by using green products as part of our everyday life, using rechargeable batteries for longer product life, solar power and so on.

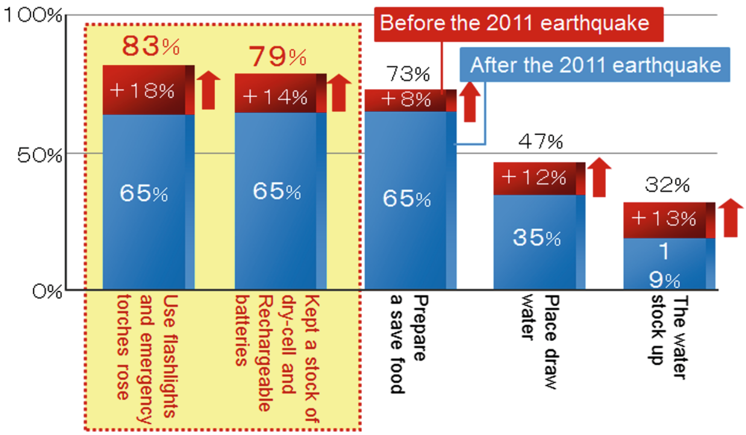

Fig. 17 What preparations did you have before the earthquake and after it? April 2011 n = 3795 Panasonic online survey

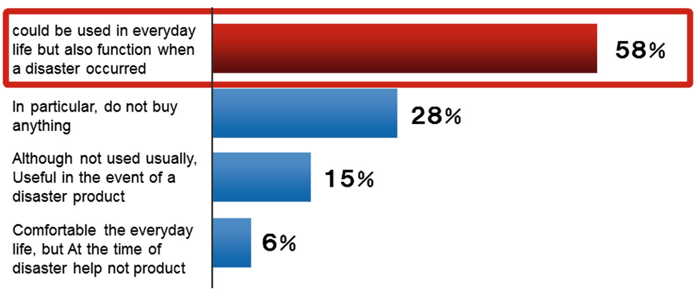

Fig. 18 After the earthquake, what things do you want to buy? April 2011 n = 320 Panasonic online survey

3.2 Introducing Examples

Compact Solar Light. Specifically, the Compact Solar Light is an LED light that can be taken outdoors anytime and used for 60 h, and can charge mobile phones and rechargeable batteries with solar power if necessary (Fig. 18).

No-contact Interior Light. The No-contact Interior Light is a product that functions as a soft interior light, yet can also be used as a flashlight that lights automatically when put on an angle (Fig. 20). This product uses contactless charging, and not only can be charged easily just by leaving it in position, also lights up as an interior light during power outages to give a sense of security during emergency situations (Fig. 19).

Rechargeable Lantern. Rechargeable Lantern is a portable light easily carried around outdoors, which can also be used as 20-h light sources in case of emergencies (Fig. 21). It comes with four strap holes enabling it to be used while carrying or by suspending it as well as leaving it in place.

Portable Power Supply System. The Portable Power Supply System is an outdoor power supply always full of power available for use, usable as an emergency power source for TVs or computers during emergencies (Fig. 22). Highly portable, compact and lightweight design with easy-grip handle yet is equivalent to IPX5 (grade indicating no significant effect on the product even if exposed directly to

Fig. 19 Compact solar light

Fig. 20 No-contact interior light

Fig. 21 Rechargeable lantern

Fig. 22 Portable power supply system

spraying water), enabling it to be used with peace of mind in outdoor environments. Furthermore, it comes equipped with simple lights and alarms for power outages to indicate its location, giving further reassurance.

Windup Radio. The Windup Radio functions as a twin-speaker radio for listening to audio, yet can also be hand-powered in emergencies, as well as recharging smartphones and mobile phones (Fig. 23). Compact and portable size of 140 mm wide and 54 mm high. The power button is made out of phosphorescent material for ease of use even in darkness. It also comes equipped with an LED light and siren function for emergencies.

Multiple Battery Light. The Multiple Battery Light can use batteries of any size, whether D, C, AA or AAA, providing an LED flashlight that can be powered by any battery available to hand in an emergency (Fig. 24). It has a compact size and a big handle plus a large sliding switch usable intuitively by anyone, from children to adults.

The first entries in the Everyday Convenience X Being Prepared for the Unexpected Series won gold at the 2012 IAUD Awards, and silver for the Multiple Battery Light and the LED Lantern at the 2015 IAUD Awards. For the gold award in 2012, the jury commented that "while these products have a specific use value in emergency situations, their aesthetics and functionality ensure that they will be used

Fig. 23 Windup radio

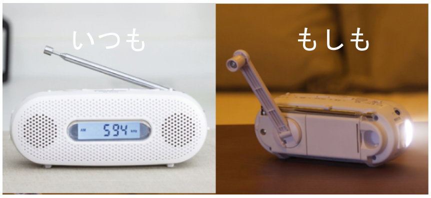

Fig. 24 Multiple battery light

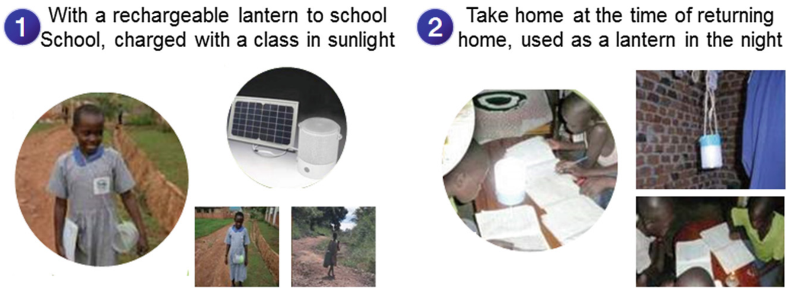

Fig. 25 Spreading into African off-grid areas

and valued in everyday life and consequently will be available, well understood and so ready for use in any emergency. This is an elegant synergy of environmental and social sustainability."

3.3 Practical Performance

The Rechargeable Lanterns were donated and sold in Africa to off-grid areas as an advance product. As can be seen in (Fig. 25), children take the Rechargeable Lanterns with them to elementary school and charge them while in class with solar panels installed at school. After school they return with the fully charged lanterns, to be used as light for all the family at night.

The Rechargeable Lanterns, which have played a major role in improving life in off-grid areas, were donated with adjusted charging sections to 80 % of households in Minamisanriku Town, which was damaged by the Great East Japan Earthquake, proving to be of much valuable use.

These Series has maintained a high popularity since its first release. In actual sales as well, as of 2011 the Compact Solar Lights (400,000 units) and Necklights (370,000 units) as handy light products have gained sales records tripling the previous year

4 Summary

We believe that our efforts, which seek to genuinely come to grips with Japan's aging population, it's greatest issue and also utilize our experience of major disasters, will be useful in many other countries in the future too.

When we develop products and services, as we mentioned at the start regarding our universal design concept, we strive to go beyond user friendliness to enable people to live better, happier and enhanced lives. Coping with the aging population and areas hit by disaster makes us realize powerfully the necessity of having meaning and happiness in our lives. This will never change, no matter how far technology and convenience progress. Our aim is to continue to provide products and services that are highly useful, fun to use and that improve the lives of our customers in more situations and for more people.

Built Environment Design Toward an Inclusive Society: How Can We Improve the Existing Infrastructure in Cities?

Satoshi Kose

Abstract Built environment design has responded to the needs of the users. However, industrialization, urbanization and drastic change in technologies revealed a widened gap between users' abilities and required ability level. Quite a large portion of population has been excluded from using the built environment, in larger cities. Those excluded and suffer most include seniors and people with disabilities. We have tried to fill the gap, but the efforts have usually lagged behind. Besides, such efforts were a bit of compromise, partly due to existing hardships of infrastructures. Should such compromises be acceptable, or should we struggle to ask more efforts toward better design for fuller inclusion? This presentation examines the state-of-the-art in Tokyo, which will host the 2020 Olympics and Paralympics Games. The discussion compares the historical background, conditions of existing infrastructures, people's perceptions toward inclusion, and global trends including UN Convention of Rights of People with Disabilities.

Keywords Accessibility · Building design · Inclusion · Olympics/paralympics · Tokyo

1 Introduction

With its successful bid to host the 2020 Olympic/Paralympic Games, Tokyo is tuned to prepare an accessible environment. The reference document is the IPC Guide made referring to London Olympic/Paralympic Games (IPC [1]). Its message is that the environment, built environment in particular, needs to be accessible and usable for everyone, not just for people with disabilities. It is in accordance with the UN Convention on the Rights of People with Disabilities, with inclusion in its heart.

However, as is usually the case, the built environment is far lagged behind the idea. It is to some extent inevitable because it costs much to improve. Once built,

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building could last more than hundred years, and the society's general assumptions at the time of its building decide the requirement level of functionality, whether safety, usability, accessibility, and provisions of building services (such as elevators and air conditioning).

2 Background

Most of buildings in Tokyo were built after the Second World War, but many were built before Japan was aware of the coming of a highly aged society. It was only in 1986 when we were told that about a quarter of Japanese population will be 65 years of age and over in around 2030. The estimate became much higher as years went by, and a quarter line was already passed in 2013, with the projected peak of about 40 % 65 and over to come in around 2055 (Fig. 1).

Before the alarm was rang, major argument was to design for people with disabilities, or barrier-free design. Therefore, it was quite difficult to convince the public to accept the importance of universal design. Even after the International Year of Disabled Persons in 1981, the move toward universal design was slow. The

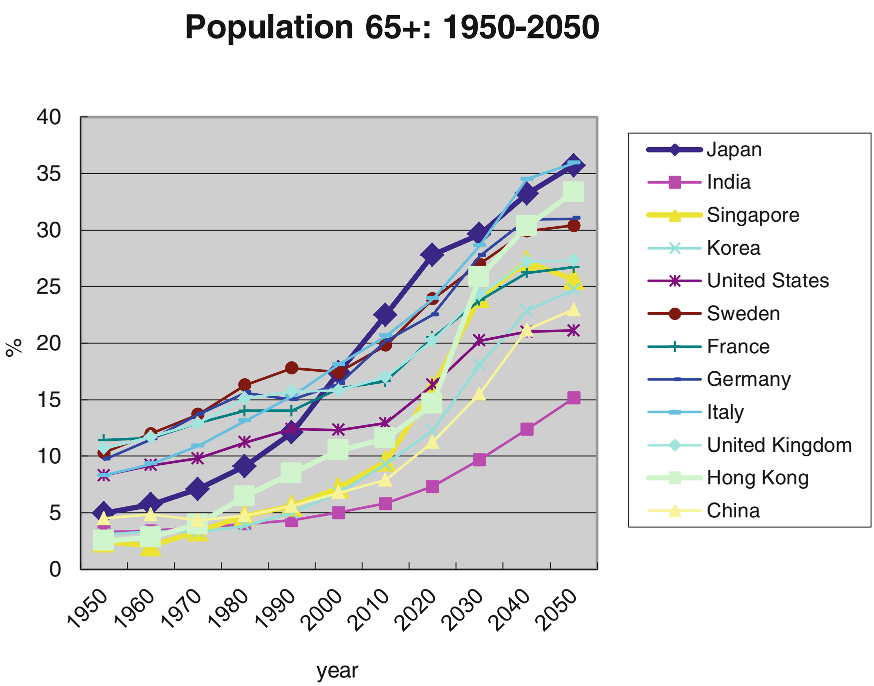

Fig. 1 Ratio of people aged 65 and over in selected countries. Japan has experienced a sharp rise and is still continuing to rise

impact of ADA was visible in the sense that a law on accessible buildings was enacted in 1994. It unfortunately lacked teeth. In 2000, accessible public transportation law was introduced, which had some obligatory requirements.

3 Level of Requirements: Past and Present

As the accessible building law started with a set of recommendations coupled with some carrots without sticks, requirement level of the accessible transportation law was modest as well. New construction must satisfy the requirement if number of daily users are 5000 persons or more, but existing facilities are only requested, not required, to make efforts to comply with accessibility (Figs. 2, 3).

Minimum requirements are, for example, at least one accessible route, or at least one accessible seat area for a whole train. The former meant people with wheelchairs will normally have to take a longer route compared to others who can climb up and down stairs, and the latter meant very limited choices of travel. It is common to the concept of minimum requirements on buildings, like having only one wheelchair accessible toilet within a whole building. Recommended higher level of requirements, linked to carrots, is of course having accessible toilets on every floor (Figs. 4, 5).

If you are not in a hurry, or prepared to wait for the station attendant to arrive to assist you, you may be able to navigate through the city to reach your destination. It

Fig. 2 This set of photos were taken in 1997, before the introduction of the accessible transportation law. With Shinkansen, the bullet train from Tokyo to Kyoto, this door at car number 11 leads to the only wheelchair designated area among the sixteen cars with more than 1000 seats. The operator JR Central still insists that the minimum required level, not desirable level is what they will provide

Fig. 3 After transferring to the limited express, the trip's destination station had quite a high step between platform and car floor. When getting on in Kyoto, the level difference was minimal

Fig. 4 A Tokyo Metro station some years ago. No elevator was in place, and stair climber was provided. Existing infrastructure makes it difficult to renovate the stairs to introduce elevators more than 10 years passed since the introduction of accessible public transportation law

however means that you have to compromise. Under current situation, not all transportation systems are fully accessible: you cannot use some of the station platforms, and may have to take a longer way to follow an accessible route. It might mean longer hours of travel, sometimes paying extra fare, losing precious time to enjoy your ultimate purpose, whether shopping, movie going or dining. Simply,

Fig. 5 An escalator with three steps flattened to accommodate a wheelchair. Compared to stair climber in Fig. 4, this does not allow frail seniors to use the system, thus they are excluded from being the users

persons with disabilities or frail seniors are not given the same rights as other people are given.

In 2013, Japan has passed its Disability discrimination law. It is not a law that prohibits discrimination: Rather it is a law to persuade people to rectify the discriminatory situation. The law will come into force April 2016, after a long period of preparation. Even so, obligatory requirements are enforced to government departments, but not to the private sector. The Lawmakers (In Japan actually, it means the central government) were hesitant to introduce a mandatory anti-discrimination law even after the ratification of the UN CRPD.

4 What Need to Be Done?

As already stated, The Olympics/Paralympics will be held in 2020. The games are the special events not to be missed. People must be given a set of choices regarding the transportation, accommodation, and other activities they will do in Tokyo and all around Japan. Most important of all, people will move toward the games site, and delays are not acceptable. Overseas guests in particular have spent quite an amount of money and time to come and see the games, and if they were to miss the game, they will have enough reason to complain, and in some cases might sue the host city and the organizer. Such potential problems must be avoided at all cost.

Tokyo needs to do quite a lot from the viewpoint of accessibility. The general accessibility level is not so much different from London, but there are a few conditions much more difficult to cope with. First, some of the physical

Fig. 6 A steep hill in the center of Tokyo. It is quite common to encounter places like this

infrastructure has been completed when the healthy and robust were assumed to be the majority, and introduction of accessible features is still slow: Will Tokyo be able to change the conditions in time for the Games? In London, buses have transported many visitors, but main transportation systems in Tokyo are railways, i.e., metros and trains, with rather complicated transfer at some major stations. Can these become more usable with better signage?

Another problem with Tokyo is that it is full of ups and downs at some places. Topographically, London is very flat, but Tokyo is very challenging. One might encounter steep hills while trying to walk through the city. Slopes gentler than 1/20 can be assumed flat, but at some places, you cannot go without negotiating much steeper hills (Fig. 6). You might be able to avoid them if you made a detour, but it of course means you need more time to travel.

The third difficulty is that the dates are the beginning of August for the Olympics, very hot and humid season. In London, where the climate was milder, one of the strategy of crowd management was to form a cue, to keep people waiting (to get into the stations after the game was over). Its effectiveness is however questionable in Tokyo, because high outside temperature and strong sunlight is more than people can endure. Exposure can be life threatening. When Tokyo hosted the Olympics/Paralympics in 1964, the game was held in October, and no problem of weather was anticipated (except rain during the opening ceremony). Some smart technology to reduce the impact of harsh weather will be necessary.

5 Conclusion

Tokyo is committed to prepare for the Games as much as it can. Some of the measures to respond to the needs of people with disabilities have been more advanced in Japan (making life easier for people with vision loss, for example), and plans are going to realize what need to be done. We can only hope that expected level will be reached in time for the Games. It will be a legacy the Games can bring about to Tokyo and Japan. It is necessary for the highly aged society, now and future.

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Effect of Cross-Sectional Shape of Small Level Change on Walkability

Yoshiaki Goto, Mai Miyake, Katsushi Sato and Satoshi Kose

Abstract Floors should be flat from accessibility viewpoint, but small additions like wires or pipes can become inevitable. Safety, walkability and usability of such level changes during trespassing was experimented. Different cross-sectional designs were made to examine their feasibility. Sensory evaluation, movement and acceleration analyses were conducted. Seven samples were chosen, with combination of three heights (5, 7, 9 mm) and three corner cut design (1/1, 1/4, 1/8) combined. Subjects participated in the experiment were 19 seniors all aged 65 and over, with nine among them used walking stick. Simple walking and walking with wheeled suitcase or walker were used to test the walkability. Sensory evaluation revealed 7 mm height with 1/8 cut the best, 5 mm with 1/1 cut the worst from the viewpoint of stumbling hazard. Walking with wheels valued 9 mm with 1/4 the worst, 5 mm with 1/1 the best and 7 mm with 1/8 s best.

Keywords Ease of overpassing · Level difference · Walker for seniors · Wheels · Impact · Acceleration

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1 Introduction

Discussion of functional requirements has been on the rise, and floor materials are no exception. In addition to durability, safety against slipping has become more important than before. From accessibility viewpoint, there should be no level differences on the floor. However, when renovation of services system becomes necessary, a level difference may come into. One such example is the replacement of an old water heater to a latent heat reclamation type. The original building design usually did not have a vertical service shaft along the water heater, but with the new one, the condensed water must be disposed of. The only way to do it is to guide the drain across the corridor, and in order to avoid the risk of water freezing during winter (because the corridor is usually exposed to the outside), such drain has to be covered. It creates level differences on the corridor, and thus problems arise of safety during walking as well as impediment to wheels, i.e., suitcases or walkers for seniors. In Japan, existing building design standards allow maximum height difference of 5 mm, and JIS on TWSI (Tactile Warning Surface Indicator) suggests height of 5 mm for raised parts. This paper examines effects of small level changes to walkability of seniors and usability of wheels, and possible measures to reduce the impact of such level differences.

2 Experimental Methods

2.1 *Walking Without Wheels*

Senior subjects, 19 in total, aged 65–79 years old (Fig. 1) walked along the simulated corridor (Fig. 2). Two section design samples of drain cover were placed, and their sensory evaluation was conducted. The movement of tiptoe during walking was also recorded with video camera for later analysis. Regarding risk of stumbling, samples were separately applied on a simulated floor and subjects checked their preferences. Paired samples were randomly selected for experiments to avoid bias. Footwear used was what is called walking shoes, fit for casual walking.

2.2 *Walking with Wheels*

Subjects walked along the simulated corridor with wheels, with walker for seniors or wheeled suitcase. Walker was placed in front, while suitcase was on the side. Paired comparison of two samples was conducted of the ease of overpassing of the level difference (Figs. 3 and 4). The movement of the wheel was recorded for analysis. Accelerometer was also applied and changes in acceleration was measured. Samples were randomly selected. Footwear used was the same. Nine subjects who used walkers were seniors who normally used sticks during daily life (aged 65–78), and other 10 subjects walked with wheeled suitcase (67–79).

No.	Gender	Age	Heigt h(cm)	Weigh t(kg)	Speed (m/m)	Stride (cm)	Cane user
1	Male	65	174.5	81	37.8	44.3	User
2	Female	74	147	93	44.2	47.9	User
3	Female	73	151.6	48.5	83.9	68.7	
4	Female	72	162	65.5	97.9	73.6	
5	Female	76	150	51	72.9	67.7	
6	Female	77	145		41.2	43.9	User
7	Female	78	135	35	31.2	38.8	User
8	Female	69	150.5	47	72.2	67.3	
9	Male	79	176.5	67	49.8	68.7	
10	Female	77	146	39	73.8	69.3	
11	Male	74	161.5	69	46.9	46.1	User
12	Male	71	160	55	53.6	53.4	User
13	Male	67	150	45	39.5	40.6	User
14	Male	68	175.5	74	80.8	68.7	
15	Male	71	162	51	79.2	80.0	
16	Female	77	142	52	40.1	42.9	User
17	Male	67	165	64.5	29.6	43.3	User
18	Female	67	157.5	55	77.8	69.3	
20	Male	69	162	58	80.2	74.3	

Fig. 1 List of subjects participated in the experiments

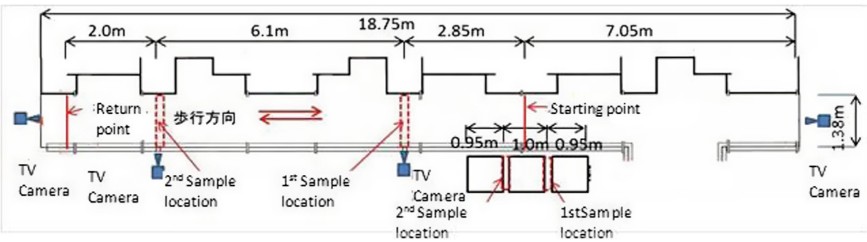


Fig. 2 Experimental setup—simulated corridor

2.3 Sample Designs and Experimental Settings

Seven sample section designs (Fig. 5) were made, with combination of three heights (5, 7, 9 mm) and three corner cut design (1/1, 1/4, 1/8) combined. Material is EPDM (Ethylene-propylene-diene rubber). The color is adjusted to have 20 % brightness difference. In total, 17 experimental walking conditions and 10 wheeled conditions were set up for paired comparison (Fig. 6). Sample G was included as a reference against F.

Walker for seniors used for the experiment is shown in Fig. 7. The width is 430 mm, depth 500 mm, grip height 810–915 mm, and the weight is adjusted to

Fig. 3 Walking with walker for seniors

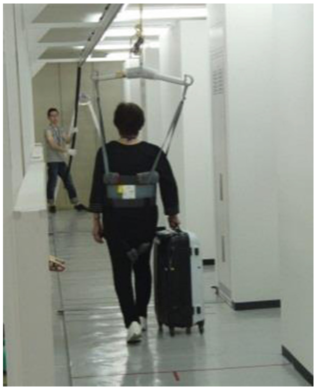


Fig. 4 Walking with wheeled suitcase

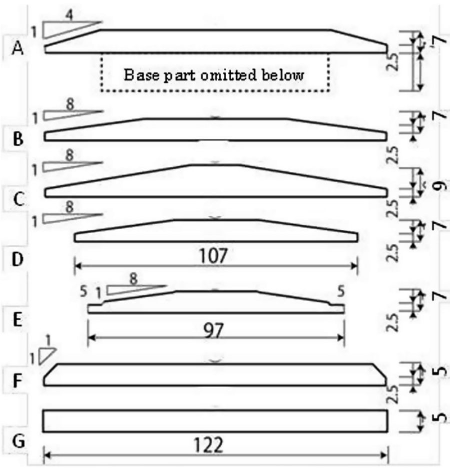


Fig. 5 Section of samples. Height was 5, 7 or 9 mm. The width was around 100 mm

Fig. 6 Experimental arrangement of samples. Two different ones were placed along the route

	Walking without wheels experiment		Walking with wheels experiment	
	1st	2nd	1st	2nd
1	C	B	C	F
2	D	B	D	B
3	B	F	B	F
4	B	A	B	A
5	A	E	A	E
6	E	B	E	B
7	A	C	A	C
8	F	A	F	A
9	A	D	A	D
10	D	B	C	B
11	B	G		
12	F	D		
13	D	E		
14	D	C		
15	C	E		
16	G	F		
17	E	F		

Fig. 7 Walker for seniors

7 kg. Wheeled suitcase, with grip height 780, 880 or 980 mm, with adjusted weight 14.9 kg is shown in Fig. 8.

Experimental subject was applied with an overhead harness to avoid fall accidents, and assistants helped with a guide rope. A nurse was in place for any health issues or accidents.

2.4 *Method of Analysis*

Ease of overpass and walkability was examined through paired comparison, and judgement of height and disturbance was measured with three level sensory comparison (Fig. 9). As to wheels, accelerometer measurement was used to examine the impact during overpassing of the level change.

Fig. 8 Wheeled suitcase

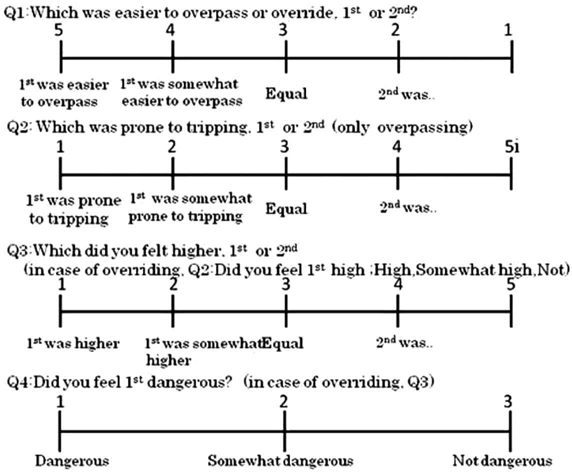


Fig. 9 Questionnaire on sensory evaluation, with four questions

3 Results

3.1 Walking Experiments

Sensory comparison. Paired comparison results were used to decide the preferred order of six sample sections with Scheffe's method (Fig. 10). Subjects who used sticks and those who did not use sticks gave slightly different results regarding ease of overpassing. Subjects with sticks ranked E first and A worst, while those without sticks ranked D best and A worst. As to stumbling, both groups rated F most prone to tripping/stumbling. Regarding the impression of height, C was felt the highest and F (which is wider) was felt lowest.

Trajectory of tiptoe. Example of trajectory is given in Fig. 11. Most of the subjects noticed the existence of the samples and they tended to walk high over them, so no one made any contact to the sample material with their tiptoe.

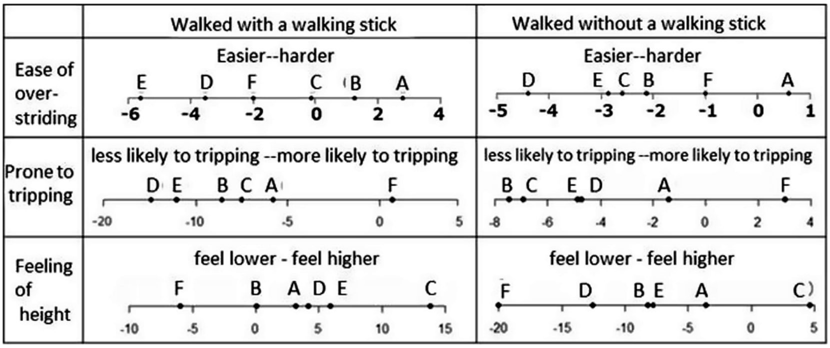


Fig. 10 Results of paired comparison of walking (Scheffe's)

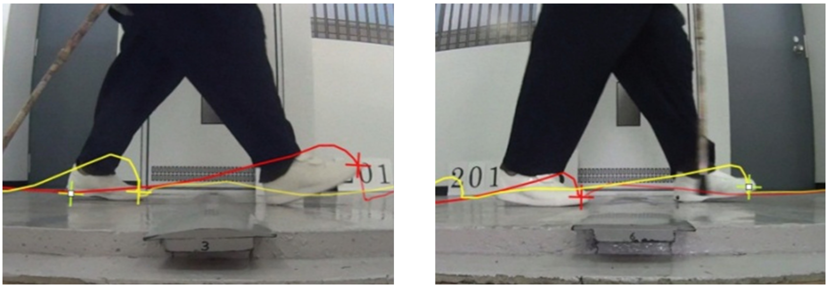


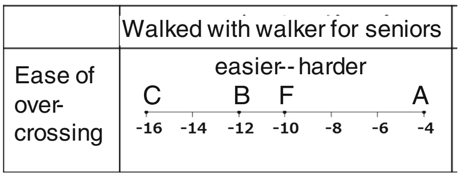
Fig. 11 Trajectory of tiptoe: Subject No. 2. Subjects typically walked high over the sample

3.2 Results of Wheeled Experiments

Sensory evaluation: walker for seniors. Regarding the ease of overriding (Q1), B and E were highly rated. Regarding the feeling of height (Q2), F was pinpointed to be high or relatively high. Regarding the disturbance (Q3), C, D and E were spotted to be annoying. With these in mind, sample A, B, C and F were rank ordered with Scheffe's method. The result was that C is the easiest while A was the most difficult to override (Fig. 12).

Sensory evaluation: wheeled suitcase. Regarding the ease of overriding (Q1), B and E were highly rated. Regarding the feeling of height (Q2), F was pinpointed to be

Fig. 12 Results of paired comparison of walking with walker for seniors



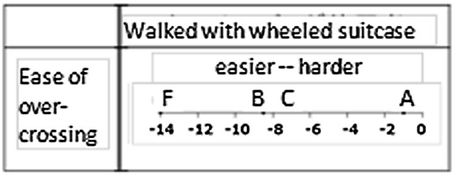


Fig. 13 Results of paired comparison of walking with wheeled suitcase

high or relatively high. Regarding the disturbance (Q3), C, D and E were spotted to be annoying. With these in mind, samples were rank ordered with Scheffe's method. The result was that F is the easiest while A was the most difficult to override (Fig. 13). **Result of accelerometer measurement**. With walker for seniors, subject No. 1 recorded the maximum acceleration in the walking direction of 7.284G with sample F, compared to 2.706G with sample D. In vertical direction, F recorded 4.2G while D recorded 1.64G. With wheeled suitcase, subject No. 2 recorded the maximum acceleration in the walking direction of 2.804G with sample F, compared to 2.157G with sample D. In vertical direction, the values were similar between sample B and F. The reason of difference in acceleration between a walker and a suitcase, i.e., the latter only produced 1/3, might arise from the wheel diameter and materials, but it needs further investigation.

4 Conclusion

Small difference in level is more dangerous when it is difficult to notice its existence. One possible experimental method was to try to make the level change invisible to the subjects, but present experiment was conducted with safety in mind. Since subjects were aware of the existence of sample materials, they usually tried to avoid them. Therefore, inherent dangers could not be examined. Asking the subjects to kick the samples however revealed relative stumbling hazard.

The experiments found that design of corner cuts affected walkability and ease of overpassing by wheels. As the cuts become gentler, stumbling hazard seemed to be reduced.

Ideally, there should not be any level changes. With this set of experiments, because of background for the research, three heights, i.e., 5, 7 and 9 mm were chosen. The results seem to suggest that as high as 9 mm might be acceptable with reasonable section design.

5 Note

The experiment was conducted as part of committee activities to evaluate the safety of drain design organized by the Japan Gas Appliances Inspection Association.

Part VIII
Designing for Inclusion in Learning Experiences

Inclusive Design for Children at the Master Education

Rita Assoreira Almendra and Gonçalo Falcão

Abstract This paper aims to present two projects developed at the level of master education both in the areas of product and communication design. Through them the authors emphasize the empirical studies that supported the results exposing the methodologies used and underlining the importance of user's participation in the process of developing a solution. Furthermore as a result of the analysis of the projects the authors suggest a matrix that relates contents to be taught with competences to be acquired at this level of design education.

Keywords Inclusive design · Master education · Product design · Communication design

1 Introduction

Inclusive design is not taught at FA ULisbon as an autonomous course. However, inclusivity issues integrate Design Studio classes and the topic makes part of the contents of curricular units such as Ergonomics and Service Design. Being the focus of this paper the master courses it is important to acknowledge that students have to develop in their second year a master dissertation. The choice of the topic is worked with the students along the first year of the master course and normally it is initiated with the presentation of important themes to be addressed (normally linked with the design research lines of the CIAUD—research centre of architecture, urbanism and Design from the faculty) in which the faculty has experts and experienced researchers.

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2 Reflecting on Teaching/Learning Inclusive Design

Design Council (2008) defines Inclusive Design as a general approach to designing in which designers ensure that their products and services address the needs of the widest possible audience, irrespective of age or ability. Inclusive Design (also known [in Europe] as Design for All and as Universal Design in the USA) is quite focused on the integration of older and disabled people in the mainstream of society [1].

However, it is important to underline that its adoption as a topic of academic education and research made it visible that other audiences also call for this framework and design approach such as, for example, gifted children. Moreover, inclusive design also claims our attention to the integration of all in respect to cultural and social differences. In fact it is all about diminishing exclusion by all means and in all its possible assumptions.

To do so, and in the context of teaching/learning inclusive design one needs to consider multiple factors, including: course content, class preparation, classroom behavior, knowledge of students' backgrounds and skills so it is possible to improve the learning climate for all students. The inclusive design principles should naturally integrate all stages of design education from under graduation to doctoral programs.

The teaching experience and literature review demonstrate that young students have trouble dealing with complex contexts and problems [2] since they lack the knowledge, the maturity and the necessary relationship skills and collaborative competences.

An environment that favors inclusive design teaching and learning processes is one that has collaborative work as a core element. The collaborative aspect is not strict to the students in class; It especially implies an openness to external elements to come and integrate the work being developed by giving their perspective on issues, by exposing their experience and sharing their view and critical thoughts. The collaborative interactions should take into account the creation of a comprehensive planning; a coherent vision; parity of decision making; mutual goals assessment; shared resources, responsibility and accountability and finally the participated evaluation along the process.

The creation of this net of connections with people with different points of view, knowledge and experiences with the topic being addressed promotes the essential climate to develop solutions towards personal wellbeing, social cohesion and enjoyment for all.

The contact and work with multiple areas of knowledge, different degrees of experience with phenomena allows students to become more knowledgeable and develops flexibility in their approaches to problems. This flexibility in mindset boosts flexibility in possible solutions never losing the sense of reality and feasibility.

Regarding the themes and audiences to be focused in designing in an inclusive approach the more common ones are related with elderly and disabled people and the contexts of the problems are usually related with the needs of mobility, security, personal basic needs (eat, drink, sleep, dress) health and education.

The children group of users is an interesting one to be approached 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.

Finally one should reflect on the differences of working with students from under graduation courses and the ones of master and PhD programs.

The first ones need to be introduced to this subject and the work to be done relies heavily on creating awareness on the topic, giving them the basic and foundational elements that structure this type of approaches and making them knowledgeable about design technical aspects.

It will be only at the master level that students will have the ability of approaching more complex aspects of inclusive design that are related with subjective issues such as the ones associated with cognitive ergonomics; psychology of behavior, social interaction etcetera. By the time a student enters a master program he/she will also have a higher degree of maturity and ability of engaging in critical reasoning processes that are fundamental to frame the immaterial, subjective issues that permeate all the inclusive design processes.

It is also at these two stages of education—master and PhD—that research skills are to be developed in a more consistent and intense way.

This way it is verifiable in FA design education a concentration of inclusive design themes and projects at the master and PhD levels.

3 Inclusive Design Projects

The selection of the projects to be presented in this paper was done having as choice criteria: (a) projects addressing children problems (b) diversity of design area (product design; communication design; other areas such as fashion); (c) focus on children and on its inclusion processes; (d) research methodology with an expressive work field with the target groups; (e) research results having a clear impact in the target population benefiting them in a visible way.

Thus, we chose two different projects: one product design master dissertation supervised by one of the authors that aimed at intervening with gifted children named: Design for Gifted Children: Playful-pedagogical equipment for children aged 7–12 years old; a dissertation in communication design also supervised by one of the authors aiming the production of activities' material to help children with visual disability to draw and express themselves named "Twelve Painters and you are one. Drawing and Tactile Illustration as Tools of Development to Children with Visual Disabilities"; Both projects had an intense field work with the children, educators and parents and resulted in products that are being used in the institutions that hosted the main experiments.

3.1 The 'Design for Gifted Children' Research Project

Gifted children—who are they? How to design inclusion with them? Intelligence can be seen as "a general basic ability responsible for the performance in cognitive activities as varied as: the resolution of a mathematic problem, a poem's writing or the meaning interpretation of a sculpture work" [3] (p. 586).

In what concerns its definition, giftedness is seen as "an individual potential for exceptional or outstanding achievements in one or more domains" [4] (p. 191).

In a short historical approach to giftedness it is known that in 1920 a child would be considered gifted or a genius if he/she would obtain a punctuation of 140 or more in the IQ tests [5].[1] Later SAT (Scholastic Aptitude Tests) were created and they were similar to IQ tests but they added the measurement of both mathematical and verbal abilities [6]. Sternberg proposes three subcategories of intelligence: analytical (mental processes that guide a more or less intelligent behavior), creative (ability of solving new problems transforming those solutions into routine processes that can be adapted to different context) and practical (deals with the mental activity involved in attaining fit to context) [7].

Renzulli [8] also recognizes two types of giftedness being the first one named "schoolhouse giftedness" and the second one "creative–productive giftedness". The first one is better measured through IQ tests and has to do with learning easiness and general cognitive abilities above the average. In general terms if a child has a cognitive development above the average on his/her age it is considered gifted [9].

At the cognitive academic level gifted children reveal to have an easy intellectual understanding of problems and instruction, high ability of logical and abstract reasoning, high concentration, attention observation and memory as well as they display a true desire to learn more and quicker. They also reveal to have a good perception and critical appreciation of ideas, people and events. They reveal preference for complexity and get bored with routine and easy tasks [3]. They are able to use the two opposite types of though: convergent and divergent. The first one has to do with the ability of solving problems and come to the right answer departing from given information; this type is measured through IQ tests. The second one involves fluency which is the ability to generate a great amount of ideas and flexibility, which is the ability to look at things from different perspectives and to make uncommon idea associations and or seeing things that are not obvious. For example, a person can be able to generate new and original ideas but it is also necessary to select among 'good' and 'bad' ideas and that calls for convergent thought. Furthermore gifted children can alternate between reality and imagination allowing them to disrupt with the present without losing connection with the past.

[1]Between 90 and 109 a child is considered to be 'normal' and around 50 % of the population is in this situation; from 130 up children are accepted in schools special programs and there are 2/3 % of children under this circumstances; Above 160 it is estimated to exist only 1 in 10 million.

In general terms gifted children perceive themselves as being different from other children and that is a challenge in terms of their social integration. Their specificities can cause them some difficulties since their emotional, social, cognitive and educational necessities might not be adapted to the conditions offered by society thus creating intra and interpersonal conflicts [10]. By having a great emotional intelligence gifted children can be very empathic understanding quite well others, being altruistic and having a very keen sense of justice and ethic that manifest itself early in their lives. This empathy and sense of justice can make them feel unsatisfied, sad or even depressed [10]. For being able to understand others they have the ability to adapt their social competences according to the situations [11]. Another distinctive aspect of gifted children is associated with their development since they reveal to be precocious quite early in their childhood. They develop interests earlier than usual and start to understand and apply the scientific area's underlying principles (both in depth and extent) much sooner than other children having in addition a greater facility progressing in it [12].

To design inclusion for these children implies to be able to consider the main distinctive and similar characteristics of these children when compared to other children in order to be able to make them part of the larger social tissue they want and should integrate in effective terms.

Project development

In order to achieve an inclusive project the accomplishment of field studies in a participatory approach is essential. Firstly, a direct observation was done in ANEIS (National Association to Study and Intervene in Giftedness).

Exploratory activities occurred during 5 Saturdays in October 2014 with a group of 16 children (7 girls and 9 boys) ages between 5 and 13 years old. These activities had the purpose of disclosing the way gifted children like to engage with each other and the way they propose social integration can be done. Several ideas and outputs come from these sessions that allowed the development of a game aiming to explore different areas of knowledge while connecting different children in doing it.

First game prototype and test

A family of figures with distinct personalities and interests was created. These characters should interact having as a support a game tray. The information contents of the game should be stored and displayed in an interactive screen so it can be updated at all times it can provide the use of images, sound and animation. In order to guarantee that the game was as didactical and enriching as possible three types of plays were designed: "Think"—corresponding to questions; "Listening"—corresponding to curiosities; "Doing" that was related with activities and challenges.

The tray that was only at the beginning was later divided in several each dedicated to a theme. They must be sold together with the correspondent character/figure. This way each set—tray/character—works individually and since trays are modular and can be joined among them one can have a group use allowing different children to play having the freedom to add the trays the way they imagine it. The character has the function of starting the game and it has the bonus of enclosing an enigma that will be disclosed the moment you overcome a challenge in the game.

Children that have tested the first prototype were enthusiastic they invented special steps with questions or steps that allow you to advance or go back in the game. This test allowed us to gauge the tray dimensions and some graphic aspects related with the scenarios, typographic issues etcetera.

Seven characters and its respective themes were than defined: Amalia, the artist (in memory to Amália Rodrigues a Fado singer); Howard the archeologist (in memory of Howard Carter that discovered Tutankhamon tomb in 1923); Jane the biologist (in honour of Jane Goodall that has dedicated her life to primates); Gustave the engineer (the one that has created Eiffel tower in Paris); Marie the Scientist (in memory of Marie Curie); Eusébio the athlete (in memory of Eusébio the soccer player); and Caroline the astronaut (in memory of Caroline Herschel the first astronaut woman). The areas are: Arts, Archeology/Paleontology, zoology; Engineering; Science; Sports and Astronomy. The game pawns are a brush, a pickaxe; diving glasses; a screwdriver, an Erlenmeyer; a whistle and a telescope.

Testing the Game prototype

(second test after iteration on the design process)

To test the inclusiveness of the game two experiments were done: one that had children that never had contact with the game and a second one with the children of ANEIS that had participated in the creation of the game. The test with children that never had contact with the game occurred in 3 sessions with 4 children; the test in ANEIS had the participation of 8 children divided in three teams. The sessions were registered in video and in observation sheet. Children had no help besides the instructions of the game. Furthermore teachers, specialists (psychologists, education) the children and the parents were interviewed (Figs. 1, 2 and 3).

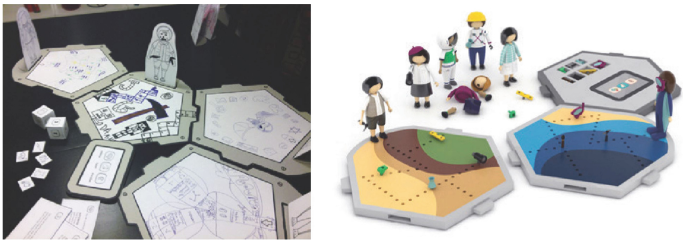

Fig. 1 A draft model of the proposed game to perform the first tests with children and to support the participatory activity (*left*); the first prototype to be tested with gifted children (*right*). *Source* Patrícia Rodrigues 2014 [17]

Fig. 2 3D Modelling of the Game Characters: Caroline the astronaut; Jane the biologist; Marie, the scientist; Amália, the artist; Gustave, the engineer; Howard, the archeologist; Eusébio the athlete (*left*); four of the characters produced in rapid prototyping (*right*) *Source* Patrícia Rodrigues 2014 [17]

Fig. 3 Rapid prototyping production of 3D game characters. *Source* Patrícia Rodrigues 2014 [17]

Results

In general terms children that were not gifted were highly satisfied with the game created becoming displeased when they had to stop playing it. They showed some impatience with long texts avoiding to read it. They enjoyed the images and adored to answer the questions having a preference for the action "Think". When the activity was "Doing" they were curious about what they had to do but not interested in doing it. On the other hand gifted children remained concentrated less time than not gifted children (with the exception of older boys). However, and according to teachers, time gifted children dedicated to the game was higher than the time they usually dedicate to his type of activity. Gifted children were more open to "doing" activities and did not appreciate the "Listen" tasks since they expected more beside the curiosity. These two experiments allowed the researchers to introduce some changes in the game namely: the reduction of the texts; the introduction of an audio button (so children could listen the questions instead of reading it and blind children could join the game too); "Listen" activity was removed since it was not challenging and more situations were added to "Doing" in order to reinforce and promote cooperation among children.

3.2 *The 'Twelve Painters and You Are One' Research Project*

Blind children—How to design inclusion with them?

Family's environment, parents' attitudes and behavior, school and society in general do affect and contribute to children development. In the case of blind children, school has a key role since it will make possible for them to learn how to better explore individual abilities and how to overcome the obstacles imposed by the deficiency. Drawing ability develops earlier in children's life since it is a way of imitating adults writing and a mode of representing narratives, situations experienced etc. However, blind children do not have the driver to imitate by drawing. Nevertheless later they will have contact with drawing that integrates educational and socio-cultural contents [13].

Using Tactile Images to promote inclusion

In this research work the focus was on tactile graphics, a practice that has its earlier reference in 1784 occasion when the first school for blind was open in Paris by Valentin Haüy [14]. By this time they were done through the use of a rather slow method using tacks nailed to a piece of wood. Technological evolution facilitated the reproduction of tactile graphics and today there are numerous print techniques to produce high-relief drawings. The reading of tactile graphics is rather important in the education of blind children along with braille one and requires learning. According to Skold [15] to interpret an image by touching is not the same as looking at it. First you feel the details, after the whole image. Part by part, section by section the image gains shape and you finally have a whole comprehension of it. Reading images can be a long learning process and aspects such the thematic and the interests of the reader can influence the velocity of learning.

"Objects need to be drawn simple and clear. All unnecessary clutter should be removed to make the tactile image easy to understand. There should be no shadows included in the image. It's best not to draw the objects in perspective but either from front, side or the top. It is however possible to make the three-dimensionality understandable on paper by showing more than one view [16]. (…) "Tactile images have to have a certain size as well. They're not supposed to be too big because then they can't be perceived as a whole anymore. They're not supposed to be too small because then they're too difficult to feel." [16].

The use of tactile graphics allows blind children to participate alone or in collective terms in the acknowledgement of information in the ability of expressing themselves, of enjoying to communicate besides the voice.

Project development

The development of a tool to help visual impaired and/or blind children was the main goal of this research. To do so a keen field work was done, together with blind children, their educators as well as with blind associations and specialists in the clinical areas and psychology.

In terms of procedures a first set of sessions was done with the Hellen Keller center (School for blind and not blind children) and another set in APEDV (an association for blind people) to explore the relationship blind users have with drawing practice and their access to art. An important amount of information resulted from these sessions namely: type of material more suitable to the users; level of interest in art subjects; perception of limitations and abilities of blind people in terms of this type of activity. There were children that enjoyed drawing, others assumed not to have a good relationship with the activity but mostly because children feel they have no aptitude to draw and feel embarrassed with it. After the systematization and interpretation of the gathered information a second phase of sessions was accomplished with a first prototype of the object that integrated only 3 activities related with: type of action; degree of difficulty; complexity of images. The analysis of results allowed us to establish well the type of activities that should be reformulated, how to do it; supplementary information to guide users in their work; ways of acquiring shape meaning and morphological aspects; acquisition of representation abilities and finally degree of satisfaction while using the object. This second test resulted in an iteration in the object's design that gave origin to the final object that was evaluated by an expert group having had a sound reception.

Results
It is rather immediate the understanding that the lack of vision affects children development especially at the cognitive level. Therefore it is essential to stimulate children so they can overcome or minimize these constraints. Drawing allows the learning of concepts, the development of vocabulary thus being a relevant mean of inclusion for visually impaired person especially children. The development of three drawing activities books to help children learn about painters and painting movements was proposed both to the Helen Keller Centre (school that has norm visual children and visual impaired ones being educated side by side) and the Association for the Promotion of the Visually Impaired Employment. Three observation sessions were done constituting a Preliminary Study serving the purpose of testing materials, illustrations, size and shapes; degrees of difficulty, pertinent traits of each Art movement.

After the adjustment done in an iterative design process the final object—3 drawing activities books—was tested with blind and not blind children proving to be a facilitator in education inclusiveness being visual impaired children able to create and enjoy art, as well as all the other sighted ones (Figs. 4, 5, 6, 7, 8 and 9).

3.3 *Reflecting on Methods Used*

Regarding children users research the participatory methods reveal themselves has being the most effective as it can be observed with Lego research a brand that often use co-creation as a method to create its products. The fact is that interaction with children avoids possible errors and misunderstanding [13].

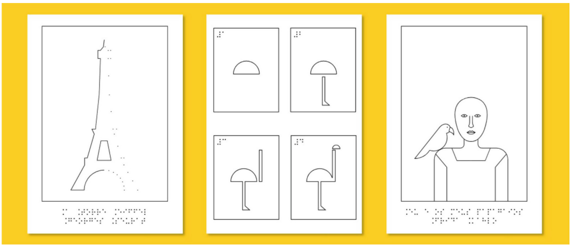

Fig. 4 Preliminary study—second phase of exploratory sessions with blind children in the Hellen Keller Centre; Degrees of difficulty from easy to hard.Source: Marta Simões 2015 [18]

Fig. 5 The activity books with all the twelve chosen artists. *Source* Marta Simões 2015 [18]

Fig. 6 An activity after Picasso work—a cubist camel—the captions are both printed in text and in Braille. *Source* Marta Simões 2015 [18]

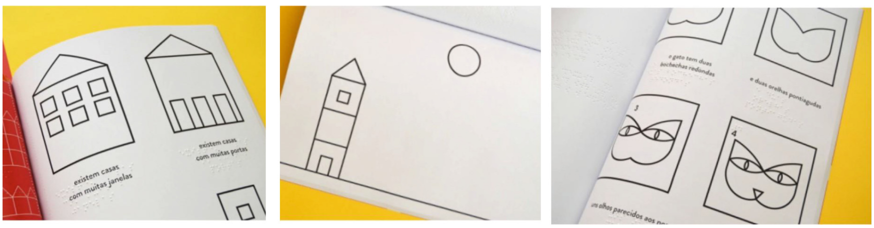

Fig. 7 Activities after Klee work. *Source* Marta Simões 2015 [18]

Fig. 8 "Leave your mark in this book"—signing the book and making it yours. *Source* Marta Simões 2015 [18]

Fig. 9 Motivational phrases on the activity books: "Art is not what you see but what you make others see" (Edgar Degas); "The reality world has its limits. The world of imagination has no frontiers" (Jean Jacques Rousseau). "To draw you must close your eyes and sing" (Pablo Picasso). *Source* Marta Simões 2015 [18]

Markopoulos et al. [14] remarked children are very expressive using tools such as pencils, papers, plaster and collages and these representation techniques can help them express themselves in focus groups. Among all the techniques the collages are very useful since when compared with other artistic types of expression this one allows children not to feel constrained due to the lack of drawing abilities as well it permits a more adequate interpretation on the part of researchers.

As it was concluded in one experiment [15] in general terms this technique allows children to develop critical thought and when incentivized by parents the creativity flourishes in an easier way and the results obtained are more diversified. The same experiment allowed also to conclude that results are more creative when children are free to create their own stories.

4 Contents to Be Taught/Competences to Be Acquired

The two research projects presented in this paper allowed the authors to reinforce previous knowledge and reflections about inclusive design education at the master level. In fact, besides reinforcing general knowledge about inclusive design definition, scope and actions design master students need to learn about other subjects being the most important ones: participatory and user centered design (definition, scope and methods) and Field work and interpersonal behavior skills.

In order to systematize the inclusive design educational proposal a table was created that crosses knowledge to be taught with competences to be acquired (see Table 1).

Table 1 Inclusive design education: knowledge to be taught versus competences to be acquired

		Competences to be acquired
Knowledge to be taught	Inclusive design (definition, scope) Participatory design (definition; scope; methods)	Knowledge about population diversity; acknowledgment of good/bad design solutions; Ability to avoid stereotype both in framing the problem and finding the solutions; assuming equality and being able to identify biases, prejudices Exploring and developing in depth and from the first moment inclusive solutions thru the integration of users in the co-creation design process and its evaluation
	User centered design (definition, scope; methods)	Exploring and developing in depth and from the first moment inclusive solutions thru the integration of users in the design process and its evaluation
	Field work theory (definitions; scope; methods and tools)	Designing field work protocols in which the human resources (the users, participants, specialists) the methodology, methods and tools are defined in an inclusive approach
	Field work practice	Understanding and being able to operate in different contexts; flexibility while framing situations and during actions; ability to deal with uncertainty and change; learn to listen and reflect
	Interpersonal behavior Interpersonal skills	Reasoning in critical terms about self-behavior, social behavior and the way this knowledge can be useful to design in an inclusive way Negotiation; empathy; collaboration and interaction; self-assessment

5 Conclusions

To work in inclusive design is to work focused on people independently of any particular physical or psychological characteristic and to promote their engagement in processes instead of assuming products as the main concern. The work to be developed must be assumed in a humanized and transformative way, i.e. privileging social contact, interaction and collaboration to achieve structural change. Students reaching the first year of a master program (average ages around 21 years old) are aware that design work has always social, cultural, economic, political, environmental implications and consequences. The work to be done is to progress from awareness to implementation of inclusive design. Since the university is the place and time for questioning functional and politically the world (including inclusive design aims and implementation) it is fundamental to activate and to develop inclusive thinking and commitment in design in design curricula. To do so we endorse a few actions [16] that would improve students' performance in this field such as: (a) to broaden their knowledge base by taking courses related with public health, psychology, sociology, anthropology, history, economics, politics and finance; (b) To promote the involvement of students with inclusive/social design firms and to incentivize them to volunteer with organizations to engage underserved communities so they will experience cultural immersion and international humanitarian aid; (c) to develop a teaching/learning culture of "learn and listen in the field, before speaking and designing" which was found to be the most critical skill students can gain from working directly with users communities.

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Mobile Device Development and Its Contribution to the Treatment of Young Dyslexic Brazilian Children

Teresa Bittencourt, João Savino, Helena Fernandes and Luiza Helena Boueri Rebello

Abstract Technology is part of our everyday life, not only for adults but also for children, who often enjoy technology as entertainment. Considering that Dislexia is the most common learning disability, this paper aims to show the development of an application targeted at 6–9 year old children. The application is intended to assist the dyslexia treatment through games that works the areas commonly affected in the dyslexic, also with participatory games, which encourage parents to get involved in their children treatment, as well as stimulate the application use by children on their own, through virtual rewards and customized items, aiming at the stimulus of continuous learning. Thus, it was intended to promote a more attractive and playful tool to assist the dyslexia treatment.

Keywords Dyslexic Brazilian children · Mobile application · Dyslexia

1 Introduction

Current technological advances seem to bring to our society more and more news that may soon be translated into new devices that will probably become indispensable to our everyday life, therefore, many technological items have already become part of the lives of thousands of people, including children. The interest of

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children in new devices, such as smartphones and tablets, is quite evident, consequently the application market for children portrays this ever growing reality.

These technological devices have also been seen as potential elements in assistive technology, providing more autonomy for people with disability. In this scenario, we highlight Dyslexia as a central element of study, considering that dyslexia is the most commonly learning disability.

The International *Dyslexia Association—IDA*, defines Dyslexia as:

Dyslexia is a specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge.

Adopted by the IDA Board of Directors, Nov. 12, 2002.

According to the ‘Dyslexia International’, a non-profit organization that provides teacher-training programs, at least 10 % of any given population has Dyslexia, depending on the orthographic system, type and degree of dyslexia. In spite of that, Brazil has never carried out a study on a national scale.

Thus, in this study we intended to emphasize the possibility of technology to promote an alternative way of learning for children with dyslexia mainly by means of the ludic aspect of this equipment, which has been shown as an extra form of motivation.

The present study focuses on the development of an application for tablets aimed at 6–9 year old children with dyslexia, which is intended to assist the treatment of the speech therapist providing activities that stimulate the areas commonly affected in the dyslexic, in a playful and interactive way.

In order to implement the study the following steps were considered: (1) Observation of the treatment of dyslexic children in order to have a direct contact with the children and the speech therapist and to perform the analysis of the task; (2) Analysis of similar applications on the market, (3) Development of design alternatives; (4) Development of the first application; (5) User testing and speech therapists‘ evaluation; (6) New research, in order to development of the new games; (7) Application Expansion, the development of the second application; (8) New user testing and speech therapists’ evaluation.

2 Treatment Observation

The initial studies were followed by the observation of the treatment of dyslexic children. The observation was carried at “Arte Expressão”, a private learning center, with the assistance of speech therapists Juliana Pereira and Juliana Muniz.

Two children and a teenager sessions were observed; one of the children was already in an advanced stage of treatment while the other was in the early stages of it and had a more severe degree of dyslexia. The teenager was in an advanced stage of treatment and had greater difficulty in the working memory area. The observation included activities that were carried out at the learning center, together with their characteristics, duration and the way the children reacted to them.

The major points observed were that children felt demotivated to do the activities entirely presented on paper. Although the use of tablets was common, they were often used as a reward because of their playful aspect, as was mentioned in the previous research. Also, parents had a fundamental role in their children treatment, which included doing home activities as well as stimulating the continuity of the treatment.

During meetings with the speech therapists children's preference for activities in tablets was reported, as well as the lack of specific applications for children in the early dyslexia treatment, especially in the Portuguese language.

From the observations during treatment sessions and meetings with the speech therapists, the following parameters for the activities were established:

- They should be entertaining;
- They should have a goal or provide something to challenge the child to remain in the activity, even when they are not in a session with the speech therapist, in order to encourage continuous learning;
- They should be similar to the activities carried out at the learning center;
- When done at home, they should integrate third parties, mainly parents in order to encourage their participation in the children treatment.

3 Development of the First Application

For the development of application games, some key areas that commonly need to be developed for the dyslexic were established, since their difficulties may vary according to the individual. Considering these varieties the speech therapists suggested that we divided the difficulties didactically into three major areas: auditory, visual and working memory.

Based on the activities already held in the learning center, we used the brainstorming method to generate alternatives. Two games were chosen to cover the three pre-established areas, which are the games called "Corrida" and "Memória".

The game "Corrida" aims to work the auditory area through the syllable count, and must be played in pairs. The game consists of counting the number of syllables of one in three words presented, the player moves forward as many spaces as the number of syllables of the word chosen. For example: if you choose the word "abacaxi" (pineapple), you move four spaces forward, which means a good score. Thus, the player should not only count the syllables, but in fact, he should also choose the word that would enable him to move more spaces to get to the end faster

Fig. 1 "Corrida" game screen and "Memória" game screen

than the other player. If a player does not get the right number of syllables, he will have another chance and at this turn, the word spelled will be displayed to assist him, since the purpose here is to enable the player to find and correct his mistakes.

The second game, "Memória", works the working memory. The game consists of a sequence of images displayed for a period of time, which can be controlled by the player. Then this sequence disappears and the player must memorize and repeat the same sequence by choosing it from a board with nine images (see Fig. 1).

The games were being developed and tested with the children accompanied by their speech therapists. From the observations made during the tests, as well as the suggestions made by the speech therapists in both games, some changes and functions were added. The main changes were related to the game settings. In the "Corrida" game, the possibility to choose the number of rounds was added, increasing competitiveness and giving the speech therapist more time control over the activity.

In the "Memória" game the function to control the time exposure of the sequences was included making it possible to adapt the difficulty of the game. The game was also divided into three levels, that is, three, four or five images could be displayed in the sequence. The scoring system, rewarding the player with stars, was added in order to motivate him during the activity (see Fig. 2).

After the final tests, the choice for the development of an application for tablets was shown as a differential, especially for being entertaining and fitting within the context of children's lives. The games seemed to be adequate to the activities performed at the learning center and the children appeared to be motivated with the challenges presented, and also showed positive learning development.

Fig. 2 Game testing “Memória” and “Corrida”

4 The Application Expansion Development

Based on the positive first games testing results, some new research was developed in order to expand the application’s advantage. For the development of the application expansion three guidelines were established, which were: providing a bigger quantity of games as well as developing broader games, aiming at the beginning of the dyslexia treatment, and focusing on the three specific areas determined on the previous research (auditory, visual and working memory areas); creating more participatory games, where there was the need for third party participation, in order to encourage parents to get involvement in their children treatment; stimulating the application use by children on their own, through virtual rewards and the customized items, aiming at the stimulus of continuous learning.

Starting from the established guidelines for the application development, first, a research was carried out aiming at the accessibility of dyslexic people in virtual environments, secondly, new exercises that would be worked on each main area previously established were also studied, and finally the required games were developed, and the theme of the application was chosen. Once the theme was settled, the application screen flow was developed with the aim of creating a contextualized narrative. Also, elements for the game development were selected, such as its layout, assets and characters. Then the database of each game was structured, seeking to use the words that are commonly part of the target age group vocabulary, and the prototype testing began from this stage on.

4.1 New Research

Considering the greater scope and variety of games, it was necessary to develop some further research regarding the dyslexics' accessibility in virtual environments. There was little research on accessibility in virtual environments, focus on mobile devices [1]. Consequently, in the present study, some research related to dyslexic website users [2–5] and low literacy users [6] were also taken into consideration. Thus, three general principles were established, each one with its specific guidelines.

Principle 1: The text

- The font should be evenly well-spaced and sans-serif;
- The font size could not be determined because it depends on the device used, but it should be big enough to make it clear, and in case of long texts, the user should be enabled to control it;
- Paragraphs should be visibly separated;
- Sentences should be short, simple and direct;
- Long texts should be left-justified with ragged right edge, in a single main column, but narrow columns should be avoided. Lines should not be too long, so that the point of vision is not easily lost.

Principle 2: Layout Design

- Background color should be used to contrast with the letter color, white backgrounds should be avoided, use cream or soft pastel colors with a dark colored text instead. In long texts, the user should be enabled to control it;
- Texts that move or change should be avoided as well as underlining, italics and texts in block capitals. Bold text for important words or boxes to highlight important points should be used, for instance, in game instructions;

Principle 3: Navigation

- It should be simple and intuitive;
- Players should be enabled to control their time to read the activities presented;
- It should be possible to expand the application by adding more games or elements without changing the application navigation.

4.2 The Games

Aiming at broader games, the following activities were set to be exercised in the application games, according to their three respective major areas:

- Auditory: Phonological awareness exercises, including syllabic awareness, syllabic manipulation and phonetic awareness.

– Visual: Lexical access exercises, visual perception of similar letters and spelling of irregular words and words with phonologic rules.
– Working Memory: Short-term memory exercises and reading and assimilation of texts.

From the activities selected, the brainstorm method was used to generate some game alternatives to each activity. To select the games that would integrate the application some criteria were considered, such as: the efficiency to fulfill the established activity, the coverage of the age group, the mechanical simplicity and the playfulness aspect.

4.3 The Prototype Development

The development of the application started from the theme choice, a balloon trip, given that the existence of a contextualized environment allowed establishing the application screens flow, creating a dynamic that worked as a narrative and resulted in a simple, intuitive and playful navigability.

The application would invite the child to make a trip that went through four islands, each one with games focusing of one of the major areas (first auditory, second visual and third working memory), and the fourth island comprising two player games. Each game generated rewards according to their island, which could be hearts, stars or wings. As the player accumulated such rewards, the customization elements, (balloon basket and envelope or the avatar), would be gradually unlocked to the player. Thus, to access all the customization elements the player needed to exercise all the major areas

After the application dynamics was set up, some available games for the specific target age were used as reference for the creation of graphic elements such as characters, assests and layout. Then the games started to be developed, considering the database in similar activities used in the learning center by the speech therapists and in some researched exercises [7] (see Fig. 3).

4.4 User Testing

Along with the prototype development process the user testing began, in order to engage into a participatory development. The tests were done with ten children accompanied by their speech therapists, at a private learning center called "Arte e Expressão", with the assistance of the speech therapist Juliana Pereira.

The application was presented orally during the testing process. For the children, it was only explained that there were some games in the application, so they were left free to explore the application, which allowed the observation of more spontaneous reactions.

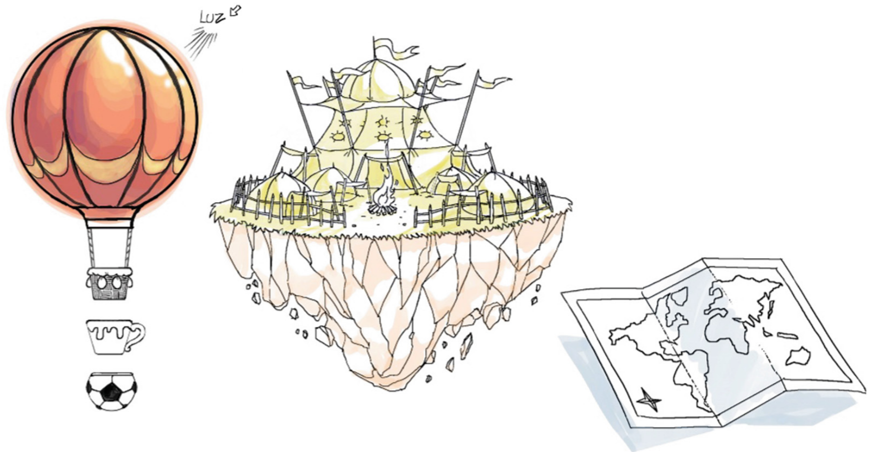

Fig. 3 Drawings and concepts

The game testings were intended to determine the effectiveness of the exercises in each game, to observe the way the children reacted to these games and to check if the game mechanics suited the target age. Regarding the application as a whole, it was important to observe the adequacy of its navigability, as well as of its narrative and also its aesthetic choice. When a need for a change was identified, the prototype was modified and tested again.

During the tests, the games were broad and efficient in relation to the proposed exercises. It could be noted that in games with simpler mechanics and shorter duration, for example, with faster feedback on failure and success, the child had greater autonomy and learned the game with ease. In a game that exercised the syllabic awareness player had to make a three-syllable word from a single fixed syllable. And to form a word he had to choose from other eight syllables placed under the screen. The player could immediately identify if he had made a mistake or not.

However, in some games it could be noticed that the mechanics was a little complex, especially when the task was longer and/or the child had difficulty, but in these situations, the child and the speech therapist tried to fit the game, either by changing the dynamics or giving tips. In such cases, the games were modified, incorporating the dynamics that emerged spontaneously after each situation. As occurred in the two player game called ‘Adedanha’ where initially the dynamic consisted of choosing a category (names, fruits, animals), then a letter was displayed and the first player said as many words as he could remember that started with the displayed letter and fitted the category Afterwards the second player did the same task with another displayed letter, and the one who said the bigger number

Fig. 4 Testing of the new 'Adedanha' mechanics

of words was the winner. This activity proved to be long, and some child had difficulty remembering the words making the game tiring, some new game alternatives appeared naturally. Based on these alternatives a new mechanic was adopted, where both players said their words alternately after a category was chosen and a letter was displayed. The player who said the last word was the winner (see Fig. 4).

It could be noticed that, in individual games, the motivation to earn rewards and customize the balloon and avatar had results, since the children showed motivated to play until they get the reward they wanted. Two player games were a challenging activity, even when there was difficulties, the child repeated the activity several times to overcome it, either with the opponent or to beat him.

Regarding the flow of screens and mechanism of the application as a whole, it could be observed that children quickly assimilated its operation, especially children who were already accustomed to using tablets, making correlations between the new application dynamic and applications that they already used, corroborating with the goal of developing an educational application using tools adapted from commercial games. For example during testing, when a boy was customizing his balloon, he asked if he would lose his stars if he choose another avatar, as usually occurs in commercial games, being happy to find that the rewards won in the games release new items cumulatively (see Fig. 5).

Fig. 5 Testing of syllables game and customization

5 Conclusion

The three established principles regarding dyslexics' accessibility to virtual environments seemed to be adequate and they also represented a great assistance for the application development. The prototype process carried out along with the users' tests was a great tool to identify more specific needs and characteristics of the users, supporting a direct improvement of the application. Thus, it was possible to make a more attractive, playful and effective application.

During the tests, the application seemed to be adequate to the children reality, since they were familiar with mobile devices, and it was also adequate to the previously identified necessities, considering that the games fulfilled the activity objective of the three pre-established areas.

The reward and customization mechanisms seemed to be a differential factor encouraging the child to play with enthusiasm and some extra commitment to the activity, which enhanced the proposed exercise in each of the games contributing to their continuous learning.

The application developed seemed to be an appropriate tool to assist the dyslexic children in their treatment, presenting broader games which suit some dyslexic necessities, and also providing participatory games, which encourage parents to get involved in their children treatment, and finally stimulating continuous learning through virtual rewards.

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Design and Evaluation of a Universally Accessible Academic Course Search Portal

Omid Elliyoun Sardroud and Young Mi Choi

Abstract The number of disabled students enrolling in postsecondary education is increasing. Many online academic resources have accessibility issues that make them difficult to use by those with temporary or permanent disabilities. This current state exists despite the enactment of laws and regulations regarding accessibility as well as growing interest in the research community in accessibility and universal access. Inaccessibility of these academic resources comes to the fore in time-pressured activities such as registration, where students have a limited time to plan their classes, layout their schedule and register using these tools. In this study an alternative academic course search interface will be designed and developed. It will incorporate existing accessibility guidelines alongside universal design principles to ensure universal and equal access. The new design will be evaluated in terms of effectiveness, efficiency, subjective satisfaction and learnability by people with different abilities and disabilities. Statistical analysis will reveal whether this approach yields significant improvements over the existing tools. The goal of the new design is to significantly increase the efficiency of the current tool both for able bodied and disabled users, by simplifying the process and removing the redundant steps, while addressing the needs of all users from the outset of the design process.

Keywords Universal design · Higher education

1 Introduction

The number of disabled students entering postsecondary education has been increasing [1–4]. In 2008, disabled students represented nearly 11 percent of the entire postsecondary students in the US [5]. With the proliferation of online

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academic tools [1, 6], and the growing number of students with disabilities enrolling in postsecondary institutions, the accessibility of these services can no longer be ignored [7].

There has been an increasing interest in accessibility and universal usability among researchers and legislators in recent years. As a result of this increased attention, anti-discrimination legislations have been put into place that mandate practitioners to comply with the proposed accessibility guidelines [8]. The 1990 Americans with Disabilities Act was one of the pieces of legislations that were enacted to prohibit discrimination based on disability [9]. Similarly, section 504 of the Rehabilitation Act of 1973 prohibits discrimination based on disability by any program or activity that receives federal funding [10], and section 508 offers guidelines on web sites accessibility [11]. In addition, the World Wide Web Consortium offers the most detailed guidelines and recommendations for accessible Web sites [12].

Despite the efforts of legislators and researchers, web accessibility practices have not been significantly improved [13, 14]. University web sites, which are of particular interest in this study, have been shown to suffer from severe accessibility issues [15]. Researcher analyzing the underlying issues have pointed out to factors such as lack of training, limited resources, and lack of interest among practitioners [16].

Universal design has been suggested as a potential solution to these web accessibility problems [17]. Universal design is defined by the Center for Universal Design at North Carolina State University as “the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design” [18]. They established a set of principles of universal design [19] which could be applied in the design of physical environments, and products and services in order to make them accessible by people with a variety of characteristics including age, gender, language, and levels of ability to hear, see, move, and speak.

In addition to Universal design, principles and best practices of interface design can be used to minimize usability problems in digital products [20]. These principles are derived from user studies, and are meant to prevent severe and frequent usability problems [21].

2 Assessing the Current System

Students at Georgia Institute of Technology use a central online system for searching and registering for classes, named OSCAR. Heuristic evaluation was conducted to further analyze the system, where the existing system was compared against some of the best practices and basic principles of interaction design [22]. Following is the problems found in the existing design based on the heuristic evaluation carried out by researchers:

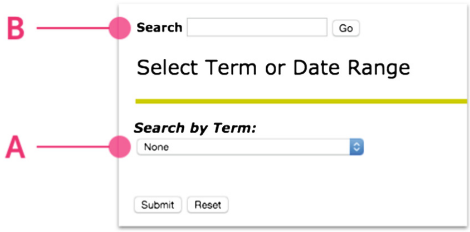


Fig. 1 Select term drop down menu, and the search box

Lack of smart defaults. Defaults can have an important effect on the overall experience of the user. Setting the wrong default settings, or asking the user for information that could be retrieved from the system can have negative effects on user satisfaction [23].

In the existing registration system, upon logging into the system, users are presented with a dropdown menu, which asks them to select a term to proceed, with the default selected option set to none (Fig. 1A). Students are generally interested in looking up the course offerings for the current term, and it is rarely the case that they would be looking for past offerings. Thus, this step seems redundant. An obvious improvement would be to set the default state to the current term. A better solution would be to remove this step altogether, while making the previous course offerings available through a secondary menu.

Inconsistency with user expectations. Conforming to users' mental models and setting the right expectations enhances learnability [24]. Interfaces should be designed in a way that users can transfer their knowledge of using other products to the new system [25].

Search boxes are a standard feature in modern user interfaces, by which users can search for the content they are looking for. The current system is not consistent with this standard practice, and it breaks user expectations. Instead of yielding results related to the course content, the search box at the top of the page seems to return results related to the sitemap and different sections of the system (Fig. 1B).

The second page after selecting the term presents a list of 72 subjects with two call to action buttons labeled course search and advanced search. In order to proceed with the "course search" button, users must select at least one subject from the list. However, selecting a subject is not required for the "advanced search" option. In fact, if users select a subject before proceeding to the advanced search section, they will need to select the subject again, since the previous list only applies to "course search" (Fig. 2). The interface does not provide any means of communicating the differences between these two call to action buttons to the users, and it does not conform to their mental models.

In the advanced search page, users can narrow down their search. One problem in this page that could go against users' expectations is the field for selecting the hours (Fig. 3). While the system asks for the "start time" and "end time", the results are actually a range between these two values.

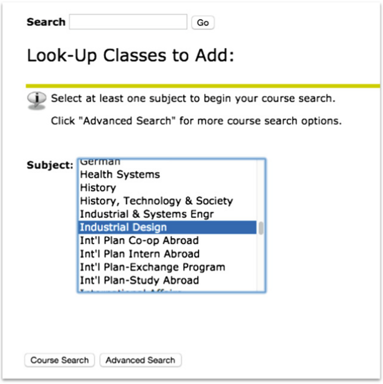


Fig. 2 Users are presented with two options: course search and advanced search

Another violation of this principles was found in the "new search" button at the bottom of the search results page. Instead of taking the users to the advanced search form, the new search button takes them back to the very first page, where they need to select the term once again.

Information Overload. Presenting too much information at once to the users would lead into distraction, and it would hinder information retrieval [26].

While the "course search" page presents only two pieces of information for each course (Fig. 4), namely their titles and their given numbers, the results of "advanced search" is a table with 20 columns, each with a unique piece of information, some of which are not of interest to the majority of users (Fig. 5). If the search query returns only 10 courses, student need to parse a table with 200 data cells. There is a lack of information in the course search page, and there is information overload in the advanced search section. Thus, the solution might lie in finding a balance between these two sections.

Readability problems. Readability of the interface depends on multiple factors, such as text size and line width. However, the way in which the information is presented can dramatically influence the readability of any interface [25].

The lack of borders in the above mentioned table for the advanced search results, and the tight space between table cells makes it difficult to distinguish the information in two neighboring cells, which severely hinders the readability of the presented information.

Cognitive overload. Limitations of human memory and cognition should be taken into account when presenting information to users. Reliance on memory can severely deteriorate the usability of the interface, and should be avoided. [27].

Fig. 3 Selecting the hours in the advanced search form

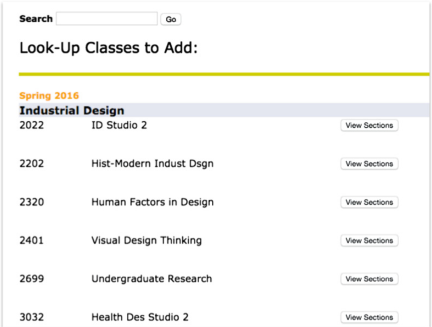
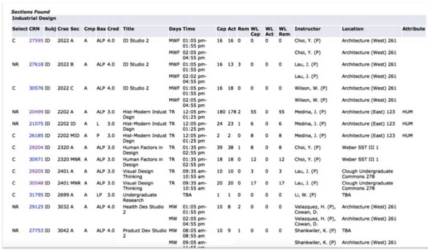


Fig. 4 The course search page presents only two pieces of information



Sections Found
Industrial Design

Select	CRN	Subj	Crse	Sec	Cmp	Bas	Cred	Title	Days	Time	Cap	Act	Rem	WL Cap	WL Act	WL Rem	Instructor	Location	Attribute
C	27595	ID	2022	A	A	ALP	4.0	ID Studio 2	MWF	01:05 pm-01:55 pm	16	16	0	0	0	0	Choi, Y. (P)	Architecture (West) 261	
									MWF	02:05 pm-04:55 pm							Choi, Y. (P)	Architecture (West) 261	
NR	27618	ID	2022	B	A	ALP	4.0	ID Studio 2	MWF	01:05 pm-01:55 pm	16	13	3	0	0	0	Lau, J. (P)	Architecture (West) 261	
									MWF	02:02 pm-04:55 pm							Lau, J. (P)	Architecture (West) 261	
C	30576	ID	2022	C	A	ALP	4.0	ID Studio 2	MWF	01:05 pm-01:55 pm	16	18	0	0	0	0	Wilson, W. (P)	Architecture (West) 261	
									MWF	02:05 pm-04:55 pm							Wilson, W. (P)	Architecture (West) 261	
NR	20499	ID	2202	A	A	ALP	3.0	Hist-Modern Indust Dsgn	TR	12:05 pm-01:25 pm	180	178	2	55	0	55	Medina, J. (P)	Architecture (East) 123	HUM
NR	21075	ID	2202	ID	A	L	3.0	Hist-Modern Indust Dsgn	TR	12:05 pm-01:25 pm	24	23	1	6	0	6	Medina, J. (P)	Architecture (East) 123	HUM
C	26185	ID	2202	MID	A	P	3.0	Hist-Modern Indust Dsgn	TR	12:05 pm-01:25 pm	2	2	0	8	0	8	Medina, J. (P)	Architecture (East) 123	HUM
C	29204	ID	2320	A	A	ALP	3.0	Human Factors in Design	TR	01:35 pm-02:55 pm	39	38	1	8	0	8	Choi, Y. (P)	Weber SST III 1	
C	30971	ID	2320	MNR	A	ALP	3.0	Human Factors in Design	TR	01:35 pm-02:55 pm	18	18	0	12	0	12	Choi, Y. (P)	Weber SST III 1	
C	29205	ID	2401	A	A	ALP	3.0	Visual Design Thinking	TR	09:35 am-10:55 am	10	10	0	3	0	3	Lau, J. (P)	Clough Undergraduate Commons 278	
C	30548	ID	2401	MNR	A	ALP	3.0	Visual Design Thinking	TR	09:35 am-10:55 am	20	20	0	17	0	17	Lau, J. (P)	Clough Undergraduate Commons 278	
C	31795	ID	2699	A	A	LP	3.0	Undergraduate Research		TBA	1	1	0	0	0	0	Li, W. (P)	TBA	
NR	29125	ID	3032	A	A	ALP	4.0	Health Des Studio 2	MW	01:05 pm-01:55 pm	10	8	2	0	0	0	Velazquez, H. (P), Cowan, D.	Architecture (West) 261	
									MW	02:05 pm-04:55 pm							Velazquez, H. (P), Cowan, D.	Architecture (West) 261	
NR	27753	ID	3042	A	A	ALP	4.0	Product Dev Studio 2	MW	08:05 am-08:55 am	10	9	1	0	0	0	Shankwiler, K. (P)	TBA	
									MW	09:05 am-							Shankwiler, K. (P)	Architecture (West) 261	

Fig. 5 Twenty columns of information can be overwhelming for the users to comprehend

The table headers are only present at the very top of the table, and the only way to figure out what each data cell represents is to either scroll up to the very top of the page, or to remember what each column stands for. Users would forget which data cell they were looking at, if they had to scroll up and down, and it would demand a high cognitive load to remember all the column headers. Moreover, the use of acronyms and abbreviations for the mentioned headers (e.g. WL Cap for waitlist capacity) presents another hurdle for perceiving the information. Users have to hover over each header and wait for the tooltip to see the unabbreviated version of the corresponding term.

Lack of autonomy. Giving users control over the interface can lead to higher efficiency. [28].

The current system does not provide any means of enabling user to control the interface, while there are several opportunities for doing so. For example, number of columns in the advances search section could be an opportunity to give users the ability to choose what information they want to see.

In line with the objectives of this project, the current system was also evaluated in regards to its accessibility. Web Content Accessibility Guidelines (WCAG) was used as the main criteria. This evaluation revealed an interesting pattern. While the current system conforms to the majority of the technical requirements of the guidelines, it violates almost all basic principles of it. The WCAG accessibility principles overlap largely with the best practices discussed above (WCAG accessibility principles: Perceivable, operable, understandable and robust). Thus, removing those obstacles would also improve the accessibility of the system.

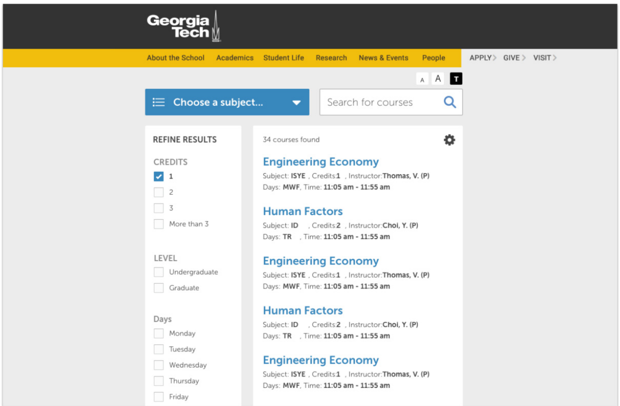


Fig. 6 The suggested design is not nested inside another services, and is a stand-alone service

2.1 Design

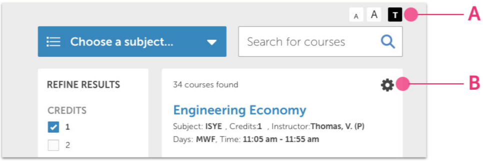
An alternative course search website designed with the objective of addressing the identified problems, and making the system equally accessible and usable by all students, regardless of their different characteristics, with the hypothesis that the new design will improve the usability of the system for all users. To achieve this goal, Universal Design principles [18] was used as a guideline to drive design decisions.

2.2 Universal Design Principles

Principle 1. Equitable Use. Instead of segregating a certain group, and designing special tools for them, the main objective of this design is to provide a single online tool that could be equally usable by people with or without disabilities. It also means that disabled users should be as efficient in using the system as able-bodied users. In order to achieve equitable use, the design had to deviate entirely from the current system, and rethink the search and navigation functionalities. Thus, the first suggestion is to separate the course search and registration webpage from the other lesser used parts. By moving this section out and into its own webpage, the navigation becomes simpler (Fig. 6).

Principle 2. Flexibility in Use. The design accommodates a wide range of abilities and is usable on all major devices including mobiles and tablet computers. This has been achieved by a mobile-first design approach [29], in which the assumption was that the design needs to fit into a small screen, which in turn makes it more usable on all devices. Select subject button is visible even when the mobile view is zoomed into the results section, making it accessible without the need of horizontal scrolling.

Fig. 7 Giving users control over appearance and presented information



In addition, the interface provides ways for users to adjust and customize the interface. Users can change the font size and contrast of the page (Fig. 7A).

Users also gain control over what type of information is presented in the search results. For example, location of the course, which is initially hidden, can be added to the presented information if users are looking for that information. (Figure 7B). In addition, the subject search drop-down menu provides two ways of selecting a course: scrolling and clicking on the subject, or typing part of its name in the search box, making it flexible for both keyboard and mouse users.

Principle 3. Simple and Intuitive Use. The design removes the advanced search section entirely, and provides a simpler and more approachable way of refining the results, by providing search filters. Instead of clicking on the advanced search button and directing users to a new page, Users are able to refine their results within the same page without losing context of what they were looking for.

Principle 4. Perceptible information. Legibility of the font is ensured according to the standards for font size and contrast [30]. Redundant visual cues such as color and icons are used where appropriate. The button for selecting the subject, which is usually the first step and the most important, is in a different color, and an icon helps to distinguish it from the rest of the layout. The course titles, which are links to course descriptions, are in internationally recognizable blue color (Fig. 6).

Principle 5. Tolerance for Error. Users will see helpful and actionable information in case their search does not yield any results. The number of results found will be presented to them at the top of the page. There are also hidden signifiers for screen-readers that will inform the users when they have reached the end of the results lists. Since all the actions are being performed on the same page, the cost of making errors is minimal.

Principle 6. Low Physical Effort. Redundant steps and unnecessary form fields are removed to lower the amount of effort required to navigate the system. Users will not have to select the term, since the current term is pre-selected for them. Actions, like selecting the subject, and search results are presented in the same page, which removes the need of navigating away from the page for a change of subject.

In the current system, users have to deal with a significant amount of horizontal scanning in order to find the relevant information (Fig. 9). Horizontal eye movement lowers efficiency, especially for the visually impaired [31]. In the alternative design, the horizontal span of the information has been restricted in order to minimize the need for horizontal eye movements. The tabular display of information has also been changed to remove the need for going back to the table

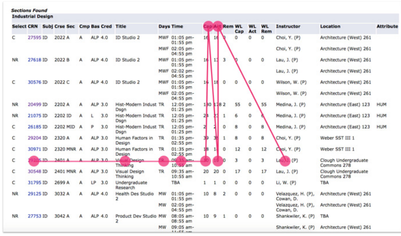


Fig. 8 The current system requires a significant amount of horizontal eye movement

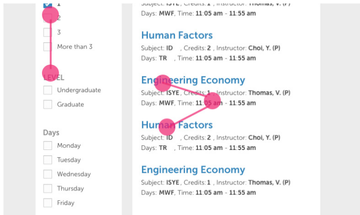


Fig. 9 The suggested design minimized horizontal scanning, and exploits the ease of vertical eye movement

headers for each piece of information. This makes it easier for users to find the information they are looking for, and it also provides context for screen-readers (Fig. 8).

Principle 7. Size and Space for Approach and Use. The size of the elements on the page and the distance between the buttons for important actions is large enough to prevent triggering accidental actions. It also makes the design equally efficient on touch-enabled devices.

3 Evaluation

The alternative design is being evaluated and compared against the existing online registration system. By using a with-in subject method, 15 students over the age of 18 will be recruited to participate in the study. Participants will be given three tasks to perform using both systems: (1) Find the list of courses for the computer science subject. (2) Find the list of architecture courses with two credits. (3) Find out who is the instructor for the "design methods" course in industrial design department. Time to completion will be measured for each task. Researchers will take notes on any usability issues that may arise during the test. System Usability Scale, which has been shown to provide superior assessments of web usability in comparison to other evaluation methods [32] will be used to assess the differences between the two systems. T-test and one-way Anova analysis will reveal if there are statistically significant differences between the two system. The hypothesis is that the efficiency of the participants will be significantly increased, since they will be dealing with a limited amount of information at each step, and they will be able to narrow down their search results within the same page, as opposed to going back and forth between search page and results. Satisfaction of using the new system is also expected to be higher, because of the simplicity and flexibility of it.

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Assessing the Reading Level of Web Texts for WCAG2.0 Compliance—Can It Be Done Automatically?

Evelyn Eika and Frode E. Sandnes

Abstract Readability of text on the web is a key prerequisite for achieving universal accessibility. The World Wide Web Consortium's Web Content Accessibility Guidelines state that general text should not require reading levels more advanced than lower secondary education. The subsequent research into readability on the web is limited. However, the literature on measuring readability and reading level is vast, but limited to simple measures of sentence length and word difficulty. This study explores the value of using other features that are harder to acquire manually, but are now readily available through computer technology. Our results indicate that the proposed features are not as accurate predictors to readability as the classic measurements. There may thus be some way to go before we have reliable automatic means of assessing texts on the web for readability.

Keywords Readability · Text on the web · Accessibility · WCAG2.0 · Universal design

1 Introduction

The widely embraced W3C Web Content Accessibility Guidelines (WCAG2.0) give advice on how to make web content accessible to users with various disabilities [1]. Most research into accessibility on the web focuses on visual impairment and some on reduced motor abilities. Cognitive disabilities have

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probably received the least attention due to its complexity. However, the cognitive task of comprehending texts on the web is central to the websites' accessibility.

WCAG2.0 addresses cognitive disabilities under section 3 and readability in particular under section 3.1. Some of the recommendations that are easy to handle include 3.1.1 and 3.1.2, which state that web pages and their parts must be correctly coded with information about the language used. Sections 3.1.3, 3.1.4 and 3.1.6 address the definition of unusual words, abbreviations and the pronunciation of ambiguous words, respectively.

A more challenging recommendation is that of 3.1.5 addressing reading level, which states that

> When text requires reading ability more advanced than the lower secondary education level after removal of proper names and titles, supplemental content, or a version that does not require reading ability more advanced than the lower secondary education level, is available. (Level AAA)

The WCAG2.0 documentation further uses the UNESCO definition of lower secondary education as being equivalent to 7–9 years of schooling [2]. It further acknowledges that it is not possible to make text universally readable because text is connected to a specific language. The WCAG2.0 documentation gives a specific example for American English using the Flesch-Kincaid formula [3] where the lower secondary education level is set at 7.2.

Although actual user testing of texts can give reliable facts about its readability, and eye-tracking data can give objective data, it is not practical to employ user testing on all text at all times. Therefore, it is desirable with simple mathematical models that could roughly predict readability. A good metric will highlight which parts are satisfactory according to some standard and unsatisfactory parts that require more work. Another perspective is to give authors tools that allow them to produce satisfactory text in the first place, eliminating need of stringent post composition audits [4].

The classic readability measures are relatively easy to compute, even by hand, as they usually evolve around sentence length and word length. These measures have also been criticized for being over simplistic [5]. This study thus attempted to explore other features that are very laborious to explore manually but are easily available using computers and openly available language processing technology.

2 Background

Readability research has been conducted for more than a century. Sentence length is one of the features that are cited as affecting readability throughout most studies [5–7], where long sentences are generally considered harder to read than short sentences. However, it is not necessarily always true that short sentences are easier and thus a simple focus on shortening sentences for the sake of improving readability is not recommended.

The second factor that is also frequently mentioned is word difficulty [5–7], as texts with difficult words are harder to read than those with easy words. However, there is disagreement on what constitutes a difficult word. Many simply measure word length, using the number of syllables or number of characters in the word. If a word has more than two syllables, it is often considered a difficult word. Word frequency has also been used to quantify the difficulty level of a word, where less frequent words are considered more difficult than frequent words. Some have attempted to make lists of difficult words through manual assessment.

Sentence length and word length commonly occur in readability metrics. For example, the Flesch-Kincaid reading easy index [3] is defined as follows:

$$206.835 - 1.015\left(\frac{words}{sentences}\right) - 84.6\left(\frac{syllables}{words}\right) \tag{1}$$

The Gunning Fog index uses similar variables, namely:

$$0.4\left[\left(\frac{words}{sentences}\right) - 100\left(\frac{difficultwords}{words}\right)\right] \tag{2}$$

Coleman-Liau is another similar index [8]:

$$5.89\left(\frac{characters}{words}\right) - 29.5\left(\frac{sentences}{words}\right) - 15.8 \tag{3}$$

Yet another is the simple SMOG index [9], which is short for simple measure of gobbledygook.

$$1.043\sqrt{30\frac{syllables}{sentences}} + 3.1291 \tag{4}$$

A practical and popular approach that can be used without computer is offered by Fry-chart [10]. In Fry's method, three 100-word paragraphs are selected arbitrarily in the text; the mean number of sentences per 100 words and that of syllables per 100 words are computed. These two values are then plotted in the Fry-chart allowing the reading level to be read off directly.

Much of the readability research, including those above, target English. However, some research has also been conducted for other languages including Chinese [11]—a language very unlike English. In Scandinavia (Norway, Denmark and Sweden), the lix-index proposed by Björnsson [12] is frequently used. The LIX (lesbarhetsindeksen) is defined as:

$$\frac{words}{sentences} + \frac{difficultwords}{words}100 \tag{5}$$

Note that the number of sentences is defined as the number of sentence delimiters (punctuations, capital letters, colons, etc.). Difficult words are defined as words with more than six letters. Values in the range 25–30 indicate simple texts, while values below 25 are typical for children's books.

One weakness of many readability indices is that they can be misleading. For example, a high readability score can be obtained by rewriting a short text with difficult words into a longer text with easier words and shorter sentences. Although this gives a higher readability score, the actual readability may be worse. This point is especially valid on the web as both overall text length and word difficulty, as well as other language aspects, can affect how effectively the readers are to read. As an example, the Norwegian language council recently removed its LIX-calculator from its web site as it is deemed not useful.

2.1 Other Approaches

Factors related to style, including punctuations, prepositional phrases, verb tense and mood, may also affect readability. Other aspects such as content, formatting and organization also play a role. Among these, content is difficult to assess automatically by machine.

More aspects of language may be captured by qualitative approaches than simple readability indexes. One good example is leveling [13]. As it is believed that text resembling speech is easier to understand, leveling allows the assessment of whether a text is similar to speech.

Readable texts are useful for all readers, and particularly for groups having specific needs. Visually impaired users relying on screen readers benefit from well-structured and short document with front-loaded sentences allowing easy navigation. Documents with these characteristics are also known to be useful for dyslexic readers [14].

3 Method

The open source LanguageTool [15] was chosen for this study (version 2.0). This tool allows more sophisticated readability models to be explored. LanguageTool is an extensive grammar and spelling framework developed for several languages including English, Spanish, Polish, Danish, etc. LanguageTool is written in java; it is the default language checking mechanism used in several open source word processing packages. It can be run stand-alone and it has an API allowing arbitrary java applications to make use of its functionality. LanguageTool has therefore been integrated into various research projects [16, 17].

In this study, the evaluation is limited to English although LanguageTool also supports other languages. Three measures are proposed, namely, language problem signature, part-of-speech signatures and part of speech entropy. Each of these will be introduced in the subsequent sections.

3.1 Language Problem Signatures

The LanguageTool framework contains approximately 1000 rules related to grammar and style in English. It is assumed that text published on the web has been proofread and therefore contains few language issues related to spelling and grammar. However, LanguageTool often triggers rules as false positives reporting issues that are not problems. The purpose of the proposed scheme is to run the framework on a text and note the type of problems that are reported. The profile of the reports may give a clue to the type of text at hand.

3.2 Part-of-Speech Signature

LanguageTool has a built-in part-of-speech tagger. This module can classify the individual parts of a sentence such as nouns, verbs, articles, etc. LanguageTool recognizes approximately 40 different part-of-speech classes. We further grouped these classes into six categories, namely, nouns, verbs, modifiers (such as adjectives phrases and adverbs), linking words (e.g., however and in addition), weights (unnecessary phrases) and complex (foreign words).The mapping from the LanguageTool part-of-speech tags to our six categories is provided in Table 1.

The framework was thus used to generate a histogram for the text according to these categories. The idea is that more complex texts would contain more modifiers, linkers, unnecessary weight and descriptors than simple texts, and that the signature would be linked to the genre of writing.

Table 1 The part-of-speech tag to category mapping

Category	Part-of-speech token
Noun	PRP, NN, NNS, NN:U, NN:UN, NNP, NNPS
Verb	VB, VBD, VBG, VBN, VBP, VBZ
Modifier	CD, DT, JJ, JJR, JJS, RB, RBR, RBS, PDT, UH, PRP$
Linker	CC, IN, RP, TO, WDT, WP, WP$, WRB
Weight	EX, MD
Complex	FW

3.3 Part-of-Speech Entropy

Unlike the two previous measures that comprise multiple values, the last proposed measure is a single value—entropy. Entropy is a quantity measure originally used in physics to quantify the amount of information needed to know the complete state of an object. It can also be considered a measure of uncertainty or randomness. We define part-of-speech entropy by computing the entropy of the part-of-speech histogram for the text with all the 40 tags. The entropy computation [18] is defined as:

$$e = -\sum_i p_i \ln(p_i) \tag{6}$$

where pi is the ratio, or probability, of token i. Tokens that do not occur are not included in the computation. The rationale for this measure is that texts that employ more varied patterns of tokens yield higher entropy, and that the entropy somehow correlates with writing difficulty.

4 Experiments

To test the proposed measures, a set of texts were selected at various reading difficulties. These include three short children's texts at three levels, a paragraph from a disclaimer, a university strategy document and a scientific journal article. The text and their traditional reading scores are listed in Table 2.

The last column shows that the Flesch-Kincaid score correlates quite well with the texts as the three children's stories have the highest score. Moreover, the levels of the children's stories correlate with the readability index where the text at level 1 has the highest score and the most difficult text at level 3 has the lowest score of the three.

Table 2 Text test suite with text length (number of words), mean sentence length (number of words), mean word difficulty (mean number of syllables per word) and the Flesch-Kincaid reading index

Text	Length	Sentence length	Word difficulty	Flesch-Kincaid
Child level 1	79	8.8	1.3	87.6
Child level 2	76	12.7	1.3	82.7
Child level 3	74	12.3	1.3	81.1
Disclaimer	109	21.8	1.6	45.8
Strategy	2235	18.2	2.0	22.5
Journal	8231	13.4	1.7	48.1
J. abstract	178	13.7	1.7	46.6
J. introduction	437	24.3	1.7	35.8
J. discussion	887	19.3	1.7	43.9

Next, the journal article is slightly more readable than the disclaimer according to the Flesch-Kincaid score, while the strategy document is the least readable. This ranking corresponds well with the authors' subjective perceived readability of the texts.

Table 2 shows that the word difficulty appears to be a relatively stable measure as it is constant for each category (children's story and journal), while the sentence length varies depending on the part of the text. Consequently, the Flesch-Kincaid measure does vary according to which part of a text that is analyzed. Clearly, the score for the introduction is significantly lower than the abstract and the discussion.

Observably, the texts vary from as little as 74 words to more than 8000 words. The short texts are realistic test cases since texts on the web often are short. In fact, the length of the text is itself an indication of accessibility as the journal text probably is less attractive to the average reader.

Table 3 shows the number of language issues reported for each text. The journal article triggers most issues, while each smaller part of the article triggers fewer issues, with introduction and discussion among the least. The results indicate journal abstract, introduction and discussion have few issues, but that there must be some issues in the other part of the journal article. Next, the children's stories at level 2 and 3 trigger the most errors and the number of issues correlates with the reading level. Simply looking at the percentage of issues does not appear useful, while inspecting the details of the issues reveal useful information. For instance, the children's story only contains a possible typo, while the strategy has several readability issues including redundant phrases, confusion of British and American English and overly long sentence. The following is a listing of the issues output for the journal article (the heading number indicates frequency of the problem).

329: Possible Typo(prio = 50)—Possible spelling mistake
136: Miscellaneous(prio = 50)—Whitespace repetition (bad formatting)
91: Capitalization(prio = 50)—Capitalize lowercase words ('i am')
38: Capitalization(prio = 50)—Checks that a sentence starts with an uppercase letter
35: Miscellaneous(prio = 50)—Readability: sentence over 40 words

Table 3 Language issues reported

Test	Issues (%)
Child level 1	3.8
Child level 2	5.3
Child level 3	5.4
Disclaimer	1.8
Strategy	4.7
Journal	8.7
J. abstract	3.9
J. introduction	0.9
J. discussion	0.5

22: Bad style(prio = 50)—Number starting a sentence
20: Miscellaneous(prio = 50)—Use of whitespace before comma and before parentheses
11: Grammar(prio = 50)—Articles: article missing before a countable noun
6: Miscellaneous(prio = 50)—Unpaired braces, brackets, quotation marks, similar symbols
5: Miscellaneous(prio = 50)—Flag passive voice
5: Miscellaneous(prio = 50)—Smart ellipsis (…)
3: Miscellaneous(prio = 50)—American words easily confused in British English
3: Redundant Phrases(prio = 50)—in order to (to)
3: Punctuation Errors(prio = 50)—Warn when the serial comma is used (incomplete)
2: Grammar(prio = 50)—Possible agreement error: numeral + singular countable noun
2: Grammar(prio = 50)—Agreement error: Non-third person verb with 'he/she'
1: Miscellaneous(prio = 50)—Repetition of two words ('at the at the')
1: Possible Typos(prio = 50)—web site (website)
1: Miscellaneous(prio = 50)—Use of 'a' versus 'an'.

Next, Fig. 1 shows the part-of-speech signatures for the texts. The signatures show that the disclaimer and the children's story have the most verbs. However, the disclaimer has more modifiers than the children's story, and the children's story has more nouns than the disclaimer. Both the journal and the strategy have most nouns, where the journal has the most even distribution of all part-of-speech categories. The journal does not have any weight tags. The strategy document, however, has some words that add unnecessary weight and it has more linkage words than modifiers. This could indicate that the text is unreadable with many prepositional phrases, or it could indicate that text is readable with linked passages. More work is needed to clarify such ambiguities.

Table 4 lists the part-of-speech entropy for the texts. The results suggest that the entropy correlates with the reading level and that it is robust to the text sample. Clearly, the part-of-speech entropy increases gradually with the reading level of the children's text as it is 2.79 for level 1, 2.81 for level 2 and 2.84 for the level three text.

Further, the entropy for the full journal article is 2.96, while it is 2.92 for the abstract, 2.95 for the introduction and 2.96 for the discussion. The length has some effect as longer texts result in a higher entropy. This is as expected since a longer text is likely to make use of more sentence variations than a shorter text. However, the variation is relatively small and entropy appears to converge with length.

An interesting result is that the lowest entropy is obtained for the disclaimer. Visually inspected, the disclaimer can be perceived as being complex to read due to its formal style, many long words and comparatively longer sentences than other types of text. However, the part-of-speech entropy suggests that it has the least grammatical variation. It may be that the disclaimer tends to use similar sentence patterns. Future research could investigate further the sentence type, inclusive of its

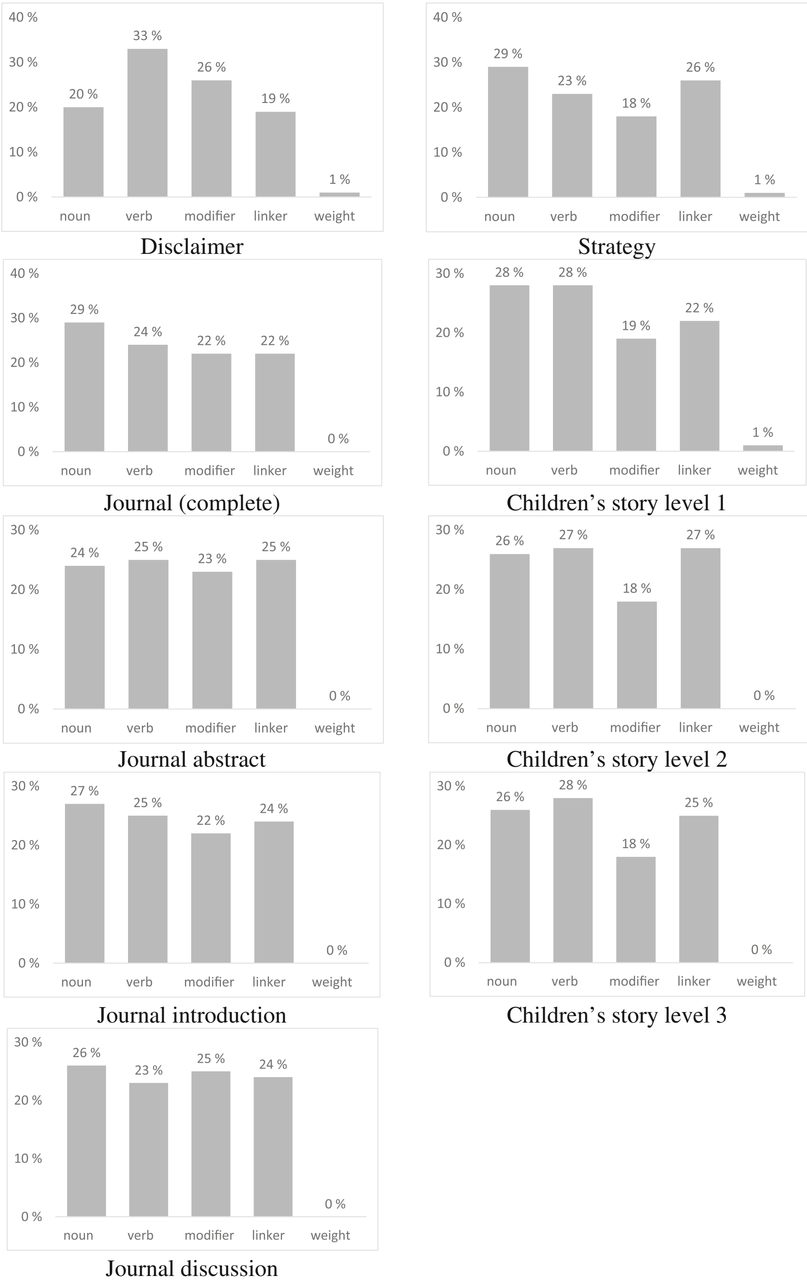

Fig. 1 Part-of-speech signatures for the texts according to nouns, verbs, modifiers, linker, weight and complexity

Table 4 Part-of-speech entropy

Test	Entropy
Level 1	2.785075
Level 2	2.805429
Level 3	2.836197
Disclaimer	2.771111
Strategy	2.889141
Journal full	2.962654
Journal abstract	2.918766
Journal introduction	2.945794
Journal discussion	2.959201

makeup involving subjects, verbs and objects. More complex constructs such as relative pronouns and subordinate conjunctions could be examined within sentence types as they can affect the precision of meaning, which further complicates readability.

5 Conclusion

This study explored the use of more sophisticated models for quantifying readability using computer analysis. Three models were studied, namely, profile of reported errors, part-of-speech signatures and part-of-speech entropy. The results show that the proposed measures do not sufficiently or entirely discriminate texts according to readability and that the simple measures based on sentence length and word difficulty appear to be better predictors. Nevertheless, the measures give some alternative views on texts and could help draw authors' attention towards potential problems. As shown, it is not trivial to automate the process of determining whether texts on the web are readable or not according to given criteria. Future work should explore natural language processing framework that explores the text at a deeper level. The ideas presented herein may also be applied to language learning [19] and the teaching of writing [20].

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Cultural and Creative Industries of the Color and Design of Packaging

Chih-Chun Lai and Lung-Wen Kuo

Abstract Cultural and creative industries, is a combination of creative thinking and cultural elements of the emerging industry, with local folk culture landscape, its religious and cultural backgrounds and other elements, and the use of creative or innovative design approach, the patterns created by new ideas industry. In this study, cultural and creative elements of products used gift packaging design to Taiwanese culture vocabulary-based, supplemented by Chinese cultural connotations, and added to the customs, specialty farming, scenic, etc., to derive new cultural and creative product design. First, the present study investigated and compared the pattern of commercially available gift for composition, color and pattern to be analyzed. Secondly, reference statistics, five different design elements used in the cultural and creative products, and Munsell color based on the use of 20 kinds of colors, a total of 20 experiments to test the theory of semantic analysis prevail, so that measured choose the most suitable cultural and creative element color, color analysis best visual effects. Experimental results show that with pineapple pattern simplicity FIG Teng packaging and Deep Blue color, the most representative places of cultural and creative in style.

Keywords Product design · Pattern · Color

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1 Introduction

Cultural and creative industries, is a combination of creative thinking and cultural elements of the emerging industry, with local folk culture landscape, its religious and cultural backgrounds and other elements, and the use of creative or innovative design approach, the patterns created by new ideas industry. In this study, cultural and creative elements used in computer peripheral products mouse design to Taiwanese culture vocabulary-based, supplemented by Chinese cultural connotations, and added to the customs, agriculture and animal husbandry specialty, such as the main scenic spots to derivative new creative product design.

Cultural and creative packaging design is to join the elements, the first is cultural characteristics to Taiwanese culture, is still subject to the influence of Chinese culture connotation more, but Chinese culture in Taiwan presents the evolution of the essence of Chinese culture did not leave. More, Taiwan's unique style of temple architecture followed the customs of the people on the ground, specialty agriculture and animal husbandry, and other scenic spots, is unique in this regard, it is easy to distinguish, is a lively and unique place for art studies.

These temples in Taiwan every town and village common, many more towns to the temple for the local landscape indicators. Taiwan and have the title fruit kingdom, specialty fruit farming is one of the local specialties, but also look for cultural and creative elements of the subject matter, this study specialty of Taiwan pineapple as an element, with flowers and birds in traditional Chinese peonies for the cultural and creative elements.

2 Discussion Document

Cultural and creative designs that combine local culture and creative industries design. Broad cultural and creative, that people live together in a society, with similar habits, customs, religious beliefs and so on; and narrow the cultural and creative means of Art and Design, is a designer by containing culture creative design implications of the newly designed product design patterns.

In packaging design and cultural and creative combination of aesthetics and economics are based in cultural and creative product design, you can add additional value can also be purchased to further improve the behavior of the product. Therefore, after the completion of product design, designers use a variety of media and then trying to market their products, so that consumers can identify with advertising media, such as network marketing, animation, micro-movies. How to use the design method of cross-media, advertising and marketing to achieve the desired effect, the final packaging design is the key to success.

2.1 Munsell Color Use

Munsell color vision developed in accordance with the characteristics of the color classification and calibration systems. It uses a similar sphere model, the three basic characteristics of various surface color: hue, lightness, saturation, all of that out. Master packaging design color and hue, the color is an important element of the design, emotional factors can trigger psychological consumers, designers with color to convey language products, increase consumer's identity, the most important thing is to bring the color consumers have a feeling of joy and pleasure, truly successful design. Finally, the pattern image and text composition arrangement with the appropriate product design elements, increase the added value of packaging design, such as the most commonly used images, illustrations, landscape drawing or abstract patterns and other product content, appropriate use of packaging material unique sense of design towards the design.

3 Research Methods

Typical conventional layout in the first phase of this study, the framework of the methodology used, first, to conduct market research, collect 100 kinds of gift packaging on the market, the statistics for the design composition, design and color pattern image to get gift market then as a guideline to design experiments to prepare. Step 2, using a psychological experiment, conducted experiments observer, viewing the projected image to the computer screen text. Etc. into the design line and color experiments. And semantic differential method (Semantic Differential Scale) experimental method to observe the use of semantic scale answer visually.

Step 3, typical for the layout, design and packaging color pattern of experimental content performed Die, patterned design, pattern design and color imaging experiments. Step 4, innovative design experimental methods to design department 90 students as experimental subjects, with the results of the market investigation as a reference sample, Daomo, patterned design, graphics design and image and other color choices, allowing students to design pineapple cake gift boxes. Finally, analyze the data, the result of the reaction with the innovative design of the experimental method observer statistical analysis and comparison. Then analyzes data in relation to the difference in reactivity results 90 kinds of gift packaging statistical results and observers between.

3.1 The First Stage of "Preparation of the Study"

First drawing up research topics and range, and then study the issue carefully planning, research head to determine after collecting three kinds of gift packaging

Number of Moon Packages	10	11	2	4	3
Number of Many packages	6	16	4	5	9
Number of Pineapple Packages	9	11	2	4	4
Total	25	38	8	13	16

Fig. 1 Gift packaging design composition according to statistics

design and color aesthetics of literature, and to discussion and analysis, as the basis for future research questionnaire. Gift for the pastry industry in Taiwan market research survey, the object selected for the Mid-Autumn moon cake gift boxes, gift boxes pineapple cakes, cake gift packaging design in three colors, composition and pattern analysis to study the target, collecting a total of 300 kinds of gift box styles, and in the classification, packaging design elements for the study of the subject of the sub-items.

First Statistics gift packaging design and patterning approach pattern design image statistics, according to statistics with the picture composition and pattern the way to give the industry the most commonly designers and fashion preferences, and as a basic composition and experimental design. Sequential pattern with Chinese traditional pattern, pineapple pattern illustration, pineapple cakes product or Landscape People image maps, text-to design, Chinese or Western flower painting images in five ways. Followed by gift color statistics, in nine colors with other colors commonly used for statistical colors (Fig. 1).

3.2 *The Second Phase, "Design of Experiments Color"*

Use pineapple cake gift box pattern making experimental stimuli, semantic differential method from the very harmonious to very strong psychological reaction test consists of ten colors. For each image color stimuli, the image is in a controlled surroundings. On-screen display annoying power to a uniform gray background bottom color pattern is placed on, and start using Adobe Illustrator CS6 and Adobe Photoshop CS6 to modify the production of 20 kinds of color design psychological tests.

Color	No.	CMYK				Color	No.	CMYK			
	1	C8	M36	Y8	K0		11	C90	M70	Y10	K0
	2	C10	M10	Y12	K0		12	C98	M97	Y60	K48
	3	C5	M30	Y5	K0		13	C0	M0	Y0	K100
	4	C10	M72	Y86	K0		14	C84	M53	Y10	K0
	5	C6	M57	Y37	K0		15	C90	M58	Y85	K30
	6	C33	M100	Y100	K0		16	C52	M43	Y40	K0
	7	C24	M48	Y24	K0		17	C87	M52	Y100	K20
	8	C16	M97	Y68	K0		18	C35	M20	Y82	K0
	9	C7	M100	Y46	K10		19	C78	M50	Y100	K10
	10	C70	M67	Y40	K0		20	C0	M0	Y0	K0

Fig. 2 Used in the experiment from Munsell color picker color

A total of 170 subjects color subjects were male 54, female 116, participated in the study. These subjects were aged from between 18 and 22 years, they are the University of Technology design department 1–2 students (Fig. 2).

3.3 The Third Stage "Analysis"

Packaging design and color aesthetics, structure and use of packaging material part, to discuss literature analysis, collate and analyze a common way to classify. Color, shape, illustration information on the brightness contrast and color harmony of color matching and psychological reactions were analyzed. Using semantic differential method (Semantic Differential Scale), set the two opposite terms of research, to provide survey questionnaire design problems. Experimental subject a total of 20 questions, with five design patterns and 20 colors of color images, generating a total of 20 experiments to screen 1–10 which represents the meaning of the semantic differential method:

1. Pineapple cake product packaging design, structure and materials for packaging, research and analysis to improve the space.
2. Packaging, tone and degree of cultural research connected color analysis. In the Munsell color system, based on the analysis of the selected object, do color matching and color research. Analysis of the results, the most suitable product color language.
3. According to the best design and cross-media marketing of the present study was designed after literature review and analysis of the questionnaire, which was subjected to research, design and creative thinking of commodity packaging design and digital media marketing feasibility want hair, and with Theoretical part confirm each other (Fig. 3).

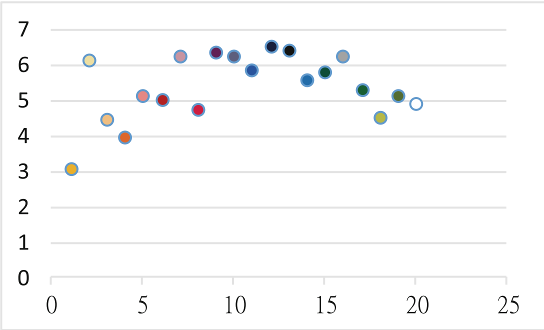


Fig. 3 Color samples of FIG mood

3.4 Phase IV "Were Cultural and Creative Design Elements Experiment"

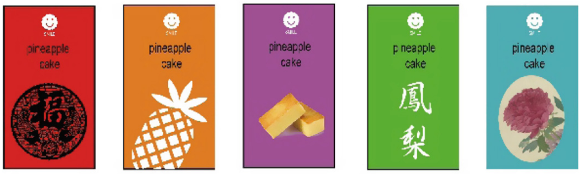
1. To survey design and statistical analysis of the experimental results, the best of five groups packaging structure design innovative design and best color match five groups, provide new creative design reference text.
2. To five groups of five sets of packaging design and most suitable for pineapple cake with color illustrations, a total of 10 combinations experiment discussed subjects a total of 70 subjects were male 34, female 56, attended the studies. These subjects were aged from between 18 and 22 years, they are college sophomores technology in the design department. Finalization of statistical results is the best and most suitable for creative design (Fig. 4).

4 Results and Analysis

Market research and cultural and creative elements of the fourth stage design experiments for the first phase difference analysis, image display gift box packaging designs to market the product or the most scenic character image maps, but students to design experiments in a pattern Illustration (pineapple) most significantly different. The results show that the design department students generally simple design pattern has a more cultural and creative cultural and creative significance.

Market research packaging color to pure black (K100) at most, but close to the experimental design color black dark blue (C98M97Y60K48) up to (6.57), black statistical times more (6.46), though not the same, but with the use of color is very close to the market. Display dark packaging and students more susceptible to market acceptance.

The significant gender differences in the color of the experimental design, statistics $p < 0.05$ colors have q1_1 (# E9AE2A) of 0.020, q1_4 (# DC652B) of 0.032, q1_7 (# C693A1) of 0.039, which is displayed three colors, higher acceptance of women than from men.



sample	1	2	3	4	5
Male	6	14	8	3	3
Female	11	16	15	6	8
Total	17	30	23	9	11

Fig. 4 Five color illustrations and the experimental image

5 Discussion and Conclusions

The importance of the aesthetic research and experimental study design methods to cultural and creative packaging color, design and ponder the cultural and creative combination of all product design, to the final products are for marketing purposes, therefore, how to make design allows the public to accept, without losing the sense of works of art and design, art design and proper use of humanistic ideas, explore the idea of design and creative industries, in order to improve the quality of the design is very important. The results suggest that, in the 18–24-year-old designer's perspective, a pattern of simplicity FIG Teng Blue or black and dark color packaging, the most representative places of cultural and creative style.

After completion of this study, the color of the cultural and creative packaging design aesthetic future, there are more theoretical and reference, provides the direction of thinking designers and creative design methods. And how the corresponding relevant cultural and creative design and graphic design composition, provides the most appropriate creative direction.

Color Size and Design of Computer Peripheral Products of Black

Chih-Chun Lai and Lung-Wen Kuo

Abstract With the evolution of science and technology, computer peripheral products increasingly progress, although due to touch developed in the Internet with the use of APP, and other communications software, computers and tablet devices, smartphones with convenient gestures have become a trend, but in the use of computers when the software design products and gaming play game, mouse is still essential equipment. In this study, the wireless mouse as the research object, the most suitable mouse product size, color and packaging design style colors. First, the present study investigated and compared the size of a commercially available wireless mouse, choose 5 different sizes, and experimental way to make selection of the most suitable size and to analyze the size of the user with the best products tested object. Secondly, the reaction of the mouse study of color psychology, semantic difference analysis, in 16 colors to psychological tests, to obtain the best color for statistical research. The results show 64.5 × 95 mm wireless mouse product size and black color most preferences.

Keywords Conference proceedings · Manuscript template · Mouse

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1 Introduction

Different color technology products, a significant effect of human emotion and desire to buy the product. Product hue, lightness, saturation of color design time, there is a high impact, each color has its own color characteristics and psychological feelings caused by each color is different.

In general, the safety and comfort of the blue and psychological feelings about, such as BMW, LOLVO, Ford and other car LOGO, added blue elements, hope to achieve the safety of consumers agree. Red, exciting and stimulating emotions in traditional Chinese red also represents the meaning auspicious, red is commonly used as a Christmas color represents the color of love; yellow for cheerful and happy, such as installation art full of yellow duckling happy atmosphere.

Discussion Document

Color is very important for determining the product of emotion, and it is considered an important element to represent the products and their functions, shape. Color is the last to attract consumers, and an important element to convince them to buy the product. Therefore, the design of the product to select the appropriate color, color properly, the product design process is an important emotion.

Compared to other colors, black exudes sedate impression represents miserable, sadness, sorrow, in the fashion design industry, black represents a stable, dignified style. China's Peking Opera, the black general represents the arbiter used upright, honest, selfless characters.

In this study, the use of color specification product design industry and digital technology, textiles, plastics, architecture and interior design of common Pantone specialty colors. First, black Pantone system, the present study to choose from Black C Black 7C total of seven kinds of black, plus nearly black 440C, 419C, 447C, 426C, 433C 5 colors, 12 color research. Thus, a color closer to black, the color tolerance becomes low, even if the color change is minimal, different shades of black are easily recognizable. Black has a noble, athletic impression of technology, science and technology in some products, the use of color, such as color TVs, cameras, stereos, sports and so on, mostly black, and black solemn imagery, also commonly used in clothing design and daily necessities, noble black to shape the image of a fashion color, and the color is also very easy blending.

2 Research Methods

Color is an important product design work, proper use of color elements to stimulate the desire to buy, to the enterprise, hoping to select the appropriate product packaging and color, in order to stimulate the growth of sales. Black commercially available mouse packaging often used, in addition to being drawn into a stable representatives and representatives of quality, advanced. Under the stimulation of black, people feel there is a good quality product is durable emotions. General technology products more commonly used blue, is the color of cool color, blue for calm, mainly affecting science and technology, to stimulate the blue mood people feel relaxed and happy and stable.

In addition to differences between cold and warm colors, the brightness also plays an important role, high brightness colors like white, pink, red, blue brightness darker color than black, gray, brown, more able to help people feel happy and other positive emotions. But the color of the product is sometimes necessary to allow users to not feel tired, or color products do not affect the visual space, such as black and white of the eye or a conventional mouse technology products, the use of a long period of time, less likely the visual impact of fatigue. The high saturation of the mouse, such as bright red, yellow eyes, use a long time will be very tired.

The first stage of "preparation of the study":

First drawing up research topics and range, and then study the issue carefully planning, research head to determine after collecting three kinds of gift packaging design and color aesthetics of literature, and to discussion and analysis, as the basis for future research questionnaire. Gift for the pastry industry in Taiwan market research survey, the object selected for the Mid-Autumn moon cake gift boxes, gift boxes pineapple cakes, cake gift packaging design in three colors, composition and pattern analysis to study the target, collecting a total of 300 kinds of gift box styles, and in the classification, packaging design elements for the study of the subject of the sub-items.

First Statistics gift packaging design and patterning approach pattern design image statistics, according to statistics with the picture composition and pattern the way to give the industry the most commonly designers and fashion preferences, and as a basic composition and experimental design. Sequential pattern with Chinese traditional pattern, pineapple pattern illustration, pineapple cakes product or Landscape People image maps, text-to design, Chinese or Western flower painting images in five ways. Followed by gift color statistics, in nine colors with other colors commonly used for statistical colors.

First response mouse studies color psychology, semantic difference analysis, in 16 colors to psychological tests, to obtain the best color for statistical research. Secondly, this study investigated and compared the size of a commercially available wireless mouse, choose 5 different sizes, and experimental wireless mouse user-friendliness, ergonomics and comfort manner, so that the target object to select the most suitable size to analyze the user the best product size. Finally, make the best size wireless mouse product packaging design style into five, with five the best color combinations to a total of 25 packaging design to Likert scale statistical data and analysis.

2.1 Research Objectives

The study determined black wireless mouse in proportion popular emotion feature various shades of black, and feel the best use of the mouse to size, and provides a suitable color of product design and packaging design experience learning styles. Thus, the goal of the three studies is as follows:

1. To investigate by analyzing the characteristics of the product color emotion emotional factors, in order to confirm the popular wireless mouse color and confirm emotional features various shades of black.
2. In order to determine if the wireless mouse nuances of different sizes, in experiments to find out the best way to use dimensions.
3. Recommend the product packaging design process, according to the desired characteristics of the product and the emotional black mouse packaging design the most appropriate box die cutter style and color, and method of learning.

2.2 A Test Plan

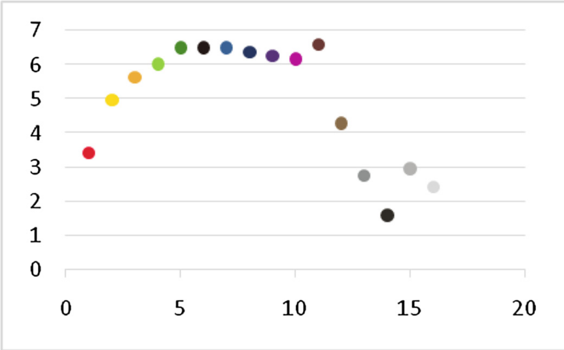
Research in various shades and emotional features black tone to three sequential experiments were conducted. First, select 16 kinds of PANTONE colors plus white 16 colors to experiment with various colors of emotional factors, and to assess the wireless mouse product color emotions. Secondly, in order to extract the PANTONE color system 12 colors close to black, to analyze the various shades of black emotion qualities, assess the best wireless mouse black color. Finally, in order to apply to the actual black wireless mouse products, mouse black image tone experimentally evaluated (Fig. 1).

Before the experiment, the mouse was observed commonly used in commercially available color shades and colors. Select from 16 commonly used and commercially available mouse being used color (red 185C, orange 143C, yellow

Color	Pantone No.	RGB			Hex
	185C	R235	G8	B41	#221814
	143 C	R255	G221	B0	#F6B333
	Yellow C	R237	G174	B57	#F4D500
	375 C	R149	G214	B57	#94D500
	363 C	R76	G139	B43	#221814
	335 C	R35	G24	B21	#00795F
	653 C	R52	G96	B148	#346094
	2748 C	R28	G45	B87	#1B2C56
	7680 C	R85	G50	B120	#543177
	233 C	R188	G0	B115	#CC007A
	498 C	R107	G56	B51	#6A3833
	874 C	R140	G171	B45	#8C6E4A
	877 C	R142	G144	B144	#8E8F90
	Black C	R46	G42	B37	#2E2925
	Cool Gray 5C	R179	G178	B177	#B3B1B1
	(White)	R255	G255	B255	#FEFEFE

Fig. 1 15 colors from Pantone color system experiment

Fig. 2 Q1 mood of the color sample of FIG



Yellow C, yellow-375C, green 363C, blue and green 335C, blue 653C, dark blue 2748C, violet 7680C, purple 233C, brown 498C, Kim 874C, silver 877C, gray Cool gray 5C, black and white black C) and select a color from the PANTONE color system experiment. Subsequently, 30 participants were asked to choose one of the surveys to Likert scale method, with beautiful, clear color and texture as the psychological test target. Experimental Q2 to very beautiful, very beautiful, some beautiful, neutral, not some beautiful, not quite beautiful and not very beautiful, seven in 16 colors and scales to psychological reactions, all of the test a total of three questions, a total of 48 tests, and as can be observed most acceptable color wireless mouse (Fig. 2; Table 1).

Table 1 Beautiful colors mean and standard deviation of the investigation

	Number	The average	Standard deviation	Standard error of the mean
q2_1	30	3.43	1.251	0.228
q2_2	30	4.97	1.426	0.260
q2_3	30	5.63	1.273	0.232
q2_4	30	6.03	0.928	0.169
q2_5	30	6.50	0.820	0.150
q2_6	30	6.50	0.731	0.133
q2_7	30	6.37	0.850	0.155
q2_8	30	6.27	1.143	0.209
q2_9	30	6.27	1.230	0.225
q2_10	30	6.17	1.234	0.225
q2_11	30	6.60	0.724	0.132
q2_12	30	4.30	1.557	0.284
q2_13	30	2.77	1.073	0.196
q2_14	30	1.60	0.814	0.149
q2_15	30	2.97	1.033	0.189
q2_16	30	2.43	1.165	0.213

First experiment in two stages, a total of 30 subjects color subjects were male 10, female 20, she participated in the study plan. These subjects were aged from between 18 and 22 years, they are college sophomores technology in the design department.

The first phase of the experiment Q2/Q3 to very clear/texture, fairly clear/texture, some clear/texture, neutral, not some clear/texture, not very clear/texture and not very clear/7 scale and texture, etc. to design 16 colors to psychological reactions, emotional features black and other colors are obtained by calculating their averages. In terms of texture warm as 185C (3.67) and 143C (5.43) is more susceptible to universal recognition, while cool colors and neutral tones no more specific performance is not considered very texture. Therefore, neutral colors such as gold 874 (4.47), 877 silver (3.20) and Cool Gray 5C Gray (3.17), is considered quite textured, but relatively white in (2.77), is considered extremely texture. The most significant is considered the most textured black (1.37). In a clear factor, to get the highest score. Final analysis, the black mouse receive the highest score higher than average factors.

This stage uses semantic difference method (Semantic Differential Scale), set up a study two opposite terms, provide survey questionnaire design problems. Experimental subject a total of 20 questions, with five design patterns and 20 colors of color images, generating a total of 20 experiments to screen 1–10 which represents the meaning of the semantic differential method:

In this experiment, it is to explore the different emotional responses to various shades of black-based. In addition, the impact of hue, saturation and brightness of mood quantified. Experiment from PANTONE Color System color choose black color. Black C, Black 2C, Black 3C, Black 4C, Black 5C, Black 6C, Black 7C, 440C, 419C, 447C, 426C, 433C a total of 12 colors (Fig. 3).

Color	Pantone No.	RGB			Hex
	Black C	R46	G42	B37	#2E2925
	Black 2C	R52	G46	B31	#332E1F
	Black 3C	R34	G39	B32	#212620
	Black 4C	R49	G37	B28	#31251C
	Black 5C	R63	G43	B47	#3F2A2E
	Black 6C	R17	G24	B32	#10181F
	Black 7C	R62	G57	B53	#3D3834
	440 C	R56	G46	B43	#382D2B
	419 C	R34	G34	B34	#212221
	447 C	R56	G58	B53	#373935
	426 C	R38	G39	B41	#252729
	433 C	R30	G37	B43	#1E242B

Fig. 3 Extraction experiments from 12 kinds of black color Pantone color

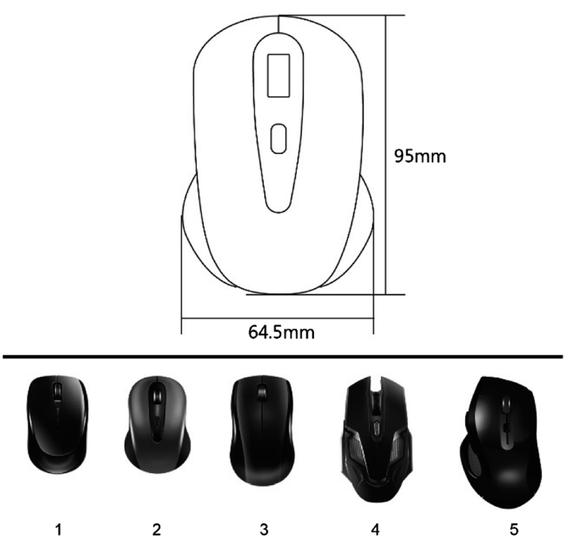


Fig. 4 Different sizes of five kinds of wireless mouse experiments

mouse	W(長)mm	H(寬)mm	D(高)mm	manufacture
1	57	95	37	TCSTAR
2	64.5	95	35.5	TCSTAR
3	59.5	104	39	TCSTAR
4	73	128	40	TCSTAR
5	82.5	130	39.5	TCSTAR

2.3 A Test Plan

In order to determine whether the wireless mouse in the nuances of different sizes to experiment to find the best way to use dimensions. In the Order of the experiments were conducted. First, select the wireless mouse basic size, big (82.5 × 130 mm), middle-1 (73 × 128 mm), middle-2 (59.5 × 104 mm), small-1 (64.5 × 95 mm), small-2 (57 × 95 mm) total of five kinds of black slip Alvin and experiment the best use of touch to evaluate the optimum size of the product (Fig. 4).

Five wireless mouse simultaneously with the same laptop to a USB hub to connect the receiver in the experiment, while the mouse DPI unified set 600DPI, to achieve the same sensitivity, and Photoshop subjects who use the software provided. After repeated use of five kinds of wireless mouse to Likert scale method, into an extremely comfortable and sensitive, sensitive and very comfortable, somewhat comfortable and sensitive, neutral, not some comfort sensitive, not very comfortable and not very sensitive to comfort sensitive total 7 scale 35 experiments to evaluate the optimum size of the statistical data wireless mouse products.

3 Discussion and Conclusions

In this study and experiment, the wireless mouse product color in 16 colors quiz, the most popular in black, followed by white and black tones, on black Pantone Black 6C most eligible for recognition. In different sizes and packaging design style color experiment to find the best use of size and color style statistical study showed $64.5 \times 95 \times 35.5$ mm wireless mouse product size and black color most preferences.

In this study, the emotional characteristics of various shades of black were studied. The three main objectives of the study, to be implemented in three experiments. First, Likert scale method, with beautiful, clear color and texture as the emotional factors of psychological tests to assess the product's color emotions. And then in various shades of black and different shades of black relative emotional test. Compared to other colors, black is found to be the most beautiful, the most clear and texture. Second, determine the most appropriate use of wireless mouse feel the size and sensitivity, it showed $64.5 \times 95 \times 35.5$ mm wireless mouse is best to use.

Part IX
Designing for Inclusion for Ageing Population

Agder Living Lab: From Ideas to Large-Scale Deployment and Long-Term User Adoption of Inclusive Health Solutions

Santiago Martinez, Silje Bjerkås, Ann-Elisabeth Ludvigsen and Rune Fensli

Abstract End-user involvement is a central part in the strategy of public and private organisations to generate user-driven innovative solutions to real-world problems. The Living lab concept is an instrument to create user-centered solutions, with almost 400 recognized in the European Network of Living Labs (ENoLL) since 2006. Living labs cover diverse topics, such as smart-cities, innovative learning and digital health. A national initiative in Southern Norway has funded the Agder Living Lab (ALL) for eHealth, a user-centered innovation environment participated by multisectorial public and private partners. ALL implements a quadruple-helix model represented by citizens, industry, academia and government, offering an experimental arena for universal design to implement welfare technology, eHealth, telemedicine and mobile health solutions. ALL aims to catalyse inclusive innovation in the health sector by creating a multidisciplinary space where end-users (citizen, patient, relative, health professional) and health services can be interlinked making technology accessible and usable to everybody.

Keywords Living lab · User-driven innovation · Inclusive design

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1 Introduction

End-users of technology have traditionally been the target of technology innovation as consumers. However, it is less frequent seeing user as the driver of innovation [1]. User-driven innovation in technology focuses on the development of solutions grounded in the understanding of user's existing and future needs. It requires that the outcome of the process ensures value for users, user participation and quality assessment. For instance, Living labs are an example of a research methodology for user-driven innovation [2, 3] for public and private organisations that target end-user involvement to create user-driven innovative solutions. In this methodology, end-user becomes a key contributor throughout the entire process of technology innovation: exploration of new use, design with suppliers, test of prototyped solution and large scale deployment with evaluation in real settings.

2 Research Background

One of the greatest challenges in health care and services is the growing number of older adults and citizens in need of multilevel treatment, while a simultaneous decrease in the proportion of people in the workforce occurs [4]. In addition, evidence [5] highlights *loneliness*, *fall* and *cognitive decline* as three of the most common unsolved problems in the care services. These issues still represent resource, financial and research challenges for modern welfare systems and the quality of care. New forms of care that efficiently embed new technologies in the common practice are needed in parallel to pertinent changes to the organizational and physical framework. The Norwegian national welfare technology program includes confidence-building technologies, digital supervision, monitoring technologies, mobile health (mHealth) and *hospital@home* technologies. However, the great fragmentation of existing health solutions on the market does not contribute to a standardised and systematised comprehensible use of the information available, which impedes informed decision-making by professionals regarding treatment plans at large scale. Technology research projects do not always reach sufficient levels of user adoption after deployment and do not generally address the long-term sustainability of the solution after project funding. Therefore, development of technology and redesigning of health services need to guarantee long-term user adoption and sustainability of services during and beyond funding period, using defined standards and frameworks supported by the infrastructure and back-end services planned in the forthcoming national strategies.

In this context, the Living Lab concept [6] is an instrument to create user-centered solutions with the participation of end-users [7]. The number of living labs that have emerged in recent years is substantial. Since 2006, there have been almost 400 historically recognized in the European Network of Living Labs (ENoLL) in Europe and worldwide. Living labs cover a wide range of topics, such as smart-cities, innovative learning and digital health. Health has become one of the research priorities in the European (EU) research and innovation agenda, receiving more than 8 € million in funds (10.1 % of the total) in the biggest EU Research and Innovation programme Horizon 2020.

3 Agder Living Lab

The ALL is a user-centred innovation environment participated by multisectorial partners. The cooperation and partnership is established between public and private actors (Public-Private-People Partnerships (PPPP), European Commission). The ALL implements a quadruple-helix model represented by citizens, industry, academia and government, offering an experimental arena for eHealth solutions, welfare technology (telecare), telemedicine (telehealth) and mHealth solutions. The aim of the ALL is to catalyse innovation in the health sector by creating a multidisciplinary space where end-users (e.g., citizen, patient, relative, professional) and health service can be interlinked in an efficient and effective way into the development of welfare technology solutions. In the ALL concept, the end-user is an active participant throughout all stages of development: exploration of new use, designing with suppliers, testing prototyped solution, and evaluation in real settings. The involvement of representative end-users into real scenarios of use will generate insights into the design of new technological solutions. These insights will be transformed into sustainable solutions tested in the field by interdisciplinary teams through open innovation processes. This approach presents qualitative advantage when compared with alternative models of technology development, because the ALL is not limited to test only in a laboratory, but to design, evaluate and deploy technology solutions based on the end-user experience with the potential for large-scale deployment and long-term monitoring of user adoption. Combining a regional influence with a national perspective, the ALL approach will meet the need for future development of Norwegian municipalities for welfare technology, with an emphasis on service innovation aspect, converging with the national welfare technology finished by 2016 (based on the letter of award from the Norwegian Directorate of Health).

3.1 Goals

The ALL's *goals* are to bring services out of hospitals to home-living patients/end-users with different levels of health literacy, reducing hospitalization and institutionalization, while empowering patients to self-care through co-creation models. To accomplish sustainability of the project, key aspects such as process change, new service management and health economy will be addressed. These specific goals are aligned with three national research goals: Digital Healthcare, Digital Interaction and Digital Welfare. The ALL will implement a research but flexible concept based on a variety of clinical conditions and patient needs. eHealth and mHealth technologies will be used to develop inclusive generic solutions adaptable to several diseases and scenarios of use, representing the core of the services performed by formal and informal caregivers. Specifically, the project will target: (1) multi-morbid chronic patient at the point-of-care services; (2) mental illness patient follow-up in home environment. The reasons for (1) are the physical, mental and social challenges that patients face when they simultaneously suffer more than one chronic condition. Health care treatments are applied independently, not considering the aggravation that multiple chronic conditions have on the patient. This structural need is also reflected in the technology and services associated with such patients. The reasons for (2) are to improve health care of patients with mental illnesses. Currently, technologies for this type of patient are focused only on prevention, rather than a continuous follow-up to aid and inform patient's health progress. In addition, new services are required to monitor these patients anytime anywhere with health professionals when needed. There are several *research problems* associated to the targeted health conditions. These are:

(a) Combination of Internet-of-Things and Big Data to provide new decision support solutions for the health personnel supported by mobile smart-health solutions and patients' self-reported data. Addressing this problem will create value for Norwegian health care system using advanced multi-morbid triage for ad hoc interventions based on new algorithms.
(b) Use of ICT system infrastructure design, security and availability of actionable data compliant with new national ICT standards and core service components. The created value for the Norwegian Health Infrastructure would be standardised and systematised advanced ICT solutions in complex and effective health service chains.
(c) Implementation and sustainable deployment with improvements in value chains requiring evaluation of service quality, efficiency and socio-economic impacts. The created value for Norwegian society would include new evaluation models with a socio-economic research focus and impact.

3.2 Method

The Living Lab employs a methodology that brings flexibility for designing and testing new technology from problem definition to deployment. Procedures are based on the specifications and regulations provided by the Norwegian Directorate of Health within the national reference architecture of framework [8]. The eHealth centre at the University of Agder is the reference laboratory used for verification of technical systems and requirements; Frivolltun development centre for nursing and home care services in the East Agder region is used for verification and testing of use under real-setting and operating conditions. The use of the different service levels in the *MediCloud* infrastructure will allow for rapid deployment at regional scale when successful results are obtained from the pilot clinical tests and verifications. A steering committee will set the direction and define the guidelines for the ALL's operation. An active user panel will plan and evaluate the current testing methodology, results and deployed solutions.

The ALL methodology ensures:

1. Technology design and evaluation compliance with non-functional requirements and regulations.
2. Participation of representative users and selection of realistic user scenarios.
3. Test under controlled laboratory conditions and in real-life settings.
4. Clinical pilots for technology verification in operational settings.
5. All steps are documented in a standardised way for quality assurance.

The 7-step methodology is divided in 4 parts (phases I, II, III and IV). The steps are incremental, i.e., a step can be executed once the previous one has been successfully completed (see Fig. 1).

Phase I: Problem Definition To elicit user needs, a representative panel of voluntary users will be selected and invited to become active participants throughout the 7-step procedure for designing, evaluating and adopting new health solutions.

Step 1—Define User requirements and Use Case

A descriptive set of user cases will be built together with the panel of users. The degree of user involvement in the next steps will be defined, together with a detailed test plan.

Phase II: Compatibility, clinical and regulatory verification and usability test in Reference laboratory To verify that appropriate technological solutions are in compliance with technical requirements and regulations, trials shall perform a technical compatibility test to verify the non-functional requirements. When successfully completed, a user test in the reference laboratory where users will use the technology and functional requirements will be verified.

Step 2—Compatibility, clinical and regulatory test in reference laboratory

Test the compatibility in relation to national reference architecture and integration with current infrastructure including data transfer and exchange of information with

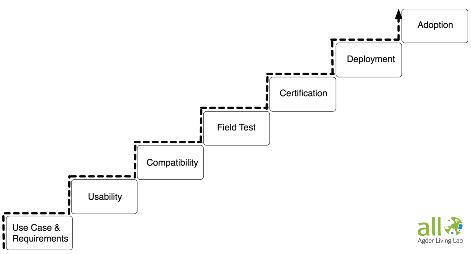

Fig. 1 Agder Living Lab phases

other systems or services. A scheduled test protocol is defined in each case based on the current usage scenarios and non-functional requirements for solutions.

Step 3—Usability test in reference laboratory

Usability test involving representative voluntary participants will be performed under controlled conditions. The test scenarios shall be conducted based on prescribed user scenarios and functional requirements for the solution.

Phase III: Test solution in home environment and health care environment. Certification A representative group of users will test a solution through a defined period of time in real settings, e.g., at home or in an institutional environment.

Step 4—User Test at home and in health environment. Clinical feedback

A pilot operating situation will be performed, where technology solutions are put into use within a healthcare environment that includes current medical treatment, follow-up and/or response from public services. The pilot will be carried out based on comprehensible descriptions of realistic usage scenarios with defined procedures for topical treatment/follow-up/response, where responsibilities in the test situation and requirements for the necessary technical documentation are prescribed in advance. Participants may include healthy citizens, patients, relatives or other relevant groups of users for the test. The test will be conducted in a defined usage scenario, within a sufficient time frame that does not interfere with the test or have any negative consequences for participants in relation to medical treatment, follow-up, response from public services or relatives.

Step 5—Certification of service/product

A certification of the product/service will be optionally performed to evaluate its compliance with current standards of service delivery, security and safety.

Phase IV: Large-scale deployment and long-term user adoption Technology solutions will be deployed at large scale with a local, regional, or even national geographical scope of installation and use. In addition, a structured plan for long-term usage monitoring of the solution will be put in place to inform the adoption at wide scale.

Step 6—Large-scale deployment

All the measures necessary for the correct installation, operation and maintenance of the solution will be put in place, together with the interoperation with existing systems. The scale of deployment will range from local to regional and national.

Step 7—Long-term user adoption

A long-term plan for monitoring the usage of the solution will inform the user adoption of the technology, whose outcome will have direct effects in the plan of future solutions.

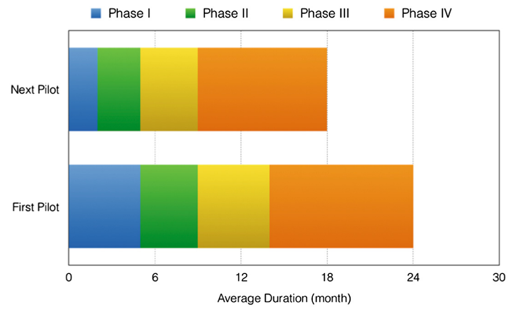

Fig. 2 Average duration of the first and subsequent ALL pilots

The ALL methodology is desgined to enhance the speed (see Fig. 2) from prototyping to sustainable deployment of subsequent selected pilots using open infrastructure and facilities accessible to local, national and international partners.

3.3 *Quality Assurance Framework*

A quality assurance system describes the relevant procedures and defines every step of the test, verification and testing. Requirements, specifications, declarations of conformity, test protocol, documentation and traceability are included in the framework, together with relevant contracts/agreements that must be signed by a responsible supplier and the ALL for the verification and testing of new technologies and solutions. The ALL is responsible for obtaining the necessary approvals from public authorities, including privacy approval for research, and the appropriate equipment supplier is responsible for obtaining the necessary technical documentation and description of current use situations/scenarios. Documentation is collected and stored under project framework guidelines established by the ALL. Appropriate confidentiality agreements between all the parties involved and the ALL must be agreed and signed up along with an assignment contract.

3.4 *ALL in Place*

The methodology has been already successfully applied in the EU project United4Health (U4H), to design, develop and deploy a telemedicine solution for monitoring of COPD patients at home after hospital discharge [9]. The solution is currently used by 3 telemedicine centers covering 23 municipalities in Norway.

4 Conclusion and Future Work

The ALL project has brought forward a framework with methods and procedures to transform ideas into new effective products and services through testing and validation within a controlled laboratory environment. The procedure involved a pilot test and evaluation in clinical settings with real patients at their home with support from the home healthcare services in the municipality of Grimstad, Norway [9]. Therefore, combining a regional influence with a national perspective, the ALL approach meets the need for future development of Scandinavian municipalities for welfare technology, with an emphasis on service innovation aspect, converging with the Norwegian national welfare technology program finished by 2016. The last stage of large-scale deployment and monitoring is targeted by prospective funding from the Norwegian Research Council that will evolve the concept within sustainable cloud-based services operating within the secured infrastructures from the Norwegian Health Network, by use of the MediCloud services.

The ALL presents a test bed where new ideas, new technology and new health care service models can be virtually trialled, evaluated and verified by partners from all over Norway. The concept applies advanced research within a structured framework of use-case descriptions to develop and verify new products and services, where the end-user is at the centre of all the stages and actively involved in co-creation processes [10]. In order to bring forward today's technology within the healthcare sector, participatory processes will involve professionals with expertise in legal and ethical aspects. Incoming changes in the regulations for shared access of medical information will create new opportunities for information access on demand, opening opportunities for solutions developed only within the highest levels of security and safety. Developing recommendations and guidelines for eHealth technology design, evaluation, deployment and adoption is in the ALL's agenda. Finally, ALL will soon organise periodic activities (e.g., ide-café sessions and workshops) open to the public, in order to get input from citizens, entrepreneurs and other public and private organisations to understand the rationale behind innovative ideas, describing the problem, determining who is affected by it and establishing to what extent the solution to a problem can be generalised to other contexts, services and end-users.

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Conflict of Interest The authors declare no conflict of interests with the participants, companies and institutions mentioned in the paper.

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Ergonomics and Inclusive Design: Innovative Medical Devices for Home Care

Francesca Tosi, Alessandra Rinaldi and Daniele Busciantella Ricci

Abstract This paper discusses: Ergonomics in Design and design-oriented strategies for innovation, like Design Thinking and Human Centered Design, to orient the design of new products in order to satisfy the needs of the plurality of user profiles involved in home care. Social innovation and appropriate intervention strategies, to guarantee the adequacy of care and to increase the independence and participation of the frail in an active life, are some of the themes of social policy and research in the international context. The role of design is essential as a strategic instrument of innovation able to respond to the needs of man and, in this specific case, of persons with reduced independence. Design helps to orientate the planning of home care products by taking safety and ease of use into special consideration. This paper presents part of the research performed by the Florence University Laboratory of Ergonomics in Design (LED).

Keywords Ergonomics in design · Human centered design · Design thinking · Social innovation · Design for all · Inclusive design · Home care devices

1 Introduction

New projections on European population have recently shown how quickly the number of elderly people is growing. The economic impact of ageing will be substantial in every EU country, and will express itself through two channels: pensions and long term health care. Population ageing is therefore a very delicate

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issue for the European community, and in terms of costs, affects the whole community. “Active and Healthy Ageing” (AHA)—that is favoring active ageing and independent life for citizens, through the education of a healthy and dynamic lifestyle, thanks to prevention and early diagnostics, as well as through assistance and care—is one of the goals of the European framework program for research and innovation.

In this scenario, themes of health care and home health care are greatly important. These themes are intended as systemic design of products and services for the health and home care sectors that could ensure the autonomy and the safety of people as long as possible in their own homes. This could alleviate family tasks that often have to seek help from ‘informal’ caregivers.[1] Houses, furniture, household appliances, objects in general, medical devices included, have to be safe, user friendly, smart and accessible for all. Environment, products and equipment design are affected by the ageing population and by the increasing number of people that require home care. Also, the products for home care are or could be often used by unprofessional people and by people with motor disabilities, perceptive and/or cognitive impairments and limitations.

Design, as strategic factor in innovation, serving humans and society, that helps to identify possible scenarios and innovative solutions in every field of application, can make an important contribution in the direction of user centered design, with the user, his needs and his expectations, at the center of design [1].

Design is often associated with aesthetic features of products but the design purpose normally extends much further than this. The starting point and the focus of the design activities are the users’ needs, their aspirations and their abilities to function as independently as possible at home. These approaches to design activities have the potential to consider many design criteria such as environmental sustainability and the safety and accessibility of products, services and systems [2].

2 Home Care Design and Ergonomics

2.1 Innovations of Objectives: A Change of Perspective

Social innovation and appropriate intervention strategies, to guarantee the adequacy of care and increase the independence and participation of the frail in an active life, are some of the more significant themes of social policy and research in the international context.

European Community defines social innovation as “the development and implementation of new ideas (products, services and models) to meet social needs

[1]Caregivers give assistance to elderly and infirm people in their home, making meals, ensuring punctual arrival to medical appointments, and generally anticipate and act on the needs of the patient.

and to create new social relationships or collaborations". It represents new responses to pressing social demands, which affect the process of social interactions. It is aimed at improving human wellbeing. Social innovations are innovations that are social in both their ends and their means. They are innovations that not only benefit society but also enhance an individual's capacity to act [3].

The main elements of social innovation are:

- identification of new/unmet/or inadequately met social needs;
- development of new solutions in response to these social needs;
- evaluation of the effectiveness of new solutions in meeting social needs;
- scaling up of effective social innovations.

Different user profiles are involved in the issues of social inclusion. In particular different user profiles are interested in the attention, the safeguard and the improvement of their personal autonomy at home and also in the possibility of having social relationships and an active participation in social life.

These themes involve a relevant change in the prospective in which both research and the experimental design field of the Ergonomics for Design and Design for All approach converge. The starting point and the final objectives of the design action of these approaches are based both on "user-centricity" and on the assessment of people's needs and expectations. This change is based on the ability to turn the attention from the specific user profiles—traditionally defined by age, physical and cognitive features or limitations, such as design for elderly people, design for people with disabilities, design for the blind—to "user needs profiles" which include everyone.

Therefore, it is not about knowing the characteristics, the capabilities or the limitations of the person, but about defining their requirements for the use of a product, of an environment, or of a service within a specific context, by taking into account all the variables. For example, this would take into consideration the condition of the environment and the specific social context, the services and the available aids for the requested activity.

In operational terms it is possible to move from a design "for people who are disabled", "for the elderly", "for the blind" etc., to a design that aims at ensuring and/or enhancing the usability and manageability of the products, their simplicity and comprehensibility, together with the visibility and legibility of the components.

In particular, the safeguard of personal autonomy and autonomy at home, therefore represent a socially relevant objective, both regarding the reduced cost in assistance and the reduced burden for the caregivers, as well as the improvement of an individual's life conditions in terms of their care, safeguarding their levels of autonomy and participation in social life.

The research and the experimental design process addressed to social inclusion start from the same objectives that we generally consider for the issues of social inclusion. This involves in particular the design criteria for environments, products and services. These not only guarantee the accessibility and the safety of the environment and of everyday products, but they can also support and empower people's autonomy and their possibility to perform normal activities of daily life and to maintain their integrity in the system of social relations.

Within this framework, themes such as the safety and simplicity of the products designed for the care and the personal assistance outside of health care structures assume special importance: such as electro-medical equipment, devices for drug administration and for measuring blood pressure and body temperature, as well as accessible toilets, beds and armchairs with adjustable heights and tilts for use at home.

The risk of accidents or the incorrect use of products might be caused by devices with illegible indications or by activities that require opening or closing or by regulation using fine motor skills or considerable strength in the hands. For example, in the case of medical devices this could lead to an incorrect dosage of a drug or to errors in the reading of data.

The wide range of people with weak conditions are considered today to be an integral part of the population, giving rise to the need to address social policies which pay attention to specific needs, expectations and desires that can bring together a wide variety of people. The relationship between ergonomics and design, like the synergy between the methods of assessing the needs of Human Centered Design users and the Design Thinking approach [4], aimed at optimizing User Experience, represents a concrete opportunity in the field of social inclusion, both as a strategic instrument for the design of innovative products and services for care and assistance, able to satisfy the requirements of users (end users, caregivers, family members) and as a method of intervention to synthesize the various professional competences involved in the design and supply of health care services and social integration [1].

2.2 Product Design for Home Care

These products aim to assist personal care at home. They include medical devices, aids and furniture systems used by older people and/or people with reduced physical and cognitive abilities. They are also used by different users like relatives and caregivers, not necessarily experts who have been trained in the use of medical devices. Products for health care can be divided into two different groups: those used for hospital or hospital related care and those used by individuals on a daily basis outside of the hospital environment.

The first group is characterized by medical devices used in nursing care facilities and for home hospitalization: from heartbeat detectors to beds with variable heights and inclinations and aids for movement. These products are designed for professional use, they can be used at home without modifications and adjustments for the different users. The use of products designed for professionals when used by untrained caregivers or patients with reduced physical, cognitive and perceptual abilities, can produce high risk problems for the safety of the patient and at the same time can cause psychological problems caused by an inappropriate use of the product which could generate a sense of fear towards these complex and potentially dangerous devices. Incorrect use of a product is often the source of error in drug administration, in the measuring of vital signs and in the regulation of equipment. Aids for personal use and specially designed furniture systems share the same critical issues: hospital beds, mobility aids, sanitary apparatus and accessories for accessible bathrooms. In addition this includes products and aids designed for private and domestic spaces, such as stair-lifts, accessible kitchens and accessories that improve the accessibility of shelves and containers. These examples suffer from image problems, due to the "hospitalization impact" of the products, creating discomfort by offering "products for the disabled" within the domestic space.

The second group consists of medical devices targeted for domestic use, such as aerosol therapy devices, blood pressure monitors, or thermometers. These products involve the same safety and security problems caused by limited legibility of instructions and by the complexity of installation and use. When patients are de-hospitalized there are numerous support and care problems. There are also consequences about the design criteria for these kinds of problems because we must consider that products for home care could also be used by nonprofessionals or by people with difficulties and limitations.

Home care differs in many ways from the assistance provided in hospitals and specialized structures. One aspect concerns the difference between products for internal use in health care assisted structures and of products for individual use. In the first case, the equipment, machinery and devices are used by specialized staff members who, depending on their role and competence, use each product for a specific purpose and, in general, adopt standardized procedures.

In the case of products for personal use, as for example medical devices or medical equipment for use, like pharmaceuticals, the reference user base is not made up of health workers, but rather of "laymen" whose characteristics and physical, perceptive or cognitive capabilities, like their knowledge or level of competence in using and understanding potential risk conditions, are unknown a priori. In this case, the device—as occurs for daily use products—can be used "by anyone, anywhere and under any conditions".

In addition the products, devices, drugs, etc. are used outside controlled procedures in often widely diversified physical contexts. Besides the direct users (patients), relatives and home caregivers must also be considered, in other words, all those people who are directly or indirectly involved in caring for the patient. Furthermore, it must be emphasized that most of the users of medical devices or care equipment, including drugs for home therapy, are elderly persons, often with difficult or limited mobility, sight or hearing problems, memory or attention impairments.

A second aspect concerns the great evolution of products, equipment and services for health care and assistance, in part identical to that encountered in other design fields and in part strongly characterized by the specificity of the sector. Like many other product types (from household appliances to the automotive sector down to communications), over the last two decades the medical product sector has seen a strong technological acceleration, which has led to a profound change in the functions and performances offered and the methods of interaction between user and product and, in particular, between user and the control/regulation/programming interface.

2.3 Users of Products and Services for Home Care

We need to consider the themes of the safeguarding of health, personal autonomy and the maintenance over time of retaining a relationship with the physical and social environment. It is also possible to understand these themes according to two parallel points of view. On one hand, there is increasing social attention given to the most vulnerable populations. On the other hand, we can consider the objectives of reducing the length of stay in health care facilities that lead to moving towards domestic care within the family structure. The problem transversally involves all user profiles and ages. From rehabilitation, post trauma and post surgery, to care of chronic conditions, moving the convalescence and care phases to domestic environments creates problems with the administration of drugs and the use of medical devices outside the direct control of health workers since it involves people who are not necessarily experts in health care activities.

Social inclusion of weak users, social sustainability of care and assistance, protection enhancement and maintenance of personal autonomy—as well as the creation of domestic and urban environments that are accessible and safe—are issues that not only involve the elderly population, but involve all people that are in a state—even temporarily—of weakness, relating to the environment in which they usually live. Those users struggle every day with physical, perceptual, cognitive barriers, which restrict their autonomy and impede the normal activities of daily life and social participation.

Situations of reduced capacities not only affect the elderly or people with disabilities, but also the entire range of conditions that can be defined as a departure from a condition that is commonly referred to as normal physical, perceptual, and cognitive capacity. This gap may be related to different aspects of individual skills and may have its effect on people's capacity to be independent, maintaining their ability to learn and to perform normal activities in daily living. The impact of this gap on daily life and relationships depends largely on the context in which the person lives.

Elderly people are just one example of such a condition, finding themselves constantly challenged in their relationship to the environment, and in the use of products and services which are both increasingly complex and in continuous and constant evolution. The improvement of living conditions, together with the possibilities of care and support that have extended the average lifespan have favored the numerical growth of the elderly population. This phenomena, which was marginal until a few years ago, has now become very relevant.

One aspect is the wide variety of personal situations and levels of autonomy that today characterize the elderly. The elderly population includes very different types of users with equally different spheres of needs, desires, habits, and social behavior. The term “aged” today does not identify a person at the end of his life or someone who is no longer active, but rather describes a complex landscape, in which people from very different conditions coexist, depending not only on age, but also on health conditions, cultural level, economic means and, above all, on life conditions and on social context.

Another aspect touches persons in their seventies or eighties who today are often active people, able to manage and plan their lives, well aware of their needs and desires and with plenty of free time.

The third and final aspect, relevant to the topic of this paper, is the growing attention given to the safeguarding of the health and the wellbeing of the young and the ‘not so young’ as well as to the promotion of lifestyles that can ensure a long autonomy for people. The social policies of European Countries are heading in this direction and they aim to promote health and to reduce the costs of an aging population.

3 Results: Innovative and Ergonomic Medical Devices for Home Care

The relation between ergonomics and design in the planning of products and services for health care and, more in general, in planning for independence and social inclusion, is one of the main subjects of research and experimentation developed by Florence University Laboratory of Ergonomics in Design.

In particular, with regard to home care, in recent years two research paths have been developed: one dealing with “furniture and accessories for home care” (Figs. 1, 2, 3, and 4) and the other with “usability of medical devices and mobility aids” (Fig. 5).

Fig. 1 MOOD. Rendering, general view

Fig. 2 MOOD. Rendering, view of the functional table

Fig. 3 360 CARE. Rendering, backside

Fig. 4 360 CARE. Rendering, prospective view of the frontside

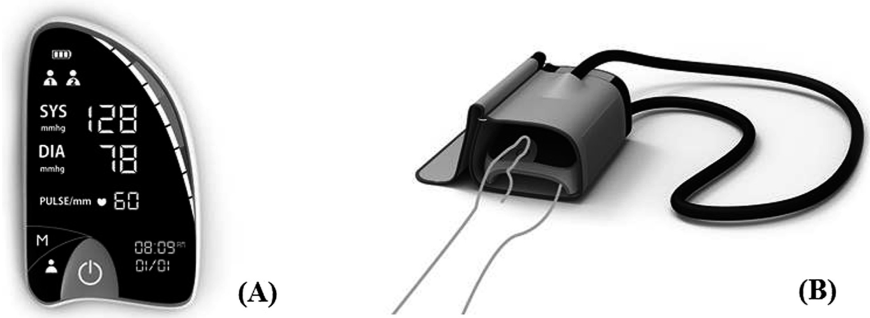

Fig. 5 **a** Sphygmomanometer. Rendering, general view of the monitor. **b** Sphygmomanometer. Rendering, grasp simulation

Research was carried out by means of a detailed analysis of the requirements of the various groups of users involved in home care, together with an evaluation of the various devices available on the market. The Human Centered Design and Design Thinking approach provided important clues not only for incremental innovation, but also for the radical innovation of existing products. Design experimentation also showed that there is still much to be done to improve user experience in this sector and to simplify and improve usability of human-machine interaction.

The research and design experimentation experience represented an initial concrete opportunity for interdisciplinary confrontation on the subject of design for health care, open to collaboration with firms and operators in the pharmaceutical and health sector.

Knowledge of the use context—starting point of the Human Centered Design process—derives from an analysis and evaluation of the context variables, including all factors contributing to defining the relationship between individual and product/environment/system. In other words, this context is defined by the users, the activities performed and their objectives, and by the physical, organizational and technological environment of reference together with the products under study.

In the case of products and aids for home care, it is a question of identifying the capacities, requirements and expectations of the main user profiles (direct users, family members, external assistants, home assistants) and, for each of them, to describe and evaluate the various activities and objectives with whom and for whom the products are intended.

The survey stage was conducted through a task analysis, developed for each user category, and by direct observation, questionnaires and interviews. Furthermore, from a design point of view, the key aspect is knowledge of possible conditions of risk and of the most frequently recurring adverse events, particularly regarding the description of exemplifying cases through evaluation of the causes leading to the incident and to possible corrective intervention. In other words, an understanding of the reasons—often complex, sometimes quite trivial—that lead to the failure to comprehend the information and/or the stages of correct usage of the product or equipment, to difficulties or impediments in their use, or to erroneous reading/interpretation of instructions, information, warnings, etc.

The following concepts have been reached by starting with a survey developed through evaluation by experts, analysis of tasks, trials and comparative analyses by users of various devices already present on the market. The projects concern the design of medical devices for personal use and the design of furniture specifically intended for home care.

3.1 MOOD, Modular System for Home Hospitalisation: Design by Irene Catalano, Ester Iacono

Mood is a modular system for convalescence at home designed to fit to users' needs. The product consists of a fixed structure on which can be added additional elements, depending on the needs of the patient and the caregiver. The analysis of similar products on the market highlighted problems, both functional and aesthetic. Several problems emerged from the task analysis regarding those solutions in use today and the emotional impact that these have on the end users. These products generally highlight the uncomfortable state of the patient because they are intended for a hospital and do not fit the users' needs within the domestic environment. The consequences are negative psychological impacts on those who use them.

The project has the following objectives:

- to enable those who are ill to be as independent as possible;
- to reduce the workload of caregivers;
- to encourage independent use by the elderly;
- to be compatible with the electro-medical products present on the market.

Mood consists of a fixed structure with some accessories that can be positioned according to specific requirements. The fixed structure, which is anchored to the wall in relation to the height of the bed, is composed of modular panels including a track that allows for the insertion of additional elements depending on the need.

The basic configuration of the system takes into consideration functions related to food, ambient lighting, chrome-therapy, and home control.

The system can be implemented with additional accessories, making operation even easier in the care and in the hygiene of the sick person: dressings organizers, drip stand, shelves, bath with integrated headrests and convertible multifunction trolley.

Mood is customizable in terms of color and finish. It fits discreetly into a home environment, moving away from hospital solutions, increasing wellbeing and comfort of the sick person and of those who look after him.

3.2 360 CARE, Bed-Head Unit for Home Hospitalisation: Design by Elisa Vannini

The number of people that need home care and long-term care, is increasing. The possibility of managing potentially critical situations also in domestic environments is much improved, both in terms of the reduction of the costs of health service, and of the positive effects on the patient, who now has the ability to maintain his habits and stay in touch with his relatives.

The analysis phase shows that most of the bed-head units on the market are strongly characterized by a very impersonal look, typical of the hospital environment which makes them a suitable tool for specialist caregivers only. This represents an important limitation for their use by informal caregivers and infirm people.

360 CARE, is a proposal for a bed-head unit, for home care, which aims to offer the patient more independence and comfort in managing his own condition. The single component beam regulates different functions, such as: lighting, power distribution, diagnostic and communication alarms, and elements for distribution and monitoring oxygen.

The main objective is to increase comfort and to give the patient an active role in managing his own condition, through:

- personalization of finishing for better integration in the home environment;
- introduction of systems for lighting management and for chrome-therapy;
- introduction of a system for the use of functional accessories.

The bed-head 360 CARE consists of a central aluminum body, featured by a rectangular individually customized plaque, which hides the lighting system.

All the functional elements are located inside the unit: plugs for the supply of oxygen, switches and connectors for the emergency remote control cable. The cross section of the beam has an inclined profile in order to discourage improper use, for example as a shelf. A track for the insertion of a rod, supporting the control panel of the lights and other accessories such as shelves or drip support, is located on the back of the lower side of the beam.

Through the control panel users can manage independently the overhead lighting and the chrome-therapy system. The panel is also equipped with other functions: alarm clock, timers, electronic agenda, music playing devices.

3.3 Compact Sphygmomanometer: Design by Ma Jing, Qiao Mengdi

The goal of this project is to simplify the task flow for measuring and reading data, through:

- reducing the operative buttons and offering appropriate sizing of the digital interface elements;
- giving feedback for the device's preparation and for reading results;
- providing compact size to facilitate handling.

For correct use of the device, the user holds it with his left hand, and slides the bracelet along the left forearm with the right hand. The orange stripe helps to identify the correct placement. The start button is highlighted with a different color and finish. Proper cuff placement ensures more precise measurements. The size of the icon on the LCD screen guarantees an immediate reading, using colorful graphics ranging from light green to dark red. The LED strip, which lights up during measurement, gives clear visual feedback of the outcome of the test.

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Creating Inclusive Living Environment in Urban Residences for Indian Elderly

Sandeep Sankat and Rachna Khare

Abstract The aim of the research is to study the situations of Indian elderly and to generate a framework to create inclusive living environment for the Indian elderly. Through preliminary diagnostic surveys the need of creation of inclusive living environments has been established. An extensive literature review is done to understand ageing. Then field surveys are performed to identify the challenges that the elderly face. The survey is done for the upcoming typologies which are identified with market survey and scientific layering of the data. Then 48 elderly in the age group of 60–85 years representing independent elderly, frail elderly, and dependent elderly are studied using environment-behavior research tools. The collected data is analyzed in layers to identify 20 environmental issues. Based on these identified issues, analysis and synthesis is done to identify the possibilities of interventions at architecture design level. It has been established through testing and validation that the gap can be filled by guidelines. Thus, following a methodology, the guidelines to create "Living Environments for the Indian Elderly" are prepared.

Keywords Elderly and design · Environment behavior research tools · Research methods · Inclusive living environments

1 Introduction

In India demographic transition is contributing to ageing population. The increased birth rate, decreased mortality rate, increased life expectancy is resulting in increased elderly population. Longevity by itself is to be celebrated, but increasing vulnerabilities of the elderly arising out of poverty, rural living, income insecurity,

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illiteracy, age related morbidity, dependency and decreasing support base requires attention [1]. In most of the western countries, advanced stages of development preceded population ageing but the same is not true for many developing and middle-income countries, including India. The government of India, being a signatory to "Madrid International Plan of Action, on Ageing" (MIPAA) deserves recognition for its foresight in drafting a "National Policy on Older Persons" (NPOP) in 1999. The NPOP is coordinated by the "Ministry of Social Justice and Empowerment" (MSJE) and implemented through the respective mandates of several ministries. The revised "National Policy for Senior Citizens" (NPSC) recommends eight areas of intervention, namely income security in old age, health care, safety and security, housing, productive ageing, welfare, multigenerational bonding, and enhancing involvement and participation of media on ageing issues [1].

The physical environment, as it relates to the dependencies of older adults, remains one of the most overlooked areas in environmental design. In order to move beyond this status quo, persons responsible for planning that environment must develop a new understanding of ways in which their influence can improve the older adult's physical and mental functioning [2].

The concept of residential design for elderly is simple: Create houses and homes that adapt to an elder population, segments of society who are or will endure the ageing process [3]. It seems pretty simple, but when we observe Indian elderly in our houses, neighborhoods, townships, markets and cities the environment created by the designers, architects and planners present numerous barriers which restrict or deter the elderly to use environment freely and with ease. These barriers restrict the elderly to adjust with the available products, restrict them to certain areas of residence, limit the use of external neighborhood environment and decrease their presence in the city areas. The lack of support in available infrastructure in the urban areas clearly indicates a need to investigate and develop an environment to enable the Indian elderly. The current research presents a sequential enquiry using evidence based research methods to develop a frame work for professionals dealing with the built environment that would help to create elderly friendly residences in India.

2 Background Context

"As people age, certain sensory changes cause them to perceive and respond to the physical environment in different ways: a person may walk more slowly, move more deliberately, hold reading material farther from the eyes, or strain to distinguish a voice in crowd. As more and more limitations in functioning are experienced, the person becomes more dependent on environment for support" [2].

As strength fails and sensory organs incur deprivation, the individual experiencing these losses reaches out to both the general social environment and physical environment in order to continue functioning [4]. Sensory changes not only increase as people grow older but are usually compounded by the simultaneous occurrence of changes in several sensory systems. However, the age of onset and the rate of decline for these functions differ markedly among and within the various sensory systems [5].

"*The Indian situations are very complex with the huge size of the country, diversity of social, cultural, economic and political background, wide variety of people with different religions, cast* etc." [6].

"*With severely different demographics, characteristically interdependent social scenario, culturally different society, wide range of economic disparity, religious and traditional systems and beliefs, the Indian situations are entirely different from the western world*" [7].

"*Borrowing any concept without understanding the needs and aspirations of the Indian elderly and their applicability to Indian situations may result in a catastrophe*" [8].

Other than the onset of physical limitations with age there are so many psychological issues which *make* their condition complex. There are social and cultural expectations too, to compound the condition.

3 Need of the Study

For all design exercises in the architecture design curriculum the data collection is done with respect to the average human dimensions neglecting the concerns and spaces with respect to the children, elderly and persons with disability. This percolates in the architecture profession as well, where all buildings are designed for average human body instead of real life users. This results in the failure of environmental designs to respond to the needs and aspirations of the vulnerable users like children, elderly, persons with disability and "All" other users. Problems faced by the children are not highlighted because they are cared by the parents but the elderly and persons with disability face serious issues when they use the environment. Thus the environmental designs fails to design for "All" and the learning of architecture design itself fails to produce solutions which cater to the issues of "All" users.

To learn about the lack of enabling environments for the Indian elderly an extensive literature survey and a few preliminary diagnostic surveys are performed. These preliminary diagnostic surveys indicated that;

1. The existing built environment lacks in inclusion of the elderly.
2. The Indian situations of the built environment and the elderly are different from the western situations.

3. There is a scope of improvement in the environment by identifying the problems, issues, barriers and challenges and removing them to make the environments inclusive and living for the elderly.
4. There is a gap in the existing body of knowledge due to which the environments for the elderly in existing Indian situations are not inclusive.

4 Aim

To develop a framework, following which inclusive living environments for the Indian elderly can be created in upcoming urban residences in India.

5 Objectives

1. To study the elderly and the situations of Indian elderly in their existing living environment.
2. To develop a methodology for the identification of problems, challenges and issues related with the living environment of the Indian elderly.
3. To identify the problems, challenges and issues, the Indian elderly face related with their living environment.
4. To test the identified challenges with stakeholders associated with the living environment of the elderly, for validation.
5. To develop the guidelines to create inclusive living environment through validated environmental issues in the urban residences to create inclusive living environments for the Indian elderly.

6 Scope of Research

India is a vast country with 72.18 % of its population living in the rural areas and the 27.82 % of the population resides in the urban areas [9]. The changing situations of urbanization are resulting in a lot of changes in the urban and rural Indian society. The issues and problems in the urban and rural India, specifically, with respect to the Indian elderly are different. The present study aspires to create inclusive living environments for the Indian elderly, in the urban environment, and is focused to the environment of Indian elderly in their residences.

The study aspires to develop a framework of guidelines, following which inclusive living environments for the Indian elderly can be created. The adoption of the recommendations/guidelines in Indian situations seems more pronounced in case of a newer construction. Therefore, the scope has been limited to the upcoming urban housing typologies.

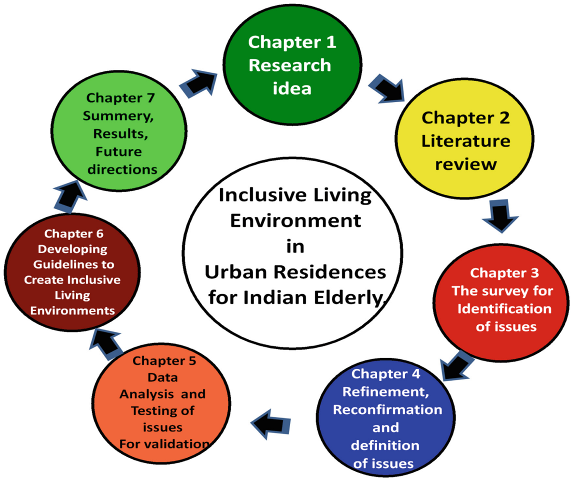

Fig. 1 The research process to create inclusive living environments for Indian elderly

7 Research Methodology

The study investigates the problems and issues which the elderly face with their environment. It aims to identify the issues to enumerate, analyse, synthesise and develop a set of guidelines to create enabling environments for the Indian elderly. It is an attempt to understand the human behaviour specific to the Indian elderly and environment. The methodology adopted is a sequential stepwise process as explained below; (Refer: Figs. 1 and 2).

8 Research Idea

The study begins with an exploratory approach with initialization of the idea and the elderly concerns in Indian situations of home, family, society, town and the city. The study then adopted user-centric evidenced-based approach with a focus on the design of residences in the upcoming housing typologies in urban India.

8.1 Literature Review

An extensive literature review is done to understand ageing, old age, elderly and the associated problems of ageing at the national and international level. The ageing issue also relates to disability thus the literature review studies included the studies of the field of disabilities at the national and international level to understand various concepts of disability.

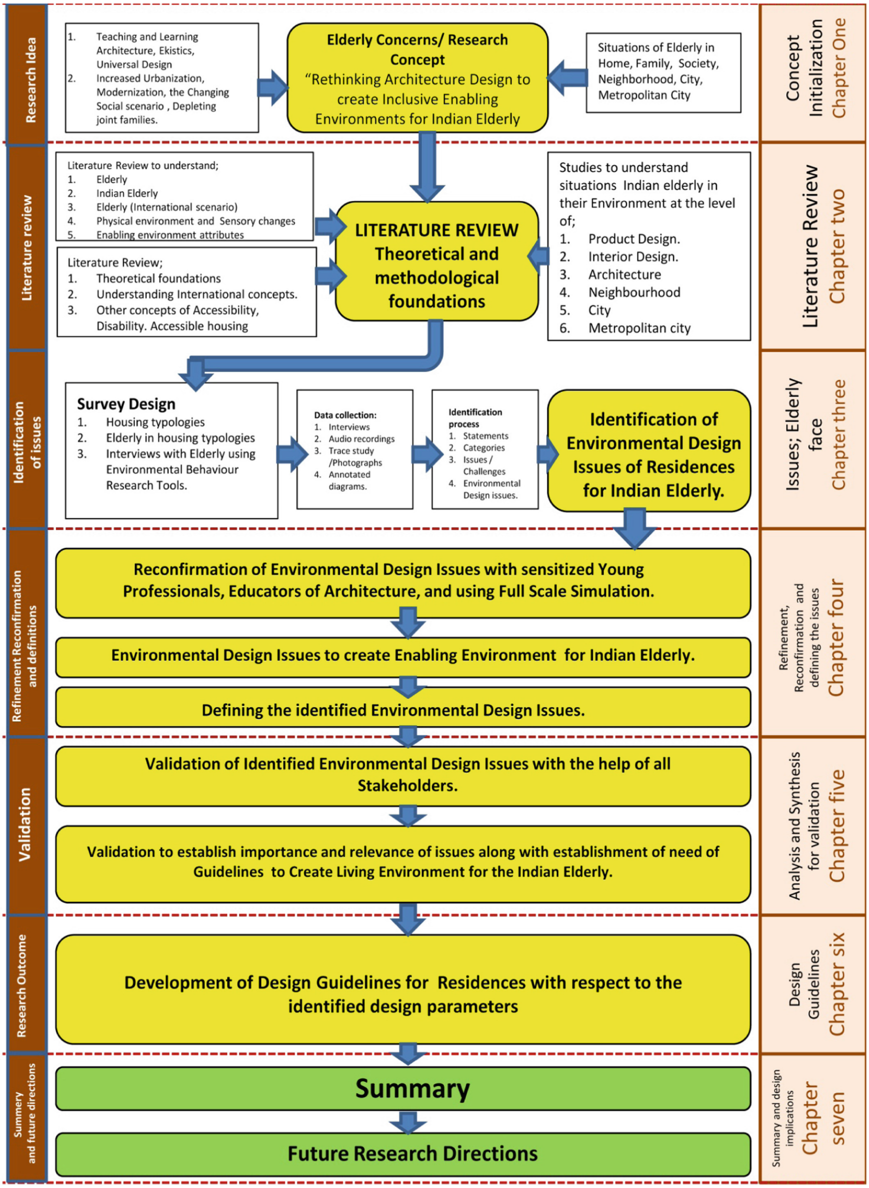

Fig. 2 Methodology of research

8.2 The Survey for Identification of the Issues

A survey to identify the issues the elderly face with their environments has been designed. Since it is an attempt to collect the qualitative data concerning the elderly and the environment, the environment behaviour research methods for survey has been adopted as mentioned below:

- Semi structured interview questionnaire [10].
- Complete audio recordings and the transcriptions of the interviews [10].
- Trace study through observations and photographs [10].
- Annotated diagrams [10].

The findings from each layer of data collection were overlapped and summarised to develop a set of identified enabling environmental issues.

8.3 Refining, Reconfirmation and Defining the Issues

The identified list of issues was refined and reconfirmed through following steps:

1. Reconfirmation and categorisation of the identified environmental issues using environmental behaviour research methods, involving young design professionals.
2. Inter-subjective transcription of semi-structured interview responses to remove bias and reconfirm the categories of environmental issues, involving sensitised architecture academicians in two layers.
3. Reconfirmation of the identified issues using full-scale simulation tool, involving young architecture professionals.

After refinement and reconfirmation, the identified enabling environmental issues were listed as final twenty identified enabling environment issues. These issues were defined and elaborated for their clarity and testability.

8.4 Analysis and Testing of Issues for Their Validation

The identified issues have been analysed, empirically tested and validated with the help of a survey conducted with stakeholders associated with the residence design, construction and use. Based on these criteria the stakeholders identified are:

- The elderly and caregivers—The users of housing.
- The practicing architects and the builders and developers—The providers of housing.

- The academicians of architecture and the young professionals of architecture—The providers (because the architectural education is resulting in professionals for the field of architecture).
- The foreign experts—International experts working for the field of architecture, interior design, disability studies, occupational therapists etc.

These stake holders have validated the identified issues for their relevance, significance and importance. The responses from the respondent groups were compared to derive the lacuna (i.e. the reason of the gap due to which the elderly residential environments in India are not inclusive). Thus the validation established the gap of context specific guidelines for the creation of living environments for the Indian elderly, suitable for Indian residences. The responses from the Indian respondents and the foreign experts were also compared to establish the difference of Indian and foreign situations. The validation also established the uniqueness of Indian situations from the foreign situations.

9 Developing Guidelines to Create Living Environments for the Elderly in Indian Residences

Through validation, the gap and the need for developing guidelines to create inclusive living environment for the elderly in Indian residences was established. Thus, the current study attempts to address this gap, through a systematic, ready reckoner in the form of guidelines to create enabling living environments for the Indian elderly. These guidelines are based on validated environmental issues and developed in terms of spatial characteristics and material characteristics for all the elements of residential design. Every element of residential design with respect to all the identified issues is analysed and synthesised in detail to develop a qualitative list of guidelines for the environmental design for the elderly in Indian urban residences. Following these guidelines, inclusive, living environment for the Indian elderly can be created.

10 Relevance of Research

A careful examination of the existing literature reveals that there is a lot of work related to socio-cultural-economic conditions of the Indian elderly has been done in geriatric and social studies. But elderly, space and environment is a domain which has not yet been explored for the Indian elderly. The only work in the field of the Indian elderly and the environment is evident through a very significant work done for the residential interior design. It is a guide book on ergonomic dimensional references for designing home interiors by Prof. Gaur G. Ray and Lavanya Bachwal. The guide focuses on providing guidelines as standards in the form of dimensions and ergonomics along with concerns for the elderly for the residential interiors [11].

It has been established by the various researchers that the situations of the Indian elderly and the elderly in developed countries are different. Thus any concept borrowed from the developed world for direct implementation may not be successful. This emphasizes the need to study the Indian elderly and the environment for creating, context specific living environments.

This research with the development of qualitative guidelines, aspires to provide a ready reckoner in the form of guidelines which when followed for the architectural design of residential spaces, will create inclusive living environments for the Indian elderly.

11 Summarizing Results

The survey conducted with the elderly in their residential environment resulted in identification of issues. These issues are then revised and refined with a four layered refinement which resulted in 20 enabling environmental issues, as listed in Table 1.

The process of making residences involves various stakeholders, right from the conception- realization- and building of the residences. A survey conducted with

Table 1 List of identified environmental issues

Identified environmental issues			
1	Safety in environment	11	Environmental support for socio-cultural connect
2	Environmental support for mobility, balance and slow movement	12	Affordable environment
3	Environmental support for better vision	13	Environment to support leisure and recreation
4	Environmental support for better hearing	14	Environment to support security
5	Light and ventilation in the environment	15	Environment to live with nature
6	Environment to support better health	16	Environment to support spiritual connect
7	Environment to support memory loss	17	Technology connect in the environment
8	Privacy and personalization in the environment	18	Usable environment
9	Degree of independence in the environment	19	Environment to provide emotional comfort
10	Environmental support for interdependence	20	Environment to address loneliness

the stakeholder to get the opinion about the identified 20 enabling environment issues for validation. These stakeholders are:

- The Indian Elderly.
- The Caregivers.
- The Practicing Architects.
- The Builders and Developers.
- The Sensitised Academicians of Architecture Education.
- The Sensitised Young Professionals of Architecture.
- The Foreign Experts.

An analysis of data collected using a tool for rating the 20 identified enabling environmental issues has been done;

A comparative analysis amongst the responses of the stakeholders has been done to understand the difference in opinions for the 20 identified enabling environmental issues and to identify the research gap. The comparisons were done amongst; The User group (The Practicing Architects and the Caregivers) and the Provider group (The Practicing Architects and the Builders and Developers)

The comparison amongst the user group and provider group revealed that both are aware about the problems and issues whereas the providers group is more aware than the user group. But, still the elderly environment for Indian elderly, lack in real inclusion. This stated the need of translating this awareness to real designs. The present research thus developed a reckoner following which the users can demand and the providers can provide the environmental designs which will result in creation of inclusive living environments. And this ready reckoner is developed as guidelines to create "Inclusive living Environment" for the Indian elderly (Fig. 3).

The second graph (Fig. 4) shows the empirical rating of all identified issues in early stage of research. All issues are rated above 60 % and thus considered very important for the residence for the Indian elderly. These validated issues provided the foundation for the preparation of evidence based design guidelines for creation of "Inclusive Living Environment for the Indian Elderly.".

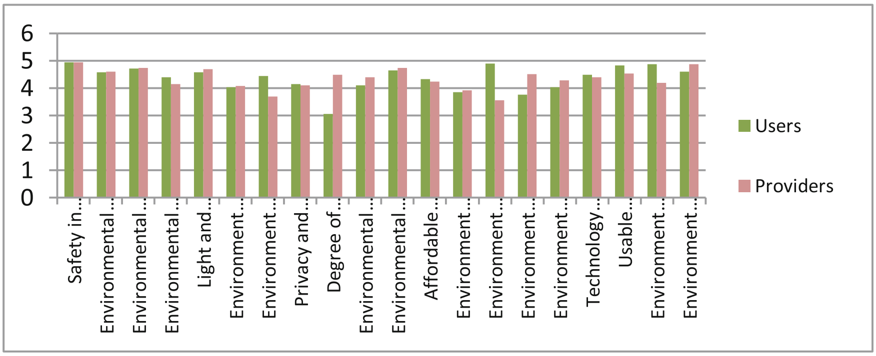

Fig. 3 Graph showing responses of Users and Providers

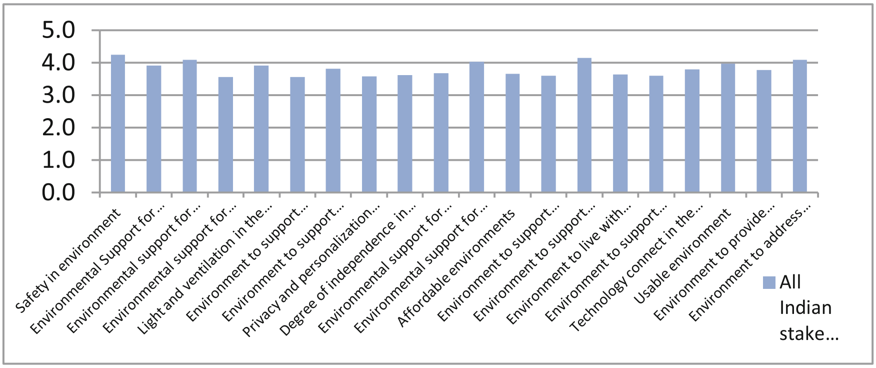

Fig. 4 Graph showing average rating of all Indian Stakeholders

With the establishment of the need to prepare guidelines for the creation of inclusive enabling environments, a set of guidelines were prepared. This research results in three major contributions;

Methodology to identify the enabling environmental design issues for the Indian elderly and environment.

Methodology of preparation of guidelines: The methodology of preparation of guidelines is a unique process which is based on the idea of identification of enabling environmental issues and then with the help of these identifications to frame the guidelines. It is a system of simultaneous considerations of the residence, the elements of residence with respect to design and its 7 subdivisions and the 20 identified enabling environmental issues (Refer detail explanation in Chap. "Bringing Universal Usability to All Users: A Case Study on Public Realm Locations of Tourist Interest in Bhopal, India" of the report).

Following the above stated methodological process of preparation of guidelines, the final guidelines for creations of inclusive, living environment are prepared (The set of guidelines is accompanied in Chap. "Bringing Universal Usability to All Users: A Case Study on Public Realm Locations of Tourist Interest in Bhopal, India " of the report). Following these guidelines for the construction of residences in urban areas, inclusive living environments for the Indian elderly can be created.

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Research Methods Applied to Studies with Active Elderly: A Literature Review

Laura Martins, João Baptista and Pedro Arezes

Abstract In almost every developed and in developing countries, the elderly population is increasing. It is assumed that environments, products and services must be appropriate and accessible to them as many people, regarding their characteristics, abilities and limitations. The purpose of this paper is to establish an outlook about the methods that are usually applied in research involving active elderly at the development stages of products designed for that specific segment of the Society.

Keywords Research · Methods · Elderly · Literature review

1 Introduction

Elderly population is increasing, both in developed and in development countries. According to the "Perspectives on World's Population: 2012 review" report of the United Nations, it is expected that, world's population increase from 7.2 to 9.6 billion by 2050, with life expectation increasing to the prediction of 76 years old between 2045 and 2050 and 82 years old between 2095 and 2100 [1].

The World Health Organization (WHO) declared that world's population over 60 years old will increase from the current 841 million to 2 billion in 2050 [2]. This new social situation had led to discussions about the necessity to meet the needs of this stage of life, fostering researches directed to this social segment.

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Assuming this scenario, it is relevant that environments, products and services must be adequate and accessible to many people as possible, regarding their characteristics, abilities and limitations.

The challenge imposed is to develop a proposition of methodological procedures that can capture the voice of older users in order to collect facilities and difficulties when using and environment, a product and a service and seeking possible solutions. Although this approach is consensual, few scientific studies indicate methods and target instruments involving the elderly in planning and controlling a significant part of the development phases of a project. Which can be performed with their knowledge and empowering them to influence both process as results and establishing desirable goals.

As the final user, the elderly must analyze, explain and offer information capable to identify their real needs providing a comprehension of the use context and functional requirements, therefore, contribute to decision-making process in their everyday living. The scientific community, in several articles published in journals, has discussed such approach.

Participatory design is a design approach characterized by the concern to improve the relation between those involved in the design process. It was developed on a political framework of democracy and it was initially applied to introducing new technologies in the workplace in Scandinavia. The key-principles are that the designer act as a facilitator, the user is raised to a position of expert within its own domain and technology should be applied to improve existing skills [3].

Throughout time, participatory design became "a set of theories, practices and studies related to users as full participants in activities that lead to computer software, products hardware and computer based activities" [4], although it is applied in many other settings.

There are some tools and methods that have been developed by researchers to support the principles of the participatory design, with particular emphasis to observation and interviews with end user in a determined context or real environment, according to the nature of the project.

The purpose of this paper if to provide an overview of methods applied in research involving elderly people in designing stages of products for this segment of society.

2 Materials and Methods

A literature review was performed through a systematic search in SCOPUS, a bibliographic database of a very wide scope, which was accessed in February, 2016, as well as through the Google search engine. The criteria included the works published after 2000 with the following search strings keywords "older" OR "elderly" OR "old people", and simultaneously related to:

- "participatory design". The final search resulted in 179 articles;
- "development of products and services" resulted in 1 article;

- "development of products" resulted in 17 articles;
- "development of services" resulted in 70 articles;
- "methods and techniques" resulted in 85 articles.

Combined keyword search was also performed, "participatory design AND methods and techniques" resulted in 1 article; and "participatory design AND evaluation" resulted in 25 articles. Thus, 378 articles were found, with 31 duplicated, resulting in a partial total of 347 articles.

In searching the keywords "older OR elderly OR old people" related to "participatory design AND development of products and services", "participatory design AND development of products" and "participatory design AND development of services", no articles were found. The 70 articles found from the search with "development of services", were discarded because the main subject was the provision of services, such as urban cleaning, telephone, etc. Thus, only a total of 277 articles were selected.

Initially, a careful analysis of the articles was conducted from reading all the abstracts. The first layer criteria for articles' selection were the premise of the use of methods in which elderly participation was decisive for survey and data analysis, development of concepts, project's criteria definition or evaluation and validation of projects that contribute to life quality in old age. The following criteria were also considered relevant to the articles' selection in this first assessment: articles published in indexed journal, available to download as, full texts, written in one of the languages accessible to the authors (Portuguese, English and Spanish). The second layer criterion was a stricter one, since it was select for the final inclusion only those works in which an active involvement of the elderly was registered during the study.

3 Results

From the carried out search, only 40 articles met the first layer selection criteria after analysis of all of the selected abstracts, but only 30 of them had available the full-text version available for download.

Thirty of the studies identified were classified as eligible for the first layer criterion:

- 5 articles addressed the needs of the elderly, but the research was carried out through the participation of family member and/or caregivers;
- 8 articles mentioned participatory design, but the elderly only participated in data collection answering questionnaires;
- 2 articles dealt with elderly people with dementia, with no conditions, therefore, to participate actively in the research;
- 6 articles did not address to product designing, but exploratory research about abilities and/or behavior;

– 1 article presented a comparative analysis of methodology;
– 8 articles were selected to compose the analysis of the methods applied in researches involving elderly people in the designing stages of environments, products and services for the specific public.

Based on that, only the last 8 papers were considered to be eligible for the second layer criterion and were selected to be included in this review.

As a guideline of this analysis, the Bonsiepe's Experimental Methodology [5] was adopted, being the methodology focused in product design, widely disseminated. According to the author, the design process can be schematically subdivided in the following steps or stages:

(i) problematization;
(ii) analysis;
(iii) problem definition;
(iv) project development: preliminary draft and generation of alternatives;
(v) evaluation, decision, choice;
(vi) achievement;
(vii) and final analysis of the solution.

This systematic review shows the 8 selected studies that contemplate the effective participation of the elderly in product development targeted to this audience and that are briefly presented in Table 1, with some basic characteristics about each of the main applied methodologies. In this table, the indicated stages correspond to the same items mentioned in the previous list, from (i) to (vii).

The article of Bossen et al. [6] the objective was "to develop technologies capable of helping a collaborative practice between the elderly and their families and professionals/caregivers in order to control activities performed by the seniors

Table 1 Reviewd papers and main characteristics of the participatory approach

Heading level	Stages in the research method	No. of participants	Age range	Type of methodology
Bossen et al. [6]	i, iv, v	14 [i] + 24 [v]	30–75	Participatory design
Keith [7]	i, iii	200 [i] + 8 [iii]	50–85	Participatory design
Iacono et al. [8]	i, v	6	Average 83.17	Participatory design
Colonius et al. [9]	i, iii, iv, v	21	Not specified	Participatory design with user-centred approach
McGee-Lennon et al. [10]	iii, iv, v	25	>60	Co-design
Demirbilek et al. [11]	i, iii, v	13	>65	Combination participatory design and USAP
Flinn et al. [12]	i, iv	26	>65	Not specified
Abeele et al. [13]	i, iv	10	68–80	User-centred design

with no intention of establishing dependency", focusing on developing a software that assist the performance of daily living activities, called CareCoor.

This article points out participatory design as a guidance approach tracing three steps for product designing: problematization, where an ethnographic research was conducted to preliminarily define the methodological tools; development of the project, covering the stages of draft and generating alternatives to develop the software; and evaluation to review and analyze CareCoor software. In the step of problematization—an ethnographic research was conducted, lasting 9 months, being conducted 12 semi structured interviews of 1 h each with 7 family members and 7 caregivers (5 men, 9 women aged between 30 and 75 years); 4 workshops were also performed, the first with 3 members of the elderly family, the second with 5 caregivers and then two conjoint workshops with both. In the project development stage—based on the previous stage, it is developed a software for assistance of everyday activities for the elderly, named CareCoor. In the stage of Evaluation, Decision and Choice—the CareCoor software was applied in two pilot testes: the first lasted a week and included 3 seniors, their family members and the caregivers, the second lasted 6 weeks, with the participation of 5 seniors, their families and caregivers.

In the article of Keith [7] the goal was to "analyze the different strategies to help older people to identify the problems with a significant activity—driving—in order to identify the variety of driving experiences and explore potential opportunities and difficulties of in-car driving assistance systems". In particular, explore methodologies that emphasize the user's role as a design partner—"designing with the user rather than for the user"—in this sense, the established goal was to understand the needs of elderly users regarding cars and its interfaces, focusing on the task of driving. The article indicates participatory design as a guiding approach and, even though the final product being a methodological approach, it followed in its development two methodological steps: problematization, to delimit the practical and subjective requirements of older users regarding the task of driving; and the definition of the problem to determine the most latent needs. The Problematization stage—consisted of a questionnaire with at least 200 elderly people (between 50 and 80 years); still in order to define potential problems, focus groups were conducted (7 groups of 2–4 participants each) and individual sessions, that lasted 18 months, with participants aged between 55 and 85 years. As a result of Problematization, the authors noted two specific needs: speeding and parking, and later held the state of art. Defining the problem—focusing on the issue of speed, a test-research was conducted on the most latent needs identified in the previous phase and in the state of art stage, low-fidelity prototypes were built in order to promote the visualization and evaluation of users. These prototypes followed three display types: static, dynamic and interactive (using games). The next phase of the process, focused on the parking issue, involved elderly participants, therefore, without familiarity with new technologies of "smart cars". The participants of this stage were 8 (eight) elderly users, 3 (three) women and 5 (five) men aged from 50 to 80 years old. Next, evaluative tests were conducted with low-fidelity prototypes, such as toy cars, printed layouts of roads and the use of drawing so that the users could register their considerations. Still in order to define problems, the users were requested that using their own cars, parked in a determined space and narrated the experience to the researchers, specifying strategies and difficulties. Subsequent to this step, the same action was taken, but this time using “smart cars” with new technologies, in order to understand the user’s familiarity with the task as opposed to the facilities and difficulties of new technologies.

In the article of Iacono et al. [8] the objective was “to develop a graphical interface with elderly users to control a robotic system of a “smart home”, proposing a system to facilitate the lives of elderly people living alone. The system includes a tablet software, which works as a remote control, and a robot that receives, encodes information and perform tasks as the user’s needs and desires”. The paper discuss the participatory design as the guiding approach and highlight two stages of the product designing: problematization, that the authors name familiarization, composed by videos of the design functioning (software and robot), interacting with an elderly user, to promote understanding of the overall functioning; and evaluation, that authors name visualization and evaluation, to reaffirm the understanding of the software functioning and evaluate its effectiveness in the elderly user opinion. In Problematization step—composed of videos of the operating design project (software and robot) interacting with an elderly user to promote the fully understand of the system. In this step, participants wrote down their comments and perceptions about the products, highlighting its positives and negatives aspects. In the step of Evaluation, Decision and Choice—participants were exposed to the functioning product, but with the aid of storyboards and colored pens where the goal was to reinsure the overall comprehension of the software and evaluate its efficacy in the perception of the elderly. Once the understanding of the interface, its functions and possibilities was stablished, participants were invited to explore potentialities of the interface design, visualizing the possibilities and performing positive and negative evaluations of those potentialities.

In the article of Colonius et al. [9] the objective was to “develop a ‘smart’ assistance device for elderly people suffering from cognitive impairment arising from diseases. The research was developed from a Project named SHARE-it, that aims to improve life quality and Independence of elderly people with cognitive problems”.

The research combines two different methods of participatory development in order to involve both the designing team as well as the real end user. It is noticed the challenging nature in proposing a user-centered design approach, given the specific audience. However, it is emphasized that the methodology can be applied in accordance with the application of domain experts, which means that the paper proposes not only the participation of the users, but also of experts from the medical and elderly care fields, in favor of a collective and cooperative experience about the specific need of the public. The project contains four stages for product design: problematization, with professionals from medical areas to address potential need of the elderly; the definition of the problem, defining the needs of the elderly; the project development with generation of alternatives; and evaluation, decision and choice from prototyping and its evaluation. The first phase, Problematization—narrative scenarios are used to maximize the communication between method and experts. This phase also includes the medical professionals as representatives of elderly users, describing their potential needs and requirements. The second phase: Definition of the problem—the elderly participate in an evaluative way, assuring if their needs were effectively described and defined, helping defining the problem. The third stage: Development of the Project (preliminary project and generation of alternatives)—in this step, a high-fidelity prototype system is developed where the elderly, the potential users, conduct the evaluation of the interface, observing its positive and negative aspects. Fourth stage: Evaluation, Decision and Choice—prototyping step is conducted again with the elderly, with several projetual alternatives and with the participation of the researcher as an observer, analyzing in details the process of evaluation.

In the article of McGee-Lennon et al. [10] the objective was "to develop a multimodal system of reminders for elderly people in the house environment, with application in mobile devices that can be highly configured by the end user in a comfortable way. Considering that the end users of the product would be elderly, concepts of Inclusive Design—forcing designers to consider the public's real problems associated with sensory, physical and cognitive disabilities—and Design for All were considered in the research". The article indicates co-design as a method that guided the research, although this approach in practice, presents concepts and steps similar to the participatory design approach. It is also presented three stages for the product design: definition of the problem, in order to investigate and analyze the best techniques for reminders configuration and user interaction with the product; the project development stage, that even though it is not explained in the article, presents dynamics that fits into this stage; and evaluation, decision and choice, involving the creation for evaluation and definition of reminders prominently in multimodal functions. Definition of the problem—6 co-design sessions were held with 25 users over 60 years to investigate the best methods and techniques for reminders settings and user interaction with the product. These sessions involved questionnaire tools, evaluation through "Keep, Lose, Change" and interactions with the prototypes, individually and collectively. Participants were selected in two contexts: "active elderly" (over 65 years old, but active and independent) and users over 75 years with sensory weakness. The stage of Project Development—the development of the prototypes were based on another study conducted in the MultiMemoHome (www.multimemohome.com) Project, which involved a questionnaire; a series of focus groups with elderly and adults with sensory impairments (25 participants); and Home Tour sessions guided by the user to understand the everyday experience of space and Technologies that could be used in a reminder system in their own environment. The stage of Evaluation, Decision and Choice—this step involved designing a variety of low-fidelity reminder interfaces prototypes with emphasis on multimodal functions (the ability to choose how to receive the reminder); and a series of high-fidelity prototypes in mobile devices to evaluate the interaction.

In the article of Demirbilek et al. [11] the objective was "to use the USAP (Usability, Safety, Attractiveness Participatory) design model to establish a matrices system of quality deployment. In order to illustrate the research, a case study was performed for development of doors and door accessories with participatory design sessions to test the conceptual design phase of the proposed model". The method chosen for the article is the USAP design model. In this particular process, hybrid from the participatory design, five phases of the method are defined proposing a relationship of interaction and cooperation with the end user: concept development; concept refinement; prototyping; user's tests and production. Although the methodological procedures performed by the researchers correspond to these five steps, as described in the paper "as product definition, three design projects were presented: door handles that could be operated with the elbow and hands and developed in comfortable materials; a shelf attached to the wall in the main entrance so that the user can support what they have in their hands while looking for keys or even to rest groceries; and a door with a glass screen attached so that the elderly are able to see who is on the other side of the door, identifying the person in a safe way", implying, according to the text, that the development of the concept corresponds to the problematization step [5], concept refinement to the step of problem definition [5], prototyping, user testing and production to the step of evaluation, decision and choice [5]. The stage of Problematization—in order to develop the concept, techniques of scenario construction, non-structured interviews and questionnaires about the topic were performed, it was also an encouragement for brainstorm with the information and materials available. At the end of this phase, all answers and ideas obtained were grouped in several topics to begin structuring of the matrices of quality implementation, which means the "definition of the problem". In the step of definition of the problem—the designer presented drawings, developed from the first part of the study, in the form of sketches, from that, the participants received a copy of those drawings and were asked to critique and redesign them, expressing their ideas and making corrections, all the results from that phase were also grouped for structuring the matrices. In the step of Evaluation, Decision and Choice—crucial points explained by the elderly were introduced in the matrices with three different categories of relevance: relevant, moderate and less important, and were used in the development of projetual drawings presented in the second phase of the study.

In the article by Flinn et al. [12] the objective was to "investigate the participatory experiences of older women with manual limitations, reduced handling, in creative activities to improve usability when opening bottles". The selection criteria included: women with 65 years or older with difficulty opening bottles or products with twist caps, who have presented hand pain and had the ability to follow verbal instructions. The paper does not specify the methodology, but it was selected due to the active participation of the user in all the steps of the project. In addition, the authors acknowledge, "the objective of the paper was fruitful, especially considering that there was an important engagement of participation of the elderly as well as the productive results while implementation of the participatory approach".

Regarding the methodological stages, the described phases correspond to the following steps: problematization and development of the project [5]. The step of Problematization—an analysis with 42 different types of bottles, available in the common marker, were conducted in a focus group with duration of 1 h. The participants evaluated their preferences in the matters of size, shape and texture of the lids. Then, the focus group initiates a manual activity with toolkits with soft and colorless modeling clay, modeling clay tools and two empty plastic containers in order to build what they considered "the best lid possible" considering possible hand limitations and using sizes, shapes and textures of their choice. The sequential phase was divided in two parts: in the first one participants were encouraged to make " the best lid design that you believe that could be in the market in at least two years"; in the second part they were instructed to make "the craziest or out of reality lid, of any size, format that they envision in the future"; after those creation phases, they were invited to present and explain their ideas and concepts for the rest of the group, being questioned about usability, marketing possibilities, etc. In the step of development of the project—the prototypes created by the participants were catalogued along with audio and video of the previous part, and, the researchers made detailed notes about the experience. Prototyping phase resulted in 36 lid design created by the elderly participants. In the step of Evaluation, Decision and Choice—from the 36 prototypes developed, four categories were created based in qualitative analysis and in the descriptions provided by the elderly women: incorporation of textures on the surfaces of the lids; lever feature by change of the format or diameter of the lid; increased surface contact area with the palm/fingers by the redesigns of side shapes and heights of the lids; and new lid designs to help different types of grip handling.

In the article of Abeele et al. [13] the objective was "To define game concepts following a "passion" model of the elderly, and, in order to achieve that some participatory methodologies where applied". The study points out the user centered design methodology for innovation in game context, using ethnographic principles and participatory design as the methodological approach, presented in two steps of product designing: problematization, with ethnographic questionnaires with elderly; and development of the project, with preliminary project and generation of alternatives. Problematization step—ethnographic questionnaires were performed with elderly people, next, seniors and researchers performed a brainstorm of ideas and converted those ideas in game concepts, during the period of one week, elderly were observed, interviewed in their own homes. In the development of the project step— session of participatory design was held with one elderly and a designer. The purpose was to perform a brainstorm, from a contextual story, where many of the elderly passions appear as potential ideas; from that stage, the group was encouraged to develop low fidelity prototypes in paper as an aid to visualize ideas. The combination of detailing of passions, brainstorm and prototyping generated concepts, although preliminary, very rich with Strong presence of multi-player components and diversity of game genres, such as adventure, puzzle, RPG, etc.

Regarding the methodologies used for and with the participation of elderly people, the researchers show the following results: Bossen et al. [6], Keith [7] and Iacono et al. [8] used Participatory Design methods; Colonius et al. [9] and Abeele et al. [13] used and approach of Participatory Design associated with User Center Design; Demirbilek et al. [11] used a combination of Participatory Design and USAP (Usability, Safety, Attractiveness Participatory) design model; McGee-Lennon et al. [10] used Co-designing; and Flinn et al. [12] did not specify a method, despite all phases of the research contemplating the participation of the elderly user.

Concerning the nature of the developed product with and for the elderly people, the focus of the researches were: Bossen et al. [6] CareCoor, software of elderly assistance in performing everyday activities; Keith [7] elaboration of methodological strategies to understand the role of the elderly user as a partner while designing a project; Iacono et al. [8] Software, graphic interface in a robotic system of a " smart house" to facilitate the everyday activities of elderly people who live alone; Colonius et al. [9] " intelligent" assistance device for seniors who suffer from cognitive impairments from diseases; McGee-Lennon et al. [10] multimodal system of reminders with mobile applicability for elderly in the home environment, considering problems of the public associated to cognitive, sensorial and physical impairments; Demirbilek et al. [11] system of quality implementation matrices, in order to achieve that, a case study was performed to develop doors and door accessories with the goal to trial the conceptual design phase of the purposed model; Flinn et al. [12] investigate participative experiences from elderly women with hand limitations, diminished handling, in the analysis and project generation phases of designing bottle lids, focusing in a make tool inspired activity to improve the ability of opening of the container and verify the utility of the results of this approach; and Abeele et al. [13] development of game concept for the elderly and with their participation, the goal was to define game concepts according to a " passion" model from the elderly.

Regarding the methods and tools used in the stages of development of the researches related to the subjects of the sample and the steps: Problematization—ethnographic research involving interviews (family and caregivers), unstructured interviews (elderly), questionnaires (elderly), workshops (family and caregivers), focus group (elderly), brainstorm (elderly), videos with reality simulation (elderly), narrative scenarios (health care professionals), dynamics with manual work/creativity exercises with modelling clay (elderly); Definition of the problem—interviews (elderly), questionnaires (elderly), low fidelity prototype (elderly), keep-lose technique (elderly), drawings (elderly), tests in real situations (elderly), tests with new technologies (elderly); Development of the project: preliminary project, generation of alternatives— questionnaires (elderly), focus group (elderly), brainstorm (elderly), home tour sessions (elderly), low fidelity prototype with paper and pictures (elderly), evaluation with high fidelity prototypes involving scenario simulation, software evaluation (elderly), audios and videos (elderly); Evaluation, Decision and Choice—pilot-test (elderly, family and caregivers), tests with storyboard and pens, with the projected product, high and low fidelity prototype evaluation (elderly), drawings (elderly), meetings (elderly).

4 Discussion and Considerations

What is observed is an active participation of the elderly in all stages. Seniors participated in almost all the dynamics of the problematization step, having also participated family members, caregivers and health professionals, all of them directly related to each elderly participant as a support, answering questions related to their needs and helping define the elderly profile.

In the stages of problem definition, project development, evaluation, decision and choice, the elderly participated actively, suggesting, giving ideas, participating in testing and evaluations, and that was acknowledge in all evaluated articles. In the pilot-test for CareCoor software, families and caregivers participation was designed to promote elderly-family-caregiver interaction.

It was also observed a variety of tools that could be used with elderly people, which should be used in a creative and playful way, supporting the use of paper, colored pens, modeling clay and everyday objects, creating a better understanding of the activity and interactivity. Regarding the tools applied in the steps of problematization, problem definition, development of the project, evaluation, decision and choice, it was observed that the use of dynamics, such as manual works, creating exercises and drawing in the stages 1, 2 and 4; structured and non-structured interviews were observed in steps 1, 2 and 3; focus group in steps 1 and 3; brainstorm in steps 1 and 3; and evaluation with high and low fidelity prototypes in steps 2, 3, and 4.

It is important to highlight that the stages of "analysis", "realization" and "final analysis of the solutions" of Bonsiepe's methodology [5] were not presented in the analyzed texts. This was due to the fact that this method was developed for designers' use and, as the analysis stage was already performed in the context of user participation, and the actual analysis may have occurred in finalizing the stage of problematization or problem definition. Relating to the steps of realization and final analysis of the solution, they remained unobserved probably because these products must also be in the final analysis phase.

Relating the papers selected with the methodological steps of Gui Bonsiepe methodology [5], the methods and techniques used in the development of the research and the sample of elderly participants demonstrate an overview of possibilities where elderly participation is crucial to the research with data analysis, to formulate concepts, defining projects criteria or evaluation or validation of projects whose nature contributes to life quality in old age.

Based on what has been achieved on this literature review, it may be concluded that bring elderly user to the early stages of the design process may enable a better assessment of activities and offers great opportunities to expand and improve the understanding of implicit and latent needs of this specific type of users. This will, hopefully, result in better informed designers and engineers and in a potential redefinition of the prerequisites in a design project. In addition, it should be considered an integrated approach involving all users, since it recognizes a cooperative network among the elderly, families and caregivers, and this integration is, most likely, the best approach in favor of a good final product.

The results of the literature review in this paper corroborate the importance of active participation of elderly users in the product design process.

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Part X
Designing for Inclusion in the Information Society

Towards Universal Design Criteria for Design of Wearables

Vladimir Tomberg and Sebastian Kelle

Abstract There are many ways of introducing ideas for Universal Design and Accessibility in a design process. One of the fast ways is supplying designers with Universal Design or Accessibility checklists and asking them to test the design against the proposed criteria. This method is especially beneficial for students who learn how to design but still are not aware of universal design ideas. Such criteria can be diverse and depend on the context of design and type of a design artefact. In particular, currently there is no a well-established evaluation framework for accessibility of wearables. In this paper, we review several accessibility evaluation tools from other fields, from which criteria for evaluation of the accessibility in wearables during the design process can be borrowed.

Keywords Human factors · Universal design · Wearables · Accessibility criteria

1 Introduction

Accessibility is a legal obligation in many countries of the world. All regulations refer to "Web Content Accessibility Guidelines (WCAG)" by W3C-WAI consortium. The awareness of accessibility issues is well established in several design domains. Sometimes, these design domains are tightly connected, like architecture and interior design; and sometimes they are not, like web and product design.

In recent past, not only the awareness about accessibility per se has improved, but there are now specific accessibility design criteria developed for many domains. For example, in developed countries, strict rules about accessibility in the physical world are associated with dwellings, the width and shape of doorways or inclination

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for curb cuts. They are described in the details and usually formalized to corresponding legislation acts. There are mature accessibility specifications like WCAG and WAI-ARIA that regulate the best design and development practices for accessible web sites. These regulations are often considered as a base for national legislative acts, and, hence, are mandatory for implementation, especially in the public sector.

However, improved accessibility comes at a price. Designers have to be educated about accessibility, and need to acquire skills of accessible design and accessibility evaluation. The need for observance of the new legislative acts made developers think about ways for efficient implementation. Variety of design and evaluation tools are developed and more widely used, allowing quick ways for the accessibility assessment. While this is true for the above-mentioned developed domains, there are still some new and emerging fields, which have a lack of such tools.

In the last decade, wearable technologies are gaining in popularity starting from small sport-oriented bracelets and watches. Nowadays, they cover several different themes [1] and use a wide spectrum of different input sensors and output media.

In this paper, we aim at identifying criteria for the evaluation of accessibility of wearables. Designing with "accessibility in mind" [2] should use a holistic approach [3], and it is important to include design tools, which enhance awareness, by providing criteria for accessibility evaluation. These criteria have to be contextual and depend on design domain specifics. Defining the set of criteria for wearables, though, seems as a complex task because of the versatile nature of wearables.

In our previous paper '*Applying universal design principles to themes for wearables*' [1] we took seven Universal Design principles [4] and examined how they apply to each theme for the wearables and what advantages the designers can expect from such an application. In this study, we review specific criteria for the evaluation of a wearable design artefact.

2 Designing with Accessibility in Mind

Modern design processes of user interfaces usually are conducted in an iterative way. They consist of repeating cycles of designing and evaluations of design artefacts [5–7].

To ensure an accessible result, designers have to consider accessibility by starting at the earlier stages of the design process [8–10]. One of the ways for doing that is empathy modelling [11–14]. If designers consider undesirability of the "One size fits all" result [15] and they model end-users including personas with different age, social, economical and cultural background, the intended result has chances to be more versatile and to provide better user experience for a wider audience.

There are different methods for ensuring the accessibility in the early design stages. Among them are ethnographic research methods, going to a "field", conducting empathy modelling and development of models for target users—personas. While designers have in mind a broader spectrum of persona types in terms of age and abilities, they have better ideas for improving accessibility already in the beginning of the design process. Such an approach is described in details in the Inclusive Design Toolkit of Engineering Design Center of University of Cambridge.[1]

At a later stage of the design process, prototyping comes into a play and designers produce their first artefacts. Following co-design methods together with end-users and other project stakeholders, designers start testing the prototypes using different evaluation methods.

Expert-based evaluation includes methods as *heuristic evaluation*, *guideline reviews*, *pluralistic walkthroughs*, *consistency inspections*, *standards inspections*, *cognitive walkthroughs*, *formal usability inspections*, and *feature inspections* [16]. While heuristic evaluation has many different advantages and disadvantages [17] it is still a good method when there is a need for providing fast and efficient evaluation of a design artefact. Going through specifically designed checklists may be especially useful for learning. On one side, design students need to learn the iterative evaluation practices. On the other side, they do not have enough expertise, so a walkthrough with lists of specific criteria can support them and help to learn how to evaluate artifacts and provide a feeling of self-confidence.

Liu et al. [10] state that design criteria should be explicitly established to ensure that the design outcome is, in fact, a universal design (UD) while meeting project-specific design goals.

For the evaluation of design universality the best known list of criteria is a list of seven UD principles [18, 19], which "*may be applied to evaluate existing designs, guide the design process and educate both designers and consumers about the characteristics of more usable products and environments*" [4]. These principles particularly include *equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort*, *size and space for approach and use.* UD principles are usually situated as a base for other UD frameworks. However, the guidelines provided under these principles are often not specific enough for a certain context. Additional refinement and adaptation for context is required for the use of these guidelines in specific design fields.

The *Inclusive Design Toolkit* mentioned above was developed at Cambridge University, and consists of seven capability categories which are helpful to measure personal capabilities, or to assess a specific ability level that a product demands in order to be usable. These categories include vision and hearing as *sensory abilities*, thinking and communication as *cognitive abilities*, and locomotion, reach and stretch and dexterity as *motor abilities*. While this framework is good for assessment of ergonomic issues, it provides no ways for assessment of other UD criteria that may be useful to access for wearables.

[1]Inclusive Design Toolkit: http://www.inclusivedesigntoolkit.com/.

Wearables do not represent one unified class of devices. Wearables can have very different forms like tattoo, jewelry, clothes, exoskeletons and others. They can adopt their properties from the adjacent design fields. Therefore, checklists for wearables may inherit criteria used in these adjacent fields.

In the field of architecture, different checklists for accessibility are used and most of them conform to national standards. A similar situation exists in field of web design: several accessibility specifications have reached maturity and are widely accepted on a national level. Situations in different fields will be shortly reviewed in the following sections.

3 Architecture and Interior Design

The domain of Architecture is without a doubt one of most important sources of modern design principles. While concepts and scholarship of this field are framed by physical constraints, one of the important achievements is the genesis of design patterns [20]. These are abstract concepts that foot on the assumption that certain experiences and ideas of a designer can be universally reused. For example, the concept of a window is something that will be found in almost all architectural artefacts. In Universal Design, the validity of such patterns or concepts is very much connected to their reusability, their durability and their performance, as well as their generalization. There is no guarantee that each of these factors are satisfied equally, however, the more these design patterns manifest, the more likely do they become not just a helpful tool for the designer, but they also become a source for scrutiny and evaluation. Design patterns can be used as indicators for the quality of a design. While Universal Design does not exist in architecture in the same manner as for Human Computer Interfaces, the notion of Accessible Design has become a serious concern supported by governments of many countries. However, to this date, for example the London Underground still has many inaccessible stations.

The wearables are intended for long, sometimes for 24/7 periods of time usage. For sure, the general indoor and outdoor accessibility requirements are relevant for wearables design as far as they are relevant for the end-users who wear them. The second important aspect that should be considered is an ability for interacting of the wearable devices with environment. Considering todays' popularity of Internet of Things wearables can be integrated into external ecosystem by gathering and exchanging important data.

4 Ergonomics

There are several design guidelines in place that aim at accessibility enhancements for societal use. These are contextualized according to the respective environment. For example, architectural design requires avoiding obstructions. Office environments, on the other hand require designs that enable a healthy work environment with rich sources of daylight.

According to Dul and Weerdmeester [21], ergonomics aims to design appliances, technical systems and tasks in such a way as to improve human safety, health, comfort and performance. Correspondingly, the majority of the ergonomic criteria are associated with workplaces first, and with living places second.

There is a variety of accessibility criteria for different ergonomic applications. In a comprehensive list consisting of 219 criteria Dul and Weerdmeester propose factors related to *work organization*, jobs and *tasks*; factors related to *posture and movement* (biomechanical, physiological and anthropometric factors), *environmental factors* (noise, vibration, illumination, climate, chemical substances), factors related to *information and operation* (information, controls for operation, dialogues, website design, mobile interaction, virtual reality) [21].

Another term for ergonomics is human factors. As the wearables are intended to be worn on a body, undoubtedly, the human factors have to be considered when designing wearables.

5 Web

Wearable devices can be very diverse in terms of ways how they process input and output. While the web is mainly a screen-oriented visual medium, wearables can also be used for the output of tactile, vibration, audio and other information, in contrast to purely visual screen-based interfaces. While wearable devices are introducing a lot of different modalities that employ sensors and actuators of a wide variety, the truth is that many mobile applications use web services as primary component. For that reason, it is important to adhere to the W3 consortium's guidelines for Web Accessibility (WCAG 2.0 AA[2]). These guidelines can be used as checklist, and stipulate detailed criteria for designing web sites in such a way that they will function in a compatible way for the use with Accessible Technology, such as screen readers and other tools. Although wearables will pose additional challenges and requirements to web content, it is important to meet the WCAG criteria first, as basic foundation for extended accessibility criteria added as a layer for wearable content accessibility.

An example is the pertinence of meta-information of a web based element such as a checkbox that will actuate its state as a vibration pattern with respect to being checked (a long vibration) or unchecked (as a sequence of short vibrations). The most important criteria is that the WCAG checklist[3, 4] primarily is directed at visually impaired users. A lot of the criteria cover image accessibility, keyboard

[2]WCAG 2.0 AA: https://www.w3.org/TR/WCAG20/.

[3]WCAG 2.0 checklists: https://www.wuhcag.com/wcag-checklist/.

[4]WebAIM's WCAG 2.0 Checklist: http://webaim.org/standards/wcag/checklist.

accessibility, structural items and color contrast. While all of these criteria are critical for the web accessibility, wearable technology also poses additional requirements, such as meta-information for each content item to be displayed on tactile or other mobile interfaces.

Besides WCAG related checklists, there are also specific criteria for making the association with age. For that, Hankiewicz et al. [22] propose a list of seven different guides that include rules concerning ergonomic web design for elderly people.

6 HCI

In recent times Human-Computer-Interaction has made strong progress, both research and industry-wise. With the advent of multi-sensory computing interfaces new chances, but also new challenges arrive. Recent research has advanced to a level of brain-computer interfaces that capture the visual information from a user's memory. However, there are also use case scenarios that serve an ethically less dubious purpose, like applications in surgical medicine, or a more leisurely context that connects friends.

In terms of criteria for HCI accessibility, Stephanidis et al. [23] proposed to evaluate accessibility on a process based model that compares different alternative technologies to achieve the same goal. This is necessary because HCI applications are highly context dependent, and do not compare easily just by feature sets. For this reason, it is important to work with use case scenarios, more so than in other disciplines.

For HCI, there is a variety of mature frameworks, standards, methods and tools available. Wearable computers inherit many different ways of other human-computer interactions. Therefore, the most of HCI criteria for design should be appropriate for the wearables too.

7 Mobile

Wearable technologies are by default mobile, therefore concepts borrowed from the mobile domain are highly relevant. Currently, mobile technologies mostly are associated with the mobile smart phones. An example of such a wearable device as Apple Watch, which works in a bundle together with the iPhone, shows that these technologies often produce a combined user experience.

Manufacturers of iOS and Android mobile platforms do not rely on developers only to introduce accessibility in their apps. They rather prefer to implement a common support for accessibility in their operation systems and provide to the developers an API with corresponding technical guidance.

Apple provides two main documents for developers [24]. In '*Understanding Accessibility on iOS*' Apple briefly describes how VoiceOver works on the device. The document 'Making Your iOS App Accessible' in turn provides in-depth guidance for making an application accessible to VoiceOver users. For VoiceOver, Apple also provides a special "Accessibility Inspector" software which runs on Mac, inside of an iOS Simulator and can help to debug a flawed accessibility implementation.

For the Android platform, the guidances are generally very similar to Apple and are focused around Google's proprietary voiceover technology TalkBack. In addition, Google provides own Accessibility Testing Checklist[5] which provides several recommendations for testing touchable actions related to TalkBack.

Another well-known guidance for development for the mobile platforms is the BBC Mobile Accessibility Guidelines.[6] They are based on the requirements of BBC.co.uk content developed for UK audiences and define three principles that embody an approach to the design and development of inclusive and usable applications and websites for all:

1. Use platform and web standards as intended;
2. Use standard user interface controls where possible (which ensures that accessible technologies could understand the controls);
3. Support platform accessibility, which is divided for two sub-principles: *Navigation methods* and *Support platform assistive technologies or features*.

As it can be seen, the guidelines are partially web-oriented. They provide detailed guidances for testing with bad and good code examples for three development cases: iOS, Android, and HTML. These guidances cover the following list of concepts: *audio and video* (subtitles, metadata, etc.), *design* (contrast, color, focus, etc.), *editorial* (labeling and language), *focus*, *forms* (labels, layout, etc.), *images*, *links*, *notifications* (instructions, standard OS alerts, etc.), *scripts* and *dynamic content* (JavaScript, controlling media, timeouts), *structure*, and *text equivalents*. There is also a list of short design recommendations like '*Use progressive enhancement*' and a bit outdated for today '*Link mobile and desktop sites*'. Overall, the guidances cover the technical implementations of content representation and are mostly based on source code.

There is also a Mobile accessibility checklist provided by Mozilla,[7] which covers such principles as *color, visibility, focus, text equivalents, handling state, general guidelines* (some recommendations for well-structured content in code and couple of references to ARIA and BBC Mobile Accessibility Guidelines). Obviously, the most of the Mozilla principles also cover web accessibility issues.

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[5]Android Developer Accessibility Testing Checklist: http://developer.android.com/training/accessibility/testing.html.

[6]BBC Mobile Accessibility Guidelines: http://www.bbc.co.uk/guidelines/futuremedia/accessibility/mobile.

[7]Mozilla Mobile accessibility checklist: https://developer.mozilla.org/en-US/docs/Web/Accessibility/Mobile_accessibility_checklist.

However, the checklist is quite short, so there should be no big expectations from its use.

In summary, accessibility criteria for mobile platforms are to a large extent focused on representation of mobile web content. Usually, the required accessibility features are already implemented into the mobile OS, so developers mostly just need to test their applications with automatic test engines. Considering media peculiarities of mobile platforms related to touch-screen input and small display sizes there is a clear focus on perceiving visual information, simplicity of using gestures and audio output. All these characteristics may be very relevant for the specific types of wearables like watches or bracelets.

8 Wearables

Introduced in the 60s [25] and named in the mid of 1990's [26], wearables are becoming a popular trend in research and development in the last several years. They allow people to implement different types of computing in contexts like industry, military, medical and health, personal assistance [26], wherever the person is, without having to involve the person's hands or another device. The idea behind wearables is making computers small and energy efficient enough so they can be used as parts of clothing or other accessories [1]. User interaction with wearables may be different to the typical human-computer interactions. Wearables usually have no a keyboard or display and use other, sometimes new input/output sensors. Gemperle et al. [27] defined wearability as the interaction between the human body and the wearable object. Therefore, much more body parts and senses are involved in interactions with wearables in comparison to traditional human-computer interactions.

Indeed, wearables are very different and they depend on the content of usage. For the better understanding of versatility of scenarios, PSFK Labs [28] defines six themes where wearables can be applied: *Bio-Tech Fusion*: creating a closer relationship between wearable devices and the human body. Examples: wearable devices such as medical devices or activity tracking; *Synced Lifestyle*: ability to sync with a broader ecosystem of connected technologies. Examples: fitness tracking devices; *Organic Computing*: introducing a more natural form of communication and computing by introducing wider range of human inputs from gestures to biometrics. Example: using touches and hugs to transmit affection and care between people; *Human Enhancement*: appearance of assistive technologies that are capable of both restoring and augmenting existing senses and abilities. Example: indicating security levels for helping someone with a disability to be more independent. *Health Empowerment*: empowering people to take a more active role in the management of their personal well-being. Example: helping keep track of a medical condition; *Personalized Context*: situated within a given context, self-aware devices and platforms can facilitate connected experiences that deliver greater meaning and relevancy into people's lives. Example: devices and wearables communicating to reduce lighting and play calming music at the end of a stressful day.

On one side, it is hard to provide any framework for standardization of devices with such different types of application. On the other side, this versatility makes unprecedented opportunities for using the wearables for accessibility—the target goal and a basic concern of the universal design approach.

Examples of different implemented user interaction styles in wearables can be sound and gestures using both head and hand gestures, capturing hand gestures using a depth camera on the user's shoe, using EMG to capture muscle activity, using user's skin as an interaction surface via finger taps, and using tongue interfaces [29]. There is a variety of other interactive wearable objects such as clothing, accessories, plush toys, costumes, sculptures, and biking accessories created using the LilyPad Arduino.[8]

There are also some general design methodologies for wearables. For example, Gemperle et al. [27] proposed a set of 13 guidelines for designing wearable devices: *Placement* (where on the body it should go); *Form Language* (defining the shape); *Human Movement* (consider the dynamic structure); *Proxemics* (human perception of space); *Sizing* (for body size diversity); *Attachment* (fixing forms to the body); *Containment* (considering what's inside the form); *Weight* (as its spread across the human body); *Accessibility* (physical access to the forms); *Sensory Interaction* (for passive or active input); *Thermal* (issues of heat next to the body); *Aesthetics* (perceptual appropriateness); *Long-term Use* (effects on the body and mind).

While these guidelines are not specifically focused on ideas of universal design, they refer to accessibility and several ergonomic issues that have to be considered when designing the wearables. The authors differentiate the first six guidelines in the physical manifestation and they found the latter seven are not easily generalized since they are much more depend of the context and constraints of a specific design problem. Some of the guidelines like *Accessibility* are too general, however some provide to the designers a great insight into the range of specific design issues related to wearables.

9 Conclusion

In this paper, we laid out the importance of many influential factors and principles that need to be addressed when determining the validity of a Universal Design approach for wearable technology. We have reviewed existing lists of criteria from the design domain that seems relevant to design of the wearables. We also have shown that a list of evaluation criteria for the wearable should utilize these criteria from the adjacent design domains.

[8]LilyPad Arduino: https://www.arduino.cc/en/Main/ArduinoBoardLilyPad.

At the same time, we have shown that inclusion of any criterion should be contextual because wearables are very different in their nature and application. It is obvious that lists of design criteria for wearables cannot be static, which would mean that they will be too long, redundant, and their usage will be too costly for implementation in practice. There should rather be 'templates' of design criteria from different domains which can be filtered according to a specific wearable theme and application. Such filtering in turn can be made in semi-automatic mode, using for example a wizard, which asks questions about the nature of a wearable, which should be designed and evaluated.

In the previous paper, we proposed several different selections of UD principles that could be used on beginning of the wearable design process depending on wearable theme selected. These selections of UD principles were made in contextual dependency to the six themes for the wearables, therefore they can become a base for different lists of evaluation criteria for wearables.

For the future works we see wide opportunities for empirical studies where specific lists of evaluation criteria for accessibility of wearables could be developed. Such tools already have high demand in communities of designers in academia and industry.

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Alternative and Augmentative Communication for People with Disabilities and Language Problems: An Eye Gaze Tracking Approach

Emmanuel Arias, Gustavo López, Luis Quesada and Luis Guerrero

Abstract Alternative and augmentative communications encapsulates the use of technology to provide communication means for people with some sort of disability. In this paper, we present a prototype that provides both pictographic and alphabetic options to allow communication. Our system was originally designed for people that suffer physical disabilities and are not able to move their body. To allow interaction we provide an eye gazed based interaction. Our system was evaluated with an experienced test subject, because the system requires training to be used. However, evaluations results demonstrated that a skilled user requires less than two seconds (average) to select a pictogram or letter (i.e., in less than a minute, a 30 characters long phrase or up to two semantically correct sentences using pictograms can be produced).

Keywords Reduced mobility · Human-computer interaction · Digital inclusion · Alternative communication

1 Introduction

Language difficulties and degenerative diseases can cause communication problems. People with such conditions rely on different ways to communicate their needs, thoughts and ideas. Efforts have been made to provide solutions and such solutions are categorized as "augmentative and alternative communication" (AAC).

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Communication boards are considered aided AAC systems. Traditionally, these boards are grids of cells containing pictograms or letters. With these methods, people incapable of communicating with words are able to express themselves.

Communication through symbols allows people with language problems to use pictograms in order to communicate. The person associates pictograms with specific meanings. Moreover, if the person has the ability to read and write s/he can form words and sentences by scanning an alphabetic grid.

People with physical disabilities are sometimes unable to use keyboard, mouse, or touch screens as input methods. Eye tracking may be a way to solve this problem. As the user focuses his attention on a screen, a device can track eye movements and that information can be used as input.

With regard to the cognitive skills and physical impairment of our target audience, we developed two aided AAC systems. Both systems use eye gaze and touch screens as input methods. Therefore, people with physical disabilities and language problems are able to use our communication system.

To improve communication abilities for people with language problems, we developed a communication board based on pictograms. The selection of a pictogram is achieved by eye fixation. This function is provided by a noninvasive device placed over the screen.

In the case of people with physical disabilities (but not cognitive disabilities or language issues), we developed an alphabet board that suits their needs. Eye gaze navigation integrates smoothly with the application interface. Scanning letters through the boards allows the user to form words. The system also provides word prediction based on previous history.

Interface design of inclusive communication should focus on the specific needs of the target audience. Most of the aided AAC systems need another person to hold and point a board. By combining AAC with non-traditional interaction mechanisms (eye gaze), we provided an autonomous communication system that could improve the quality of life of people with language problems and physical disabilities. Moreover, our system is easy to use (usability tests were carried out by several experts in the topic) and cheaper than the ones already provided industrially.

As was mentioned before, we do not only propose an AAC system, but also complement it with non-traditional ways of interaction (i.e., eye tracking). The effectiveness of eye tracking technology depends on certain factors including: costs, complexity and usability [1]. Eye gaze has been complemented with AAC systems before; however, the technology applied was not as advanced as is currently available. Moreover, eye gaze interaction may provide an attractive option to implement electronic communication systems for children and adults with disabilities or language problems [2].

Regarding proposed communication systems that use eye gaze interaction, we found no references in academic literature. Private systems implement AAC systems using embed eye tracker devices. However, we were unable to verify the design and evaluation undertaken to assess those systems.

2 Augmentative and Alternative Communication

Augmentative and Alternative Communication is "the field or area of clinical, educational, and research practice to improve, temporarily or permanently, the communication skills of individuals with little or no functional speech and/or writing" [3]. A person with an acquired disability can regain a capability or develop a new one using AAC systems [4].

There are no restrictions or defined characteristics of the population that require AAC systems. However, this population includes people with physical impairments and speech-language conditions [5].

For this project, our target population focuses on people with physical impairment, such as cerebral palsy, amyotrophic lateral sclerosis (ALS), or people that suffered cerebrovascular accidents. These conditions, among others, affect the person's motor skills and communication abilities.

2.1 AAC Systems

AAC systems can be classified into two categories: unaided and aided systems. In the first type, the communicator uses only his/her body. Clearly, this kind of communication is not viable for our target population. However, aided AAC systems use special equipment to achieve communication. These systems implement graphic symbols and messages so the individual can communicate to another person [5].

There are two types of aided AAC systems: low technology and high technology systems [6]. Low tech systems use non electronic options to provide communication. For example, a low tech system can be a carton board with pictures. The main disadvantage or low tech systems is that they require a communication partner (other person) at all times [5]. High tech systems use a computer-based approach. For instance, the same picture grid can be implemented on an electronic device using touch screens or eye gaze interaction.

2.2 Accessible Technology in the Communication Process

Medicine, rehabilitation and special education have their own models of disability. These models share the perspective of considering a person with a disability as someone who needs to be cured or constantly assisted in their everyday activities [7]. However, the social model of disability is better situated in a context of communication systems. This model envisions people with disabilities as any other person, performing everyday activities autonomously. Technologies can provide the person with a disability with tools to accomplish their everyday tasks [7].

Providing accessible technologies to aid the communication process of people with disability can resolve the primary disadvantage of using low tech AAC systems.

3 Prototype Design

People with disabilities and language problems develop communication abilities through an educational process. Providing a communication system can support and improve this learning process and provide a certain level of autonomy. They learn to communicate in different ways. Thus, the system must support communication through symbols and through spelling.

A user must have visual dexterity and some sort of communication skills in order to be able to use our system. These abilities must be evaluated and trained before using the system. Once these skills are strengthened, a complete communication system will serve as support in the educational process and as an independent means of communication for the user.

3.1 Conceptual Design

We propose a communication system on an electronic device for people with physical disabilities and language problems. The application implements the communication board concept in an eye gaze directed environment. In our proposed setting, a screen (with the eye-tracking device mounted in it) is placed in front of the user.

In consideration of the particular capabilities of our target population, the application provides two methodologies: communication through symbols and through spelling. The first one is based on symbols and pictograms. This way, the user can choose from a set of known symbols in order to express an idea, a desire, a thought, etc. For users with the ability to read and write, the second system provides a spelling system in order to compose written messages.

The prototype uses text-to-speech as the output method. As the person uses pictograms or build sentences the systems records and stores the selection for future reference. In the communication through spelling method, the feature suggests words or sentences based on dictionaries and past uses.

3.2 System Features

The system is formed by two main components: the eye position indicator and the communication elements. Throughout all the views, the eye position indicator is drawn as a semitransparent circle in the place where the user is gazing. This control interacts with the buttons of the application and triggers its events. Sensitivity of the component can be adjusted to the user's dexterity.

A communication event may contain, as illustrated in Fig. 1a, an image with a description below. However, an element in communication through spelling contains a letter or a word. Figure 1b shows the communication elements to indicate

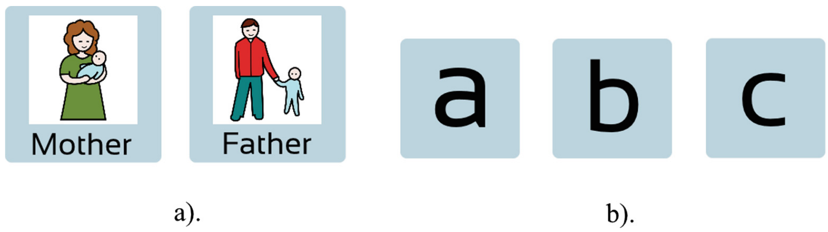

Fig. 1 **a** Communication elements for the words “mother”, “father” and “baby”. **b** Communication elements for the letters ‘a’, ‘b’ and ‘c’

the vowels. The events triggered by the communication elements relate to either of two contexts: communication or action. Communication events add new information to the message that the user wants to compose. Action events change the state of the system.

To activate an element, the user fixes its eyes on a clickable area. When the eye position indicator enters the communication element, a timer starts the countdown. The background will change progressively to a darker color until the timer finishes.

After this, the element executes an event. The process is canceled if the eye position indicator leaves the element area before the timer stops. After the first activation, the element allows new activation after a short period of time.

The **grid** contains the communication elements to form messages. Traditional grids arrange the elements consecutively in rows and columns. Laid out in this way, a grid may cause the user to involuntarily activate communication elements. For this reason, our prototype implements a modified version of the traditional grid.

Our grid provides a neutral area without communication elements. In the prototype, the grids are located at the center of the screen. Therefore, the neutral area is located between the tiles of the grid. This provides a place where the person can think, rest its eyes, or wait for indications.

3.3 Training Process

Before introducing the communication functionality, it is necessary to test and train the user’s visual dexterity. Due to their condition, some users may have problems interacting with an eye gaze based environment. The prototype provides the user with the application to calibrate the device.

After the user successfully calibrates the device, the prototype presents the **communication elements** training screen. This training screen displays for the user one communication element only. Figure 2a shows such a sample screen using communication through symbols. When an element is clicked, it automatically outputs its description via voice synthesizing. In addition, the element appears in a random place on the screen.

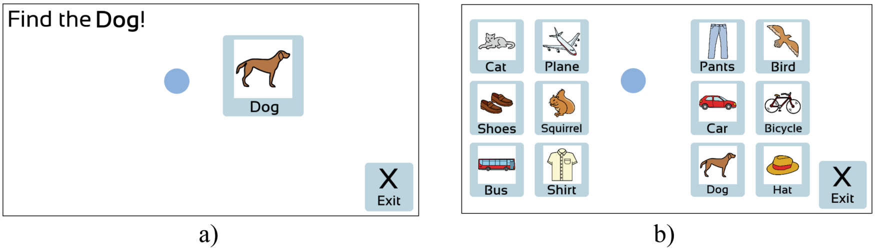

Fig. 2 **a** Communication element training screen. **b** Grid training screen. In both screens the eye position indicator is located near the center of the screen

Once the user is familiarized with the communication elements, the next step is selecting an element from a **grid**. In the communication through symbols the pictograms are arranged in a grid. Also, the keyboard in the communication through spelling follows a rows and column distribution. Therefore, the prototype requires the user to train its visual dexterity to select elements from a grid.

For this purpose, the prototype presents the grid training screen. This screen presents the user with a grid of pictograms. When the user selects an item, the system outputs the description of the image. The purpose of this level is to familiarize the user with the environment. Figure 2b illustrates the grid training screen with a 3 × 4 grid.

3.4 Communication Systems

The prototype provides communication using two methods: symbol selection and spelling. In the first method, the user forms messages by selecting elements from a grid. These elements are separated by categories. In the case of communication through spelling, the user spells the message by gazing at letters from a grid.

The **communication through symbols** functionality is composed of three main components: the pictogram grid, the output board and the category chooser. The communication elements are associated with one or more categories. Also, the elements in the grid are ordered by ranking number. Every message output increases the ranking number associated with an element.

At the left of the screen is the **category chooser**. This element shows to the user a grid with the available categories. Selecting one category will load the corresponding communication elements on the screen.

Over the grid is the **output board**. User selections are displayed on the board (see Fig. 3). **Configuration buttons** to delete the last element and clear the board are also available.

The main components of the **communication through spelling** functionality are the keyboard grid, the output board and the suggestions box. The user composes messages using the letters and symbols from the keyboard grid. The process is

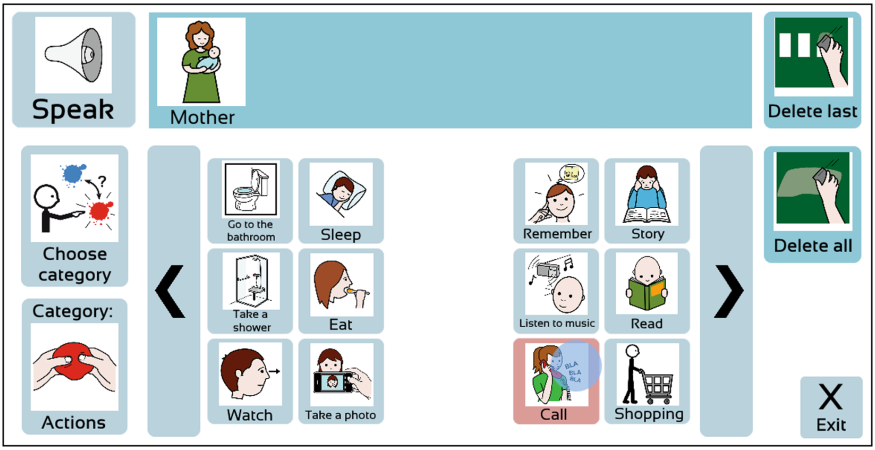

Fig. 3 Communication thought symbols screen. In this screen the element representing "mother" is already selected. Also, the user is selecting the element representing "call" from the grid

reflected on the output board that is positioned over the grid. Letters and symbols on the keyboard grid are arranged according to a distribution. Furthermore, the grid can be set to show only a subset of letters and symbols.

As the user selects elements, the suggestion box presents word and sentence predictions. Predictions are based on the user messages history. Additional to the suggestion aid, the keyboard grid shows a **word preview**. With this, the user can type a word and be able to see the result without looking at the output box.

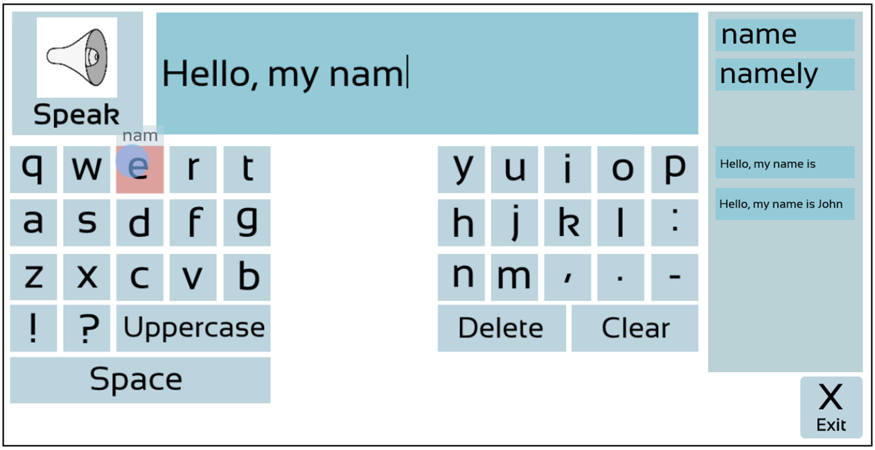

Fig. 4 Communication thought spelling screen. The user is selecting the letter 'e' to complete the word "name". However, the systems suggest complete the word and the full sentence based on previous messages

The output communication element is located at the top left corner of the screen, as shown on Fig. 4. When the user has completed the messages, clicking this button outputs the message using a speech synthesizer. Additionally, in Fig. 4 over the communication element the user is observing, the word preview box appears with the text 'name'.

4 Evaluation

We performed usability tests with a person previously trained in the use of the eye tracker device to assess our system. The participant did not present physical or cognitive impairments. A system is usable when the user can interact with the it in the expected way without problems, doubts or barriers [8].

The purpose of an assessment test is to determine how well the user performs using the different parts of the system. In this test, the user is asked to perform tasks while a moderator observes and measures the process [8].

4.1 Procedure

The participant was initially guided through the eye tracker calibration process. After that, the participant was given the information necessary to use the screen and the instructions for the task.

In the **first training task**, the user was presented to the communication elements training screen. Then, the participant was instructed on how to activate a communication element. The task consisted in activating the element as requested by the instructor and listening to the output five times.

The second training task introduced the pictograms grid. First, the user had to observe the elements of the grid for a few seconds without activating them. Then, the participant was requested to activate four specific elements. The elements selected by the instructor were distributed following a pattern or randomly in the grid.

The **communication tasks** consisted in forming messages. This was first carried out using communication through symbols. The instructor explained the category chooser and requested the users to form messages using communication elements from different categories and to output the message. Then, the instructor introduced the communication through spelling system and requested the user to spell words.

Throughout the tasks, the instructor measured the time required to execute every task. Time between instructions and tasks was not taken into account.

4.2 Results

For the first training task, the minimum executing time was 10.66 and the maximum was 13.19 from a sample of ten iterations. To determine the outliers, we used the formula Q3 + 1.5 * IQR, being Q3 the third quartile and IQR the interquartile range. The maximum value was considered the only outlier. Without this value, the sample showed an average value of 11.34 and a standard deviation of 0.34. In this task, the average time for each click was 1.89 s. The activation time of the communication elements was 1.25 s.

The second training task was executed in two iterations. In the iteration, the instructor selected the elements following two patterns (see Fig. 5) and two more times the elements were selected randomly. Between the iterations, the content of the communication elements was changed.

On the first iteration, the selection of the elements of the patterns 1 and 2 presented an average of 10.75 and 10.98, with standard deviations of 1.25 and 0.99 respectively. Selecting random elements was a little faster, with an average of 9.65 and 9.63. For these selections, the standard deviations were 0.96 and 0.21.

Then, on the second iteration the participant performed faster in the pattern selection, with averages of 9.40 and 9.71 in patterns 1 and 2 respectively. However, on this iteration the participant spent an average of 10.46 and 10.47 selecting random elements.

For the iterations of the communication through symbols task, the instructor chose six different messages (2, 3 and 4 elements long). All the messages were repeated until the time of execution converged. Nevertheless, the messages "I want to say—Happy Birthday—Sister" and "Which—House—Big—Green" did not. In the case of these messages, the convergence time was set as the average of all iterations. Else, the convergence time was set as the average of the last two iterations. Table 1 shows the convergence times, the amount of click and the average time per click for this task.

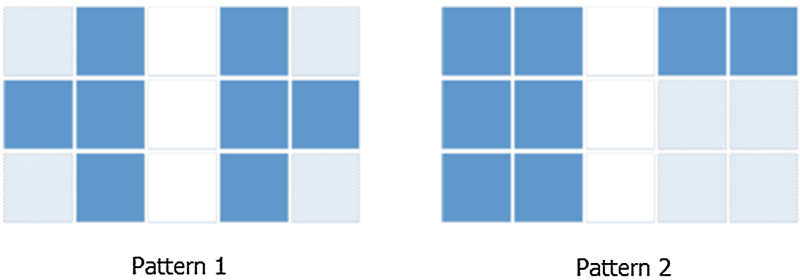

Fig. 5 Patterns used by the instructor for the task 2. Pattern 1 selects the *corner* elements; pattern 2 selects the elements in the *bottom-left side* of the grid. Element in *white* correspond to the grid neutral area

Table 1 Results for the iterations of the task 2

Message	Convergence time (s)	Amount of clicks	Average time per click (s)
Scared—Dog	30.17	14	2.15
Go—Bathroom	26.55	12	2.21
Go—Plane—Where?	31.68	15	2.11
I want to say—Happy Birthday —Sister	24.51	12	1.90
Which—House—Big—Green	31.51	17	1.97
Mother—Sleep—Back pain—Sad	40.19	19	2.12

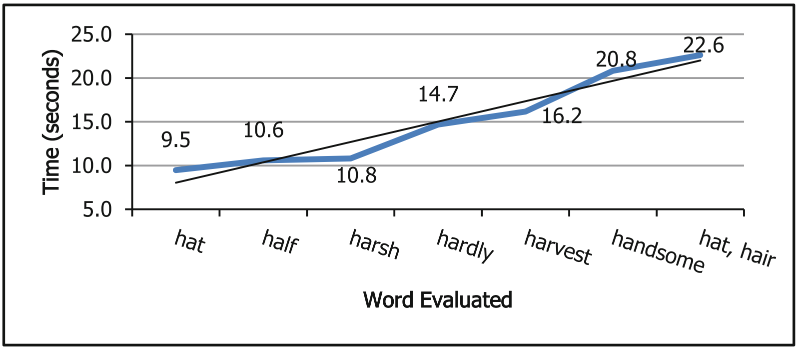

Fig. 6 Average time the user spent spelling the evaluated word. The graph also shows the trend line of the sample

In the case of the communication through spelling task, the instructor selected seven texts with a length from 3 to 9 characters. The average time to spell each text is shown on Fig. 6. This figure also shows a lineal tendency of the data.

The average time for each click was 1.89, 2.03, 2.08 and 1.82 s for the tasks 1, 2, 3 with symbols and 3 with spelling respectively. The maximum standard deviation of these averages was 0.20. In general, the average time per click was 1.96 s with a standard deviation of 0.12.

5 Discussion

The participant had a better time selecting communication elements on the first training task and the communication through spelling task. In these activities, the participant only listened to instructions previously. During the tasks, the participant only had to scan the screen to search for the proper element. In the second training task, the average time for selecting elements increased because the participant had to listen to the instructor's indication.

The communication through symbols task were more challenging for the participant because of two aspects: searching through the categories and remembering the location of the elements. Although not tested, ordering the communication elements by its ranking number can improve the speed to form constantly used messages.

On the communication through spelling task, the growth of time was almost lineal. Alterations of the average times may be because the participant spent more time trying to click elements far from the center of the screen.

In general, the user had problems reaching the outer areas of the screen. After a few tests with all the screen of the prototype we determined the problems of performance might be due because of the eye tracker device. However, the time per click for the participant throughout all the tasks was consistent with a standard deviation close to zero.

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Web Accessibility for People with Reduced Mobility: A Case Study Using Eye Tracking

Emmanuel Arias, Gustavo López, Luis Quesada and Luis Guerrero

Abstract Traditional web interfaces often rely on keyboard/mouse input to work. This characteristic forces people with reduced mobility to adapt or do not use the applications at all. This paper proposes a prototype to increase web accessibility for people with reduced mobility. Our prototype proposes an eye gaze based interaction between the user and web browsers displaying a web site (compliant with the web content accessibility guidelines proposed by the World Wide Web Consortium). We implemented a plug-in that adds functionality to allow user navigation, cursor control and text input.

Keywords Digital inclusion · Web accessibility · Reduced mobility · Eye tracking

1 Introduction

Traditional web interfaces rely on keyboard/mouse input to function. This characteristic forces people with reduced mobility to adapt or do not use the applications at all. The main goal of inclusive interfaces for people with reduced mobility is to consider the human factors of users in the interface design. For instance, an inclusive interface design should allow access to web content to a person with reduced mobility in a natural way.

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Eye gaze interaction provides a tool to increase web accessibility via graphical user interfaces (GUI) for users with reduced mobility. With an eye tracking device, it is possible to detect the user eye position in an unobtrusive way, thus, a person with reduced mobility can access web content and applications developed for traditional GUIs.

To improve accessibility for users with reduced mobility, it is not necessary to re-engineer the interfaces models. They can be adapted to eye gaze navigation. Diverse mechanisms such as eye fixation combined with high fidelity icons and eye gaze triggered gestures can be used.

In this project, we designed and implemented a wrapper for web content with controls and tools that enables fluid user interaction for people with reduced mobility. We developed a web browser plug-in that allows eye gaze interaction for web content. Our solution models available events in web browsers and provides accessible ways to trigger such events.

Navigation is improved using controls located within the natural scrolling space so the user can scroll freely throughout the web content. Further, the user can use a set of tools in order to improve web content interaction.

Our solution allows users with reduced mobility to access and interact with web content otherwise inaccessible. Therefore, we achieve accessibility and inclusion for our target audience.

A related work review shows that several projects of interfaces using eye gaze as input method in the Human-Computer Interaction have been proposed. In 1989, a workstation with a special interface guided by eye gaze interaction was proposed. Such application included functionalities in control, communication, recreation and text reading areas. However, the authors reported limitations [1].

Other application implements the typical controls of an operative system's GUI (e.g., icons, menus, folder systems) in a way that allows the user to interact only using eye movements [2].

Abe et al. [3] proposed a prototype of a web browser using eye gaze interaction. The input method is based on the detection of horizontal and vertical gestures of the eyes, the design consisted of a browsing area within a window. On top and bottom of such area the user had access to a series of tools to facilitate navigation and interaction. Other authors proposed a method to improve the link selection [4].

2 Accessibility and Barriers in Web Content

People with reduced mobility have to deal with barriers when accessing web content. This section describes the characteristics of this population and the problems that they face. Furthermore, an initiative with the purpose of providing developers with guidelines to make a more accessible Web design is discussed.

2.1 Characteristics of People with Reduced Mobility

There are multiples definitions and models of disability [5]. Areas such as medicine, rehabilitation and special education have their own models. In the social context, people with disabilities are described as persons which cannot carry daily activities autonomously [6].

The term reduced mobility covers a wide area of medical conditions which affect and deteriorate motor skills of a person. A person can suffer reduced mobility due to a degenerative disease, such as amyotrophic lateral sclerosis (ALS), or a trauma that caused a partial or total body paralysis.

People with such characteristics have difficulties to use electronic devices. Personal computers and tablets must be adapted so the person disable people can use them. However, common input methods, such as mouse, keyboards and touch screens require a level of dexterity to be operated.

The majority of actions that people with motor disabilities perform are reading wikis, filling forms, viewing photos and writing comments. Problematic aspects on operability, navigation and orientation are related to these actions [7]. When a web application presents barriers to the user, a support mechanism might be implemented to reduce or eliminate such barriers.

The World Wide Web Consortium proposed user agent accessibility guidelines and web content accessibility guidelines. These guides help developers make web content more accessible to people with disabilities [8].

A user agent is as a piece of software which retrieves, renders and facilities web content [8]. The UAAG 2.0 dictates a series of principles that a user agent must meet in order to achieve accessibility for end-users. Those principles dictate that a user agent must be perceivable, operable, and understandable by the user.

Moreover, the "Programmatic access" and "Specifications and conventions" principles guarantee compatibility with assistive technologies, specific conventions and platforms. Thus, user agents that follow UAAG 2.0 recommendations ensure the end-user that such barriers will be absent.

3 Assistive Technology

Formally, the World Health Organization defines assistive technology (AT) as "any product, instrument, equipment or technology adapted or specifically designed for improving the functioning of a disabled person" [9].

Designing and selecting an assistive technology must consider the user requirements. Moreover, the chosen AT must adapt to the abilities and dexterity of the person. This process can be guided by the human activity assistive technology (HAAT) model.

The HAAT model is based on four elements: the activity, the context, the human and the assistive technology. The human element considers the physical, emotional

Table 1 Conceptualization of the human activity assistive technology model

HAAT element	Description
Activity	Use a web browser to navigate through web content without any accessibilities barriers
Human	Person with reduced mobility but able to have eye movement control
Context	Conventional web browser retrieving and rendering web sites and application. The web browser runs on an electronic device, such as a desktop computer, although conventional input methods cannot be used
Assistive technology	Eye gaze as input method in order to replace traditional mouse and keyboard interaction

and cognitive factors of the person. The activity refers to the task performed by the person. This task responds to a need or desire. In the context element, the aspects and description of the environment in which the person performs the activity are modeled.

Finally, the assistive technology element refers to the characteristics of the interface the person will use to complete the activity. This way, the assistive technology is chosen for a specific population performing a specific activity in a certain context [10]. Table 1 describes the activity, human and context elements on first instance. The last element, the assistive technology, is described as the solution considering the aforementioned elements.

The assistive technology proposed respond to the difficulty of operation in traditional web browser environments. The Web applications expect an interaction with the user based on traditional input methods. People with reduced mobility are unable to use such methods, thus having a restricted access to the information and services that the Web offers.

4 Prototype Design

This section describes out prototype, its requirements, design and components.

4.1 Requirements

When a user requests a certain web site or application, the browser retrieves and renders the content. Traditionally, Web content is made to interact with classical input methods, such as mouse, keyboards or touch screens.

Even when the content of a website is designed in way that improves accessibility, the user usually requires additional support to interact with it. A common web browser lacks the tools to provide such support.

Eye gaze interaction offers an alternative input method to navigate through Web content. So as to provide an assistive technology using eye gaze interaction, the browser must be capable to support such input method.

Modern web design follows a responsive design. Web content can be accessed from web browsers running on desktop computers, smartphones and tablets. These devices have different size screens so the content has to adapt to each environment. Responsive design proposes the use of viewing contexts in the design [11]. Thus, the web page structure varies among different screen sizes. By this means, navigation within a responsive web page happens fluidly vertically.

Most of the content people with physical disabilities consumes is based on readable content. Activities such as reading wikis, filling forms, viewing photos and posting comments turn out to be the most outstanding [7]. So as to provide a fluid navigation for responsive web, eye gaze interaction can be implemented as a navigation gesture.

The assistive technology can substitute the physical use of mouse and keyboard and instead interact with the browser using eye gaze interaction. Enabling mouse controlling via eye fixation allows a natural way to navigate through Web content. Behavior and events of the mouse and keyboard must be mapped. Furthermore, it is required to integrate a set of tools in order to facilitate the operability and navigation within the web content.

4.2 Conceptual Design

Our prototype proposes a Web browser plug-into implements the assistive technology. With this, the assistive technology changes the mouse and keyboard behavior using eye gaze as input method.

For this project, we used the Tobii EyeX tracker. This device is capable of detecting with precision the user eye position. A calibration process is needed, in which the user observes a series of point on the screen.

After the calibration process, the device can detect where the user is observing on the screen. Tobii EyeX provides a service and developer tools to access the information [12].

Our prototype was implemented using Windows. This operative system supports the Tobii EyeX engine and provides an API to modify the system cursor status. The selected browser must have a user script manager extension. These extensions execute scripts before the web pages are showed. For this prototype, we chose Mozilla Firefox using the Greasemonkey extension.

The main components of the prototype are the **cursor controller** and the **plug-in**. The cursor controller sets the cursor position to the place the user is observing on the screen. Additionally, the controller handles the click events. To accomplish this task, the controller communicates with the eye tracker engine and with the operative system service that allows changing the cursor behavior.

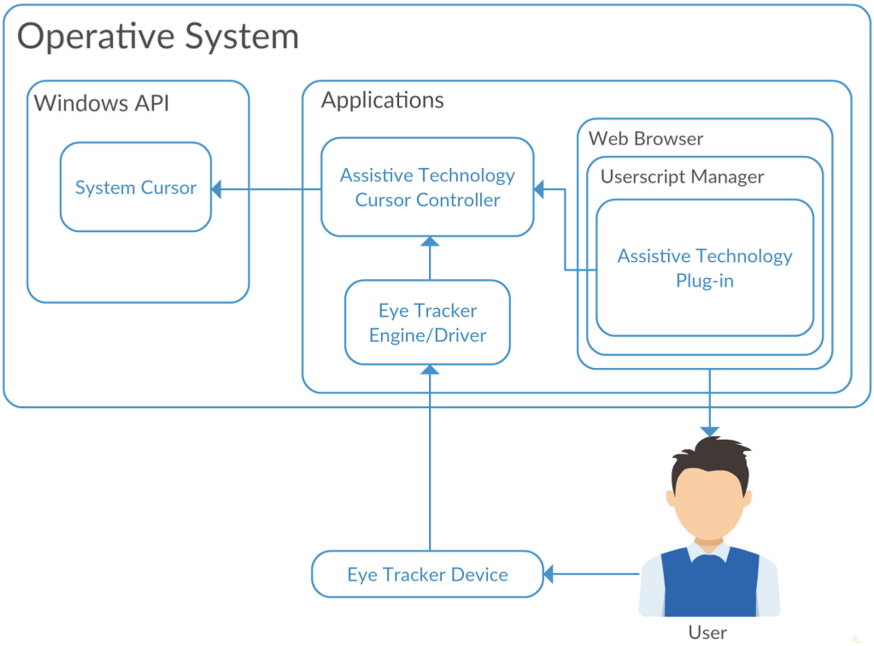

Fig. 1 System's architecture and workflow

Figure 1 shows our prototype's architecture and workflow. First, the eye tracking device takes the input from the user. Then, the device sends the data to its engine for processing. The engine passes the information to the cursor controller and finally, this controller evaluates the information and sends the proper request to the operative system service.

User interaction with the web browser is provided by the plug-in through a set of controls. When the user requests a web page, the browser renders the content and shows it to the user. Before the content is showed to the user, the plug-in adds the controls to support eye gaze interaction with the original content.

To modify the content, the web browser implements the Document Object Model (DOM). This platform driven by the World Wide Web Consortium (W3C) allows changing the style, content and structure of the web page [13]. Thus, the plug-in can modify the web content by adding elements to the DOM.

4.3 *Plug-in Features*

Access to services and controls of the plug-in is provided through two **sidebars**, as shown on Fig. 2a, c. These bars contain an array of buttons, each one with a representative text. The buttons on the dock will trigger if the user fixates its eyes

Fig. 2 Elements of the main interface of the prototype. *Marked* content was inserted by the pug-in on the web site

over them for a certain time. To indicate this event, the button will change its color progressively as triggering time passes. Both docks hide when the user is not fixating his/her eyes over them.

Regarding the cursor, this will not trigger any click event unless the user indicates it. To send the command to the cursor control, the user can trigger the **left and right click buttons** (see Fig. 2c). When the user's gaze leaves one of these button the cursor enables the clicking procedure.

The plug-in also includes in every page the **navigation control**. Figure 2e shows this control as two buttons on top and bottom of the viewport. This control facilitates page scrolling without using the web browser scroll bar. The set of buttons have three settings: large sized centered in the viewport and short sized aligned on the left or right. Location of the buttons can be set on the right sidebar.

The left bar contains the buttons for the cursor events. These controls are going to be more frequently used than the **browsing buttons**, located inside the right sidebar.

The browsing buttons permits an easier way to navigate between pages. The supported events are: go to a new page, previous page, next page, and refresh page. Further, the **bookmarks button** shows the user a list with his bookmarks in order to have an easier access. The user can also add the current web site to the list. Bookmarks provide an easier way to access frequently visited web sites.

A special browsing button is the reading mode button. The reading mode provided by the web browser shows a cleaner version of the content. Readability is improved by removing the unnecessary elements of the page, such as ads, buttons and backgrounds [14]. The control toggles the reading mode if the Web content design supports this mode.

Also, in the right sidebar the user can change the settings of the navigation control position. By default, this control is centered in the viewport. However, the user can change the position of the control to the left or right of the viewport. Changing the position is useful when the control is blocking visibility or keeping an element from being clicked.

4.4 Text Input

In case the user needs to introduce text, the prototype provides an on-screen keyboard adapted to eye gaze interaction. The keyboard is centered over the viewport and the rest of the content is dimmed so the user can input text comfortably. Figure 3 shows the keyboard being used to enter a search query.

The keyboard appears in several cases. One is if the user clicks an input text (i.e. when filling a form). If for some reason an element does not trigger the keyboard, the user can activate the **input text control** to edit the text of said element. This control is located on the dock.

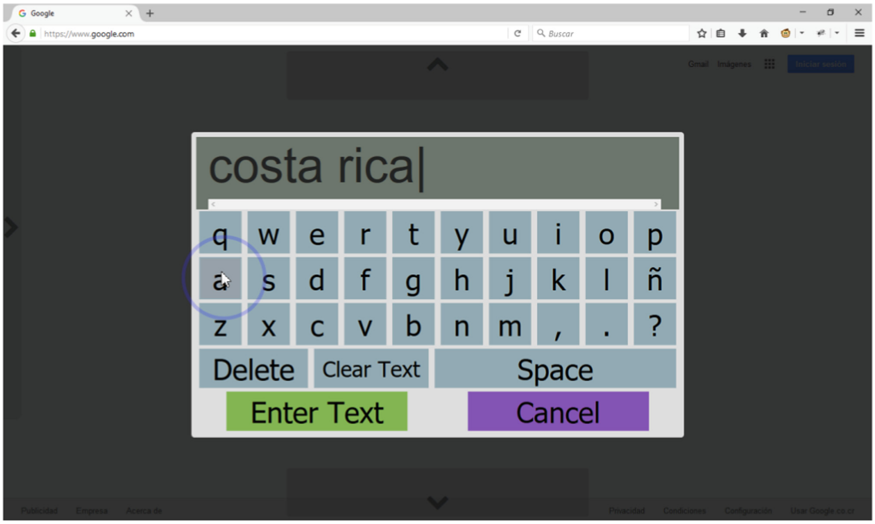

Fig. 3 The on-screen keyboard appears over the web content

4.5 Cursor Interaction

The prototype modifies the cursor behavior and events based on the information provided by the eye tracking device. This device outputs the position where the user is observing on the screen. Concretely, the prototype drives the cursor to follow the user eye fixation.

Every new point corresponding to a change in the position of the eye fixation is valuated to determinate if it is under a margin of error. In case the new point is close to the current point, the cursor ignores this point and does not move. This margin of error is set in order to improve accuracy for people with lower visual dexterity.

The user can trigger these events using eye fixation. Surrounding the cursor appears a semi-transparent circle to indicate the click countdown. To perform a click, the user fixates its eyes over a point on the screen for a certain time. During this time, the circle around the cursor will start to fill into the center. If the user moves its eyes outside the error margin area, the circle will cancel the operation and returns to its original state. However, if the circle fills, the click event will be performed.

5 Evaluation

This section describes the evaluation performed to our system, the participants and procedure.

5.1 Participants

We evaluate the prototype by performing a focus group. In this methodology, we were able to gather opinions, suggestions and the general perspective from the users towards the prototype [15]. The group consisted in 18 people, with ages around 18 and 21 years old. None of the participants presented physical or cognitive impairments.

5.2 Procedure

First, the presenter showed the eye tracker device to the group and performed a small demonstration of the device functioning. The presenter was using a laptop computer and was located in front of the participant. The computer was hooked to a projector so that the group could see the demonstration of the prototype in real time.

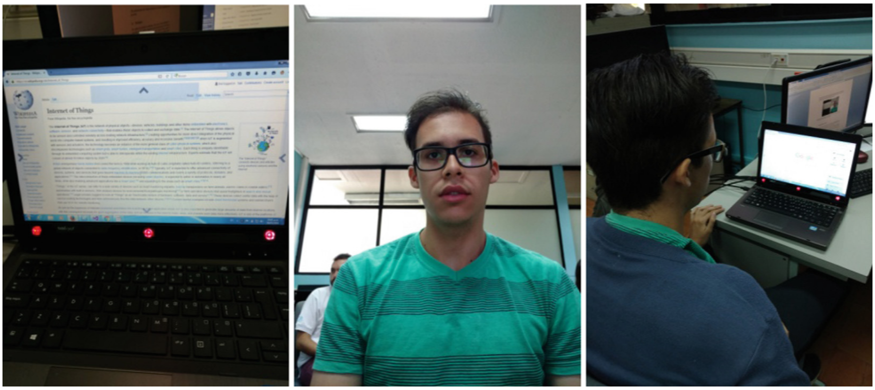

Fig. 4 User testing the system. *Left* User's perspective (1st person). *Center* Eye tracking device perspective (1st person). *Right* 3rd person image

Then, the presented exposed the different features of the interface, as well as the text input and cursor interaction mechanisms. After the demonstration, participants were asked to answer three questions regarding the prototype design. Below are enumerated the questions:

1. Do you think this design helps improve web content accessibility using eye gaze interaction?
2. Do you have any doubts or unclear aspects about the prototype design?
3. Do you have a suggestion that might improve the design?

The system also passed functional testing with an experienced user. We realized that in order to use the system some skills must be obtained from practice. Figure 4 shows a user testing the system from 3 different perspectives.

6 Results and Discussion

Regarding the question 1, all the participants agreed that the prototype might be a useful tool for people with reduced mobility. Most of the participant did not know an eye tracking device or heard about applications of this technology.

The participants express doubts about various aspects of the prototype, in specific aspects of usability, performance of the eye tracking device and possible side effects of this type of interaction. Several participants mentioned if the device needs a specific environment to work and if the user needed previous training in order to improve his/her precision using the system.

The question 2 received the most feedback. The participants suggested additional tools such as zoom controls, a method to undo an action and a mechanism to control multimedia elements. Further, some recommended the personalization of the activation time, so users more experienced can navigate in a faster way.

Additionally, the suggestion that was present in more than the half the participants was implementing this prototype at a wider context. According to the participants, a prototype that enables eye gaze interaction throughout the operative system improves the accessibility to technology for people with reduced mobility.

Future work includes integrating our prototype with other available platforms in order to increase effectiveness. Moreover, we would like to extent our prototype to work at operating system level.

Finally, once we complete our product, we pretend to test it with users with reduced mobility and assess its effectiveness in real context. We understand that the system will probably require adaptations according to the application context. However, we expect those to be minor adaptations.

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Virtual Accessibility Guide in Brazil

Regina Cohen and Cristiane Rose S. de Duarte

Abstract The "Virtual Accessibility Guide" informs accessibility conditions, aiding people when choosing routes and helping to promote social inclusion. The application is for people with disabilities, for the elderly, people with reduced mobility, as well as for the general population. Lack of information, makes people with disability not to consider themselves as part of spaces and to reject them, which results loss of contact with the inhabitants of the city. With a platform compatible with Android or iOS, mapping and diagnosing the accessibility conditions to tourist sights, historic buildings and cultural services, will be continuously updated with new information. Underlying this work is the expertise of the "Pro-access" Research Bureau (ABNT, NBR 9050 in Acessibilidade de Pessoas com Mobilidade Reduzida às Edificações, Espaços e Equipamentos Urbanos. Rio de Janeiro, 2015), which has developed methodologies for diagnosis accessibility, and is a national and world reference in the field. Our knowledge must be put to be used by society. Everyone have the right to access any place.

Keywords Accessibility factors · Designing for inclusion · Virtual guide · Accessibility for digital print and interface design · Virtual accessibility

1 Introduction—People with Disability, Accessibility and Universal Design in Brazil

This paper deals with situations found in Brazil regarding Accessibility. Most of our cities have many barriers preventing the free circulation of people with disabilities and to have the same opportunities.

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For these physical barriers there are solutions, however, there are other obstacles we consider much more difficult: attitudinal barriers. Physical obstacles may be adapted with good design and project, social barriers on the other hand, are harder to fix.

In Brazil, there is little information and awareness regarding the importance of urban planning and public policies in the area of accessibility. Because of this many people with disabilities have quite a bit of difficulty when it comes to being accomplished and successful. Taking into consideration the current situation in Brazil and the lack of accessibility in universities, we created group on accessibility —the Núcleo Pró-acesso[1] (Pro-Access Group) linked to the research in the Post-grad Studies Program in Architecture (PROARQ) at UFRJ.

The research developed by our Group—coordinated by Cristiane Rose de S. Duarte and Regina Cohen—has been producing documents to subsidize actions to design and create accessible spaces, which take into account the difficulties faced by people with disability or reduced mobility. Here we present our current project: an app for a Virtual Accessibility Guide in Rio de Janeiro.

First, it's important to state that according to the 2010 Brazilian Institute of Geography and Statistics (IBGE) Census, 23.9 % of the population have some form of disability. These people have at least one difficulty related to seeing, hearing, moving around or intellectually understanding the world.

Most of these people are denied their citizen rights, are not embraced by urban spaces, and cannot move around freely and have contact with the rest of society. There are several reasons for these barriers to accessibility: political problems, and the national panorama, which excludes most of the basic needs of these people.

The Federal Government of Brazil has approved the 2004 Edict n. 5.296 which regulates, among other preventive measures, the implementation of architectural and urban accessibility to all means of public transportation, technical services, cultural heritage landmarks and buildings, in addition to means of information and communication. The article 15 of the Edict states that all the planning and urbanization must conform to the guidelines laid out in the Brazilian Technical Standards of Accessibility (EDICT n. 5.296/2004—Presidency of the Republic).

Disability is often related to social and economic matters and interferes in education, employment, health treatment and the accessibility to physical spaces in the city. Constitution of Brazil (1989) along with the United Nations Convention for the Rights of Persons with Disability (part of the Constitution) is one of the most elaborate documents in the world, but it is not always respected.

Many of our Brazilian cities are rife with urban barriers. However, despite these barriers there have been a few ad hoc solutions: the adaptation of public transportation; good planning of open recreational areas; and work inclusion. Not with standing, these are very small changes when compared to the size of our country. In

[1]Research, teaching and design group on accessibility and Universal Design—the Núcleo Pró-acesso (Pro-Access Group) linked to the Post-grad Studies Program in Architecture (PROARQ) at UFRJ.

addition to a more concerned posture from public space planners and politicians, Brazilian cities require global changes, not only physically but also socially, Brazil has always had a wide range of social segments that are culturally, spatially and economically segregated from the rest of society. To improve quality of life to those who have been excluded from urban life, we must provide an environment that guarantees equal treatment when it comes to accessibility. However, unless there is a profound transformation, the appropriation of spaces will go unsolved.

It was only in 1994 that Brazilian authorities published a new version of the Brazilian Accessibility Technical Standards, which had last been edited in 1989. Another significant year for Brazil was 2004 with the development of a new version of the Brazilian Standards and two Federal laws that have become the most comprehensive documents regarding accessibility.

In August 2015, the government promulgated the “Lei Brasileira de Inclusão” (Brazilian Inclusion Law), which converts the principles of the UN Convention into laws and technical regulations. This law - along with the specialists who dedicate themselves to improving accessibility, advocates design and project of public spaces that caters to everyone: the Universal Design.

This guide will foster the inclusion of more people into urban, cultural and transportation systems. By treating accessibility according to the Universal Design, we will enable people with disability to become more active in society and enable those without disability to live with diversity.

We want the Virtual Accessibility Guide to be an invitation to greater social interaction in the cities. In addition to the physical improvements that will come as an indirect result of the Guide, our intent is for people to understand and become more aware of the importance of diversity and accessibility as a way to enrich the country. The Virtual Accessibility Guide is just a path to reach a greater goal.

2 The Living Without Barriers Program

With the launch of the “Plano Nacional dos Direitos da Pessoa com Deficiência—Viver sem Limites” (National Plan on the Rights of Persons with Disability—Living without Barriers), from 2011, the Federal Government acknowledged Brazil’s commitment as well as the responsibility of the country in meeting the prerogatives of the UN Convention on the Rights of Persons with Disability.

The proposition is that the Federal Government, by enacting governmental policies of access to education, inclusion, health and accessibility, will force the states and the cities to make the Convention a reality and a part of people’s daily lives.

With the participation of the Conselho Nacional dos Direitos da Pessoa com Deficiência (CONADE)/(National Counsil on the Rights of Persons with Disability) and contributions from the civil society, the Living Without Barriers Plan involves all the states and cities, and had a total investment of R$7,6 billion until 2014.

Fig. 1 Federal program booklet: "Viver sem Limites" (living without barriers). *Source* Inclusive: http://www.inclusive.org.br/?p=27972—website access done April 16, 2015

In terms of Federal Programs, on a nationwide level, the Living Without Barriers Program (2011) has the goal of promoting inclusion, assistance, accessibility and developing treatment technologies to people with disability (Fig. 1).

In Brazil, the concept of Universal Design was first associated with urban interventions, however since universal spaces presupposes everyone has access to all public spaces, implementing this sort of change is harder in a country that has such great geographic, economic, political and cultural differences. Laws and technical regulations do not bring permanent change, but they help pave the way for sustainable actions. Real transformation will only be possible through the awareness of an accessible environment for everyone. Therefore, we believe that one of the best return-on-investment initiatives, putting ideas into action, is to focus on university courses, playing a crucial role in the development of inclusion. With this in mind, our research group, "Núcleo Pró-Acesso" (Pro-Access Group), has sought to improve academic skills in the field of Universal Design, developing projects and excellent work, which influenced other universities. We have invested in architecture students from the Federal University of Rio de Janeiro, but we know that there is still a long way to go.

3 Inclusion in Brazilian Tourism

The research we mention here began in 1998 and was impelled by international movements that have worked on designing accessible facilities, and producing tourist guidebooks of accessible cities since the 80s. In France, Germany, the USA and some Scandinavian countries, the international tourism understand the importance of this market and have consolidated the concept of "tourism for all". In

Brazil, despite the global consciousness, the "accessibility agenda" has been put aside for too long.

The state of Rio de Janeiro started a movement called "Accessible Tourism and Recreation For All"; while the Legislative Assembly of the State of Rio de Janeiro —through the "Committees for People with Disability and Tourism"—carried out the "Rio de Janeiro, a State For All" Conference, 2004, that focused on the importance of planning inclusive tourist spaces in the 98 municipal districts of the state. In this event, the guidance syllabus called "Accessibility For All" (Cohen and Duarte—Pro-Access 2004) was distributed among Tourist Offices and districts in the State of Rio de Janeiro.

The research done by the Pro-Access Group has shown that the City of Rio de Janeiro—known for its abundant tourist potential on account of its beautiful landscape and architecture—has few adequate places to receive and host people with disability.

Our proposal towards a specific methodology for the creation of a guidebook, which the Pro-Access Group has been developing is a result of our efforts on researching and cataloguing since 1999 to increase knowledge and information on accessibility.

4 The Importance of Accessibility for the Image of Rio de Janeiro

Some world famous tourist spots, in Rio de Janeiro, such as the 'Sugar Loaf' and 'Corcovado' have gone through various adaptations but still present many barriers. An American tourist, on a wheelchair, spoke to us informally that his trip to Rio de Janeiro had been fantastic, especially when visiting 'Christ the Redeemer' (or 'Corcovado'), until the moment he decided to go to the snack bar accessed through a small stairway with a very tall flight of steps. Simple obstacles invalidate the adaptation done to an area. A mere step marred the image of the city considered the "Marvelous City".

The research developed throughout these last years by the Pro-Access Group also indicates that a great deal of the population have a number of aspirations in relation to the city and its image. Looking at Rio de Janeiro through the inhabitants and visitors' imaginary we perceive that the symbols are developed not only according to the Ideal City, where those people want to live, but also according to the meanings they get from the image of the city and thereby construct their own identity. Rio de Janeiro is, then, a city they want to show to the world (beautiful, accessible, artistic, cultural and owner of a solid historical tradition) (Figs. 2, 3, 4, 5, 6 and 7).

Fig. 2 Christ the Redeemer

Fig. 3 Pro-Access Group at Christ the Redeemer

Fig. 4 Monument for the Brazilians who died in World War II

Fig. 5 Sugar loaf

Fig. 6 Rio museum of art

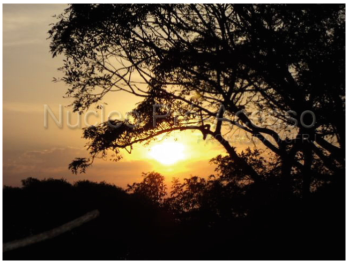

Fig. 7 Tijuca forest

5 Virtual Accessibility Guide in Rio de Janeiro and in Brazil

Thinking of accessibility to physical spaces and tourism for all, the Pro-Access Group is making an APP guidebook, and the first case-study is Rio de Janeiro City. This is being done with the support of the University and the Brazilian Institution for Sponsoring Research (CNPq).

People with disability or reduced mobility have an even greater need for this guidebook since they will get indispensable information about accessible tourist spots. It is essential to know which facilities are accessible, helping these people in participating in the different social and recreational activities, also encouraging tourism in the city.

The "Virtual Accessibility Guide" will offer access information to tourist attractions. The pilot sample is the City of Rio de Janeiro, since it's where our University (UFRJ) is located and the host to the Olympic and Paralympic Games—RIO 2016. The App is free for adjustments and tests until it's ready to be updated with the data.

The methodology will be available, so that various centers from the National Network of Assistive Technology, of which we are part, may feed the platform, thus continually increasing the quantity of information available for all of society.

A solution with future perspectives will also be developed in English, which include the development of compatible solutions for mobile devices, such as tablets and smartphones, within the operational Android or iOS systems.

The "Virtual Accessibility Guide" with apps for mobile devices will identify the user's position through GPS systems—Global Positioning System, and, from this position, will indicate the contiguous locations where there are points of interest (PIs) that match the spatial needs of users with disability. A user with reduced mobility will be able to find spots close by that provide accessibility to people in wheelchairs, such as elevators and access ramps. Users may search for points of interest in a specific neighborhood or in a category, such as a museum, park, historical building, and tourist sight (Figs. 8 and 9).

In order to develop the Guidebook, the accessibility conditions of some places and tourist attractions are being assessed through a pre-established checklist surveying specific data related to the city of Rio de Janeiro. The solution must also interact with software (already in the market) that has the required facilities for users with low sight, such as expanding the text font or mechanisms for text sound reproduction.

The content of the solution, which includes the identification of Points of Interest (PI), its description in multiple languages and its geographical location, will show the facilities and barriers, researched and assessed by the UFRJ Pro-Access Group.

Fig. 8 Applications for mobile devices and GPS location on accessibility maps

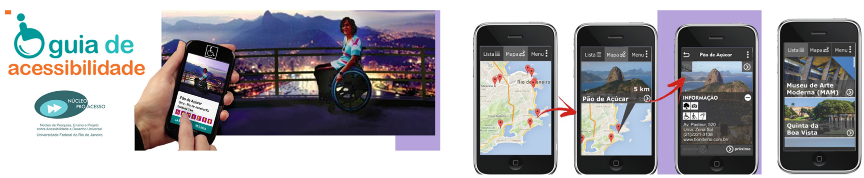

Fig. 9 Example of the first tests developed for the virtual accessibility guide application

5.1 Features

Web Interface for the Virtual Access Guide; Compatible with the Web and Web Mobile platforms (iOS, Android); Selection of user's language (Portuguese, English or Spanish); Identification of user's location in Android; Identification of user's location in iOS; Search for Points of Interest (PIs) through user location proximity, city, area in the city, neighborhood, type of accessibility and PI category; PI search result in a list; PI search result in a map; detailed visualization of a selected PI (Fig. 10).

Universalization: Internationalization of content; Interface screen for content entry in multiple languages; Interface adaptation for the visually impaired.

Interface management of interest spots: Interest spot registry; Geographic coordinates, name, description, images, telephone, site and summary; Interest spot visuals already registered; Editing of these interest spots; Admins authentication; Admins password recovery (Fig. 11).

The Pilot Sample of the Guide will receive validations for improvement until it is ready to be used by other states.

The accessibility investigation will also take place in the most visited cities of Brazil. We analyze and research the following details: parking convenience—for

Fig. 10 First proposals of layouts for the virtual access guide app

Fig. 11 Examples of the first tests for the VIRTUAL ACCESS GUIDE app

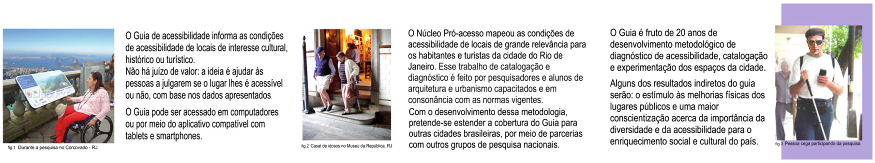

Fig. 12 Testing the field research in the city of Rio de Janeiro VIRTUAL ACCESS GUIDE

disabled drivers or passengers; parks and tourist sights with adequate dimensions according to the Brazilian technical standards (ABNT, NBR 9050/2015) and signaled; the access to transportation must also be analyzed; with measures such as ramps, for example.

During the analysis of important urban mobility aspects, we take into consideration the urban elements that guarantee: Access, Movement, Utilization, Performance, Permanence, Safe Information, Independence and Autonomy (Fig. 12).

6 Software Development

1. Every development cycle of the software is broken into smaller cycles. The project scope and its requirements are analyzed right at the beginning of the proposal, and as soon as the cycles are completed, small changes may be made to the scope allowing the project to adapt to changes in a swift and efficient way. Every cycle may be defined by the following stages:
2. Scope and planning: Survey of important features for this cycle; Prioritization of critical activities to meet the client's demands; Organization of "stories" that need to be met to satisfy the client.
3. Analysis and Design: Analysis of requirements, complexity, and cost estimates for the development of the cycle.
4. Implementation and verification: Development of a code to cater to the stories; Tests of the developed code.
5. Introduction and Support: Release of functionalities based on stories for wider tests and verification made by the client; Client's feedback and backup for understanding of the problems that were found; Adjustment suggestions and changes that can be made to the next cycle.

These steps repeat themselves in every cycle, allowing the client to be close to the development process and define his priorities and necessary adjustments in every cycle to match the app to the demand.

7 Final Observations

Working with physical accessibility, the Virtual Accessibility Guide seeks to render services to society and increase knowledge of accessibility issues, paying special attention to the spatial needs of people with disability.

As a final product, the Guide will not contain any assessment or judgment value: it will be exclusively informative. The idea is to allow people with limited mobility, the elderly, the visually, hearing, intellectually or physically impaired, among others, to assess, on their own, if the location is accessible to them or not, based on information.

The Project is the result of the acquired experience by the Pro-Access Group, professors, students and researchers of the Architecture and Urbanism College of the Federal University of Rio de Janeiro (FAU/UFRJ), over the course of the last eighteen years of work dedicated to research on Accessibility and Universal Design.

We consider it relevant that the portal allows the data to be read by blind people through software available for free on the internet. There are voice synthesizers that allow blind people easy access to texts and websites. By incorporating the description of images, we intend to offer a friendly guide to people with visual impairment.

The communication between researchers who dedicate themselves to the Accessibility theme (in Brazil and abroad) must happen constantly at all stages of the work. We foresee the creation of a network that unifies researchers, in order to establish a productive dialogue regarding the Accessibility we all wish for Brazilian cities.

Therefore, the mechanisms generated on this project will happen in three levels. This project is important due to its inclusive aspect in that an interdisciplinary network on Accessibility and Universal Design will be created, a vehicle of communication and exchange between researchers and professionals who are dedicated to this subject. Secondly, there is transfer through teaching. The afore mentioned network will need to be qualified and trained to be able to pass on knowledge. This will aid in the creation of teaching methods and propagation of knowledge. Training courses, experience workshops, applications, technical reports and diagnosis courses will be promoted.

Finally, there will be a social transfer; the population along with the public authorities will be encouraged to participate. Since the urban and architectural environment play a social role in welcoming human diversity, and are also able to change mentalities and overcome physical and social inequalities. The elimination of barriers to accessibility helps decrease social, cultural, political, economic and bureaucratic barriers which have been solidified due to lack of information. Like a wave that opens itself to diversity, the Guide will bring irrevocable changes to urban Brazilian life.

The promotion of this Project will create a domino effect: when theaters, museums and public visitation spots are not included in the list of accessible places, they will definitely see urban renovation to improve access as something of utmost importance.

Although we foresee physical improvements as indirect results of the guide, our main goal is to help people understand and become aware of the importance of diversity and accessibility as an agent that will bring enrichment to the country as a whole.

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Multimedia Interfaces for People Visually Impaired

Alexiei Dingli and Isaac Mercieca

Abstract In our society, there is a substantial number of visually impaired individuals. However many social mechanisms are not designed with these people in mind thus making the development of electronic assistive tools essential in order to perform basic day-to-day activities. Due to the penetration of capabilities of mobile devices, such devices have become an ideal candidate for designing solutions to aid the visually impaired. The objective of this research is to develop a multimedia user interface whose scope is to aid the visually challenged. We propose and design a product recognition system utilizing computer vision and machine learning techniques. Our system allows visually impaired individuals to identify products in grocery stores and supermarkets without any additional assistance, thus encouraging them to perform daily activities without requiring any additional help thus further promoting their independence within society. Our approach is composed of two main modules one capable of classifying grocery products using an unsupervised feature extraction methods posed by deep learning techniques while the other module is capable of recognizing products in an image using the traditionally handcrafted feature extraction algorithms. We considered multiple robust approaches to identify the one most suited for our task. Through evaluation we determined that the best approach for classification is to fine-tune a convolutional neural network pre-trained on a larger dataset. We were successful in not only surpassing our base accuracy but also obtaining an accuracy of 63 %.

Keywords Visually impaired · Computer vision · Image classification · Object recognition · Deep learning · Mobile technologies

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1 Introduction

Visual impairment is a crucial subject, which should be explored in depth in our visually centered world. For even the simplest of tasks, visually impaired individuals must depend on others for help. One such task is performing their daily grocery shopping, where they must compile a shopping list and entrust a supermarket employee to collect the required items for them. This not only runs the risk of such individuals being taken advantage of but also strips them of their independence. With the system we are proposing in this research, we attempt to not only solve these problems, but to also make the lives of these individuals easier by aiding them in performing such tasks completely independent of others.

Recognizing grocery items is quite a challenging task as multiple products can share similar visual attributes, one such example is a chocolate bar where one is plain and the other contains nuts while both have the same brand. Similar systems [1–4] approached this task by using a classification paradigm known as cross-dataset classification [1]. This problem paradigm refers to the case where the train and test data were not acquired from the same distribution. They used images of products, which were captured under ideal conditions for the train data, and for the test distributions they used images of the products in their real-world environment. These were referred to as in vitro [3] and in situ images [3] respectively.

These systems used a relatively small number of grocery products for example 120 [3, 4] and 30 [2] and for each one these products multiple images of the same product were used. Each class in their classification process represented a single product [2, 3]. Although multiple classification approaches were considered, the method which showed best performance was the standard bag of visual words approach [5]. However, a recent system approached our problem, by grouping multiple products depending on their particular product category one such example is pasta [1]. This system used a fine-grained classification algorithm [6] to predict the product category. Recognition was performed by matching the handcrafted SIFT [7] features. In contrast, to the other systems recognition is only performed on the products pertaining to that particular category. This system used a multi-label approach, which was not fit for our task as we attempt to identify a singular product in the individual's view. Although this system outperformed the others, the best classification accuracy achieved was 21.9 %.

By following on the method used in [1] we explored our problem by initially classifying the product and then recognizing the product by comparing the particular product with those in a precompiled database pertaining to that same product category. In our background research, we examined numerous classification approaches and observed that the recent deep learning techniques have performed quite impressively, even surpassing human performance in some cases. We approached our classification problem using convolutional neural networks (CNNs) a deep neural model which has proved to achieve a great performance for image classification tasks [8, 9]. We consider training the deep model by initializing the weights randomly, then using learning methodologies and evaluate them by identifying the best performing approach for our task.

On the other hand, recognition was approached using Lowe's methodology [7] by matching the key points extracted from the product in the scene to those in a precompiled database. The item, which had the most number of matches, was thereby the best match for that particular product.

Our contributions in this research included a categorized dataset of in vitro images of grocery products and a methodology for identifying grocery products in a store which aids a visually challenged individual without requiring any additional assistance.

2 Aims and Objectives

The aim of this research is to aid a visually impaired individual to identify products in a grocery store. We proposed an approach where products are classified by a particular category and recognition of the product is only conducted on the training distributions pertaining to that category. To reach this aim we consider the following subsidiary aims:

We first aim to review the most recent and robust classification methodologies, commonly used in literature, in order to determine the most suitable approach for our task. The above will be achieved through the design and implementation of a sound methodology, based on approaches proposed by other researchers within the field of image classification. The basis of this methodology will consist of compiling a data collection of grocery products by acquiring image of groceries from the web and categorized these manually. Preprocessing and feature extraction techniques are then performed to attain the common attributes for classification. These attributes must be common for the products with the same category irrespective of scale, viewpoint and other transform and environmental conditions.

Secondly, we aim to investigate the most common approaches used for object recognition applications, which were examined in literature and identify the best methodology for our recognition procedure. This will be achieved through the design and implementation of an approach, commonly used throughout the literature reviewed to recognize a product in its natural environment, which in our case is most usually a shelf. The same requirements were considered for this objective as for the one highlighted above, meaning that the recognition must be invariant to most of environmental conditions.

Finally, we aim to surpass a classification accuracy of 21.9 %, which was obtained by one of the similar systems reviewed in literature [1]. In this system, the authors performed classification of grocery products using hand-crafted features and attempted to solve this particular task using a multi-label approach. This was achieved by implementing the most recent and robust image classification approaches in the design of our final system.

3 Methodology

3.1 Grocery Products Dataset

In the approach our proposed design was broken down into two components, one to predict the product's category and another to recognize the product. These required a dataset of grocery products to train our classification engine and to extract local image features for recognition. Despite the fact that in literature researchers argued that the low performance attained by their proposed system was the result of using in vitro images for the training procedure, we still used this type of images for our dataset. This is because a grocery product's packaging is continuously changed due to marketing campaigns and thereby it is nor efficient to continuously update a dataset collection of in situ images.

As we approached our classification component using deep learning methodologies this required a large collection of training images as these systems tends to attain a low performance when applied on small datasets. Though similar systems have com piled their own datasets, these were relatively small for our process. Our dataset consisted of approximately 5000 images spanning amongst 5 categories: Yogurt, Pasta, Cereal, Candy and Beverages. For each product we had a maximum of three images from three different viewpoints: front, front left angle and front right angle. These images were acquired from the web, more specifically web stores for example www.maltasupermarket.com[1] and itemMaster.[2]

3.2 Our Classification Approach

In literature, we examined that convolutional neural networks have achieved a good performance for many image classification tasks. One of the most well known models was the one proposed in [8], AlexNet [8] which led to the researchers winning the ImageNet LSVRC-2012 competition. We considered three approaches for our classification component, one where we trained our deep network model by randomly initializing the weights and the other two where we apply transfer of learning methodologies. The reason behind the latter was that these methods have achieved great performance when applied for fine-grained classification tasks [10, 11]. Although these were applied for such tasks, in literature CNNs were never utilized for cross-dataset classification more importantly trained on images in ideal conditions to be used on test data collected from a real-world environment. This module was implemented with functionality provided by the Caffe framework [12], which also provided us the ability to train our network on the GPU thereby minimizing time consumption while training. Despite the fact that our networks were

[1]http://www.maltasupermarket.com.

[2]http://www.itemmaster.com/.

trained on the GPU, this phase of our approach still consumed an enormous amount of time. The machine learning functionalities offered by scikit-learn [13] were utilized for the third approach.

3.3 Data Preprocessing

Data preprocessing was limited to only down sampling the images and subtracting the mean pixel activity. CNNs require that the images must have equal dimensionality i.e. the height must be equal to the width and vice versa. We resized the images to a size of 256 × 256 as used for AlexNet [8]. In cases where the image dimensions were not equal we added extra white pixels to the smaller dimension thereby keeping the product's structure intact. The mean pixel activity was subtracted to ensure that the network was trained on the centered raw RGB values [8].

3.4 Designing a Convolutional Neural Network

For the first approach we based our network architecture on a replica of the state-of-the-art network model, AlexNet [8]. Our network architecture consisted of 8 layers: 5 convolutional layers and 3 fully connected layers. For the first convolutional layer we used 256 filters, 128 for the second and the third, and 96 for the fourth and fifth. All convolutional layers were set a kernel of size of 3. Max pooling and local response normalization was applied to the output of the first and second layers while only mas pooling was applied to the output of the fifth convolutional layer.

We used ReLU as an activation function, as this was proven to perform well for CNNs. As examined in literature this function reduces both over fitting and time consumption while training. The first two fully connected layers were initialized with 1024 neurons while the last one only had 5 as a result of having only 5 categories in our dataset. For the sixth and seventh layer we applied dropout to minimize the issue of over fitting the network. Finally, the output of the last layer was fed to a 5-way softmax classifier.

For every iteration, we used a batch size of 64 for train distributions and a size of 35 for the test data. The batch size was dependent on our GPU memory. To train the network we used the learning procedure used in [8]. We initialized our network with a learning rate of 0.001, which decreased by a factor of 10 every 10,000 iterations. We stopped the network from training when it reached 50,000 iterations. Moreover, with every iteration we applied two data augmentation techniques, cropping with a size of 224 × 224 and horizontal mirroring to help reduce over fitting. Mirroring was only implemented for the train iterations.

3.5 Transfer of Learning Methodologies

For transfer of learning methodologies we considered fine-tuning and extracting CNN features from a pre-trained network. For both approaches we used a network pre-trained on the ImageNet ILSVRC-2012 dataset, CaffeNet (which was based on AlexNet [8]. Fine-tuning was performed by training the network on our dataset after this was pre-trained on the much larger dataset. Thus the weight would not be initialized randomly. We modified the last fully connected layer of the CaffeNet network to 5 neurons. Moreover, we initialized the learning rate multipliers for this layer to a higher value. By decreasing the global learning rate to 0.001 from 0.01 the weights for the first 7 layers adapt less quickly to our data in contrast to the last layer which had a higher learning rate multiplier. Training was performed identically to the ones in our first approach.

For the final approach we used the pre-trained network to extract a feature vector with a dimensionality of size 4096 for all the images in our train distributions. We reduced the dimensionality of these feature vectors by applying PCA dimensionality reduction. The newly reduced feature vector was fed to a LinearSVM classifier as considered for [10].

3.6 The Recognition Approach

The secondary component involved extracting SIFT [7] and SURF [14] descriptors form our dataset and store these to disk. This method was based on Lowe's approach for recognizing objects in a scene. When extracting features we applied Lowe's ratio to minimize the number of false matches. Furthermore, we used a nearest neighborhood algorithm, FLANN [15] to identify feature matches. The best match was identified by calculating the total number of matches for each comparison and identifying the product in the database, which had the most number of matches. Functionality for the feature extraction and matching was provided by the OpenCV library (Bradski).

3.7 The Client–Server System

Finally, we implemented a simple client-server system, which used the approach highlighted to recognize the grocery items. The client system was implemented with a simple interface to capture photos and sends these to the server, which in terms makes use of both components to recognize the product. The name of the product is then sent to the client, which outputs the response through a voice interface.

4 Results and Evaluation

To evaluate our proposed approach we distributed the dataset in a ratio of 75:25 for the train and validation distributions respectively. These two distributions were used for training our CNN and fine-tuned network. For classification we evaluated the performance of the approaches with the set of in vitro images in the validation set and compare these to the performance of the particular approach when applied to the in situ images. The collection of in situ images was collected manually by capturing photos of products using mobile phone. This collection was limited to a small number of popular grocery items, as we could not capture photos from local stores. The main reason for this issue was that grocery store owners did not allow us to take photos of products which also included the price. To overcome this we bought some of the products in our dataset and captured the photos while these were placed on a shelf.

By evaluating the performance of the CNN network on the validation set we concluded that the network adapted quickly to the data. One of the main reasons was that these images were too 'perfect'. In fact, we achieved good performance when evaluating the network every 10,000 iterations. However, when we tested the performance of the network on the in situ images we obtained very poor results (highest accuracy was only 34 %). In light of this we eliminated this approach from the classification module as the performance achieved on the in situ collection clearly showed that the network required to be trained on the more generic features contained in a much larger dataset and which were not available in our in vitro data.

A similar approach was considered to evaluate the performance of using a fine-tuning approach. Similarly, the evaluation on the validation set showed that the network adapted too quickly to our in vitro data. Moreover, better performance was obtained on the validation set than when using the first approach. However, the results achieved when testing the performance on the in situ data showed a much higher level of performance. In fact we achieved an accuracy of 63 %.

For the final classification approach we conducted two tests, one where we use a PCA threshold of 0.5 and another of 0.9. Similar to the previous approaches, better performance was obtained on the validation set while a lower performance was attained when applied to the validation set. Moreover, for this approach best performance was achieved using a PCA threshold of 0.9, which resulted in an accuracy of 57 % on the in situ set.

In light of the results obtained by the classification approaches considered for our problem we concluded that transfer of learning methodologies are best suited for our task. The results clearly indicate the issues that arise when training a network on a different distribution from the test set. Although both transfer of learning techniques achieved a promising performance, fine-tuning obtained the best results. Further evaluation on the results obtained using this approach indicated that worst prediction performance was obtained for the 'Yogurt' category as these products are small and with a white packaging which blends to the white background in the in vitro image. Moreover, best performance was achieved by the

'Beverage' and 'Candy' category. The reason for this is that packaging for beverages differs from the rest and the products in the 'Candy' category have a complex colored packaging, which surpasses the others. In fact most of the false predictions, were a result of predicting products as 'Candy'.

We tested our recognition component by evaluating the performance when using SIFT [7] and SURF [14] descriptors. A higher recognition rate was achieved using SIFT [7] descriptors. In fact when we used multiple viewpoints of the same product instead of using a single image, we achieved a higher recognition rate. In contrast to similar systems our product collection had products, which had very similar packaging. One such example is a yellow M&Ms and a blue M&Ms. Our results indicate that although SIFT [7] descriptors are robust, our approach could not distinguish between the two. In fact as a result of this drawback our best recognition was of 41.38 %.

We conducted one final test where we presented our system to visually challenged individuals, who tested our system and gave us feedback using a questionnaire which was e-mailed to the participants after the sessions. To test the system we visited the visually impaired participants, where we took a small number of products to be used for performing the tests. Feedback from the gathered questionnaires clearly indicate that our system was well-liked by the participants who encouraged us to keep working on it beyond the scope of this research as it provided them with a sense of independence when performing this daily activity thereby confirming that we reached our main aim, that of designing an interface to aid a visually challenged individual.

5 Conclusion and Future Work

In this research we proposed an approach, which aids a visually challenged individual to shop for groceries from local stores. Our approach consisted of two components, a classification module which aids the secondary component, recognition by only matching the products to a specific category. In contrast to similar systems, we approach our classification task using deep learning methodologies, which proved to achieve a great performance. Our results indicate that by fine tuning a CNN on our dataset we achieved promising performance, which is mostly effected by using a training set gathered from a different distribution than the test set. Recognition showed a good performance where products shared different packaging however in the case of similar packaging, this component obtained lower performance. This indicated that future work could include updating our dataset with more product images to achieve better performance for both components. Recognition could be further improved to cater for issues that arise when matching products that share an almost identical packaging. Finally, the feedback from our participants in the user evaluation clearly indicate that our system was well-liked. One participant even pointed out using video instead of photo, which could be implemented as future work.

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Improving Deaf People Accessibility and Communication Through Automatic Sign Language Recognition Using Novel Technologies

Luis Quesada, Gustavo López and Luis Guerrero

Abstract Communication is a key for human development. Nevertheless, deaf people have difficulty interacting with hearing and hard of hearing people. On the other hand, new technology allows gesture recognition. This work aims to promote the development of tools to take advantage of 3D camera technology for the benefit of the Deaf Community around the world. This research proposes a sign recognition model using 3d cameras (i.e. Leap Motion and Intel RealSense) and support vector machines (SVM). The goal is to support the communication process between deaf and hearing people. Furthermore, we conduct an experiment determining an appropriate amount of training sample signs to ensure satisfactory results using SVMs.

Keywords Sign language recognition · American sign language · Leap motion · Intel realsense

1 Introduction

Research has been done for several years in automatic translation of sign languages using different types of devices and sensors. Nonetheless, result normally lack of detail on the implementation and evaluations show performance issues.

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The goal of this research is to propose an algorithm using 3D cameras that allows hand tracking and automatic sign recognition. Our algorithm uses less data than the others found in literature and shows similar results.

Our research provides several contributions in terms of implementations details, evaluations rigorousness, and general results. First, we provide a representation model of the signs using the direction vectors (by the positions of the phalanges of each finger relative to the 3D camera). Our representation model requires less data than other proposals found in literature. Second, we determined the average amount of training data required for "good" recognition. This conclusion was drawn of experimental results. Finally, we evaluated our proposal with one, state of the art, hand tracking device.

The devices used for evaluation use 3D cameras, which by infrared technology and depth sensors, recognize hands and allow position recognition in a given moment of time. The devices used for experimentation were the Leap Motion and the Intel RealSense. One major advantage of such devices is that computer manufacturers begun incorporating them into laptops and mobile devices.

There are many scenarios where our proposal can be applied, for instance:

- Fingerspelling training of most sign languages.
- Sign translation between different sign languages.
- Sign language training.
- Increase computer accessibility to deaf people.
- Comparisons of results in different sign languages. Our evaluation considered Costa Rican Sign Language (LESCO) and American Sign Language (ASL).

This work aims to promote the development of tools to take advantage of 3D camera technology for the benefit of the Deaf Community around the world. The benefits extend to the hearing people, by helping to understand the deaf who prefer the use of a sign language [1].

This document describes the research. In the next section we refer to the hand tracking devices. In Sect. 3 the sign recognition model is proposed. Section 4 assessment system is presented. Finally, the discussion is presented.

2 Sign Language Recognition Using Hand Tracking Devices

There are hundreds of prototypes trying to achieve sign language recognition using devices that support gesture recognition. This section describes the devices selected for this work and some of the research that use it.

2.1 Hand Tracking Devices

We considered a list of devices to develop this project. There are a variety of 3D cameras mainly for use in games or in activities that requires gesture interaction. Two devices were selected: Leap Motion and Intel RealSense.

The Leap Motion is a device available since 2013 to track the fingers. Using an infrared camera technology, the device obtains the coordinates (x, y, z) of 27 points for each hand that are located in the area of range of the device. The device based on the anatomy of the hand to achieve the recognition [2].

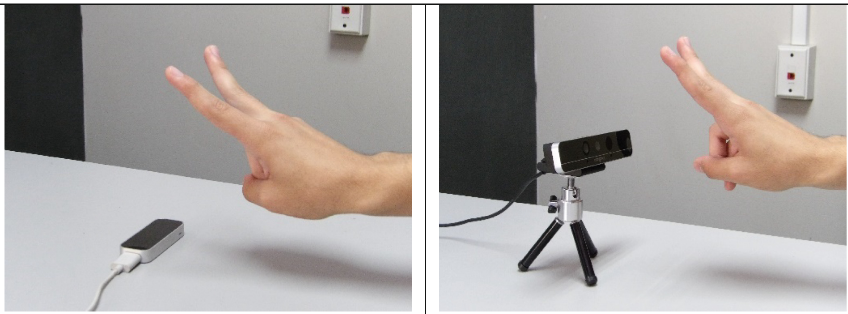
In addition to the coordinates, it is also possible to obtain other relevant data, i.e. unique hand identifier and the approximate hand dimensions. This information can be acquired up to 200 times per second (200 frames per second, fps) according to the manufacturer [2]. A frame corresponds to the position information of the hand at a given point in time. However, the number of frames per second recognized depends on the specifications of the computer.

Furthermore, the manufacturer provides different libraries to develop applications in programming languages such as C++, Objective C, Java, JavaScript and Python. The variety of programming languages allow to develop mobile, web and desktop applications.

Figure 1a shows the sign performing of the "number 2" and "letter v" sign (according to the American Sign Language, ASL). The device of Fig. 1a is external. However, there are also embedded devices in laptops and desktop keyboards.

Figure 1b shows the performing of the same sign using the Intel RealSense. The Intel RealSense is a set of cameras and development libraries that allow users to use gestures to interact with computers. There are two versions, one for mobile devices (R200 and SR300 models) and one for computers (F200 model). The F200 Developer kit model was used in this project. Embedded devices can be found in some laptop models [3].

The Intel RealSense F200 include two cameras, one conventional camera and one infrared camera, one laser infrared projector and an array of microphones. The



(a) Leap Motion (b) Intel RealSense

Fig. 1 Using the selected devices: **a** Leap Motion and **b** Intel RealSense F200 developer kit

F200 model reaches a maximum of 90 fps. The device can recognize hands, bodies and objects using an integrated image processor. Intel provides a library to develop solutions using different programming languages, i.e. C#, C++, JavaScript, Java and Processing [3].

The next section feature research works in sign automatic recognition using 3D cameras are described.

2.2 Related Work

Research related to the sign language recognition include a variety of devices, i.e. 3D cameras, gloves and specialized hardware. This paper will focus solely on the Leap Motion and Intel RealSense. The Intel RealSense has been slight explored, given its recent release (March 2015). We did not found research works using the Intel RealSense for sign language recognition in the main databases. The Leap Motion was available to developers in July 2013 therefore exploratory work can be found [2].

Potter, Araullo and Carter discussed the feasibility of using the Leap Motion in Australian Sign Language (AUSLAN) recognition. At that time, it was only available the first version of software development libraries associated to the Leap Motion. After an analysis of the strengths and weaknesses of the device, they concluded that although the Leap Motion has potential, recognizing complex signs is not yet possible [4].

In 2014 and 2015 Leap Motion manufacturer provided an improved versions of software development libraries [2]. After the release of the latest versions of the development libraries, other researchers worked using the device, for example, Chuan, Regina and Guardino. They selected the signs of the ASL alphabet and underwent a process of recognition with neural networks and support vector machines (SVM). Some letters were not correctly recognized by the Leap Motion. Although the device is not yet a mature stage, the technology has the potential to impact positively on the Deaf Community [5].

A similar work was implemented for the Arabic Sign Language (ArSL) by Mohandes, Aliyu and Deriche. They selected the 28 letters of the Arabic alphabet. Although reported rates greater recognition to 95 % for some signs, 6 signs were not recognized completely. The main reason why some signs were not recognized correctly was the range of vision of Leap Motion, because some fingers were covered by other fingers while performing a sign. They proposed as future work using two devices to cover blind spots [6].

Elons, Ahmed, Shedid and Tolba also research about ArSL recognition. They tested 50 signs equivalent to selected words. To achieved the sign recognition, they used neural networks and obtained a success rate of 88 %. The authors also proposed to use a second device to enhance the effectiveness of the recognition [7].

These works did not describe the recognition method neither the implemented algorithm. When the works used SVM, there is not clues about how many trainings were conducted for each sign and how such training were obtained. The next section proposes a sign recognition model using SVM.

3 Sign Recognition Model

This section proposes a sign recognition model using 3D cameras and SVM. The 3D cameras obtain the coordinates (x, y, z) of key points in each hand. These points denote the sign. The SVM predict performed signs, considering minor variations while a user performing a sign. Figure 2 shows the proposed model proposed.

The recognition model has two main features:

SVM Training: The training stage needs samples of each selected signal, At least one example of each sign for training must be provided. The maximum training samples is determined by the capabilities of computer equipment. Later, we will discuss about the recommended number of training samples.

Sign classification: We read the hand shape every 6 ms using the 3D camera. Based on the training, a decision module predicts a final classification.

Main components of the sign recognition model are 3D Camera, user interface (GUI), data processor, SVM and decision module.

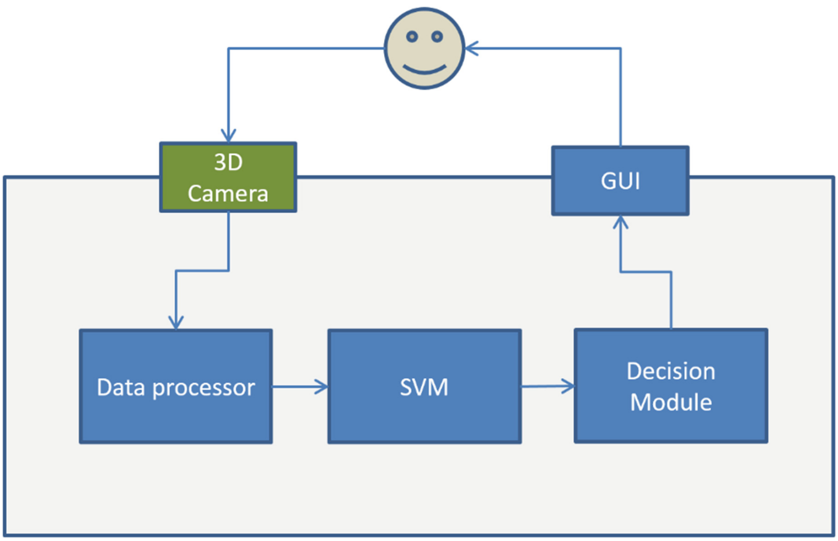


Fig. 2 Sign recognition model

3.1 3D Camera

This module includes hardware and software (libraries) provided by the device manufacturer. The hardware recognizes the position of each finger and the software provides the key points describing the performed sign.

The hardware module accomplishes the communication between users and the recognition system. This module is used both during training stage and sign classification stage.

3.2 GUI (Graphical Interface Unit)

The GUI inform the system status to the user, including the recognized sign in the sign classification stage. Through the training stage, the GUI is used as input data (which is performing sign identifier: NUMBER_1, NUMBER_2, LETTER_A, LETTER_B, and so on).

3.3 Data Processor

This component receives the data from the hardware recognition device (i.e. the Leap Motion or the Intel RealSense). The key points used for each sign description are: (1) the coordinates of the fingertips and (2) the coordinates of each proximal phalange (the phalange closest to the hand). These coordinates allow to calculate the direction vector of each finger.

Fig. 3 Performing the letter W sign includes direction vector and fingertips markers

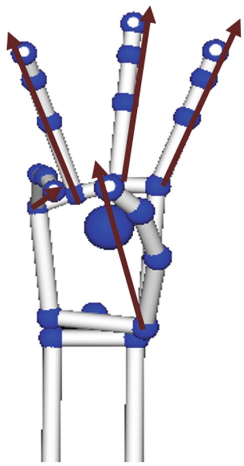


Table 1 Sign representation using the fingertips coordinates and the director vector between the fingertip and the proximal phalange

Finger	Fingertip (x, y, z)	Direction vector
Thumb	(56.56, 200.00, 45.14)	(−0.56, 0.10, 0.81)
Index	(61.30, 268.08, −0.61)	(−0.03, −0.19, 0.98)
Middle	(76.30, 186.51, 57.51)	(0.10, −0.01, −0.99)
Ring	(89.88, 189.19, 70.06)	(0.19, −0.07, −0.97)
Pinky	(105.65, 196.58, 70.35)	(0.17, 0.03, −0.98)

Figure 3 shows the letter W sign (from the ASL alphabet). The finger tips are marked. Figure 3 also shows the direction vectors. This module has the same behavior both in training and sign classification stages.

Table 1 shows an example of the data recollected by the 3D Camera and formatted by this module. The coordinates belong to the positions of the fingertips and the direction vector of each finger.

3.4 SVM

This module predicts the sign performed by the user. SVMs are supervised learning models that use training observations to recognize patterns. The SVM must be trained using samples of each sign. Each sample will be positioned in a 2-dimensional plane. To classify the signs, a new observation is positioned in the plane and a prediction is provided using regression analysis [8].

3.5 Decision Module

Based on information provided by the SVM, this module decides which sign is performing in the device vision range. Every 5 ms the SVM send a prediction. When 5 identical consecutive predictions are accomplishing by the SVM, this module decide which sign was performed.

For example, suppose the SVM was trained with SIGN1 and SIGN2. Then, the user performs a SIGN1. This module receives the predictions every 5 ms, beginning at time 0. Table 2 shows the predictions send by the SVM.

Consider the prediction sequence shows in Table 2. This module will predict SIGN1 as performing sign. Although the SVM predicted SIGN2 in times 10 and 15, these predictions were ignored when the SVM predicted a different sign (SIGN1,

Table 2 SVM predictions in a 40 ms time lapse

Time	0	5	10	15	20	25	30	35	40
Sign	1	1	2	2	1	1	1	1	1

Sign 1 represents SIGN1 and sign 2 represents SING2 time 20). Only when five signs in a row were predicted, the decision module produces a prediction. A wrong prediction results from incorrect sign performing, device lack of precision or infrared light distortions.

In the next section, we describe an experiment using this sign recognition model.

4 Experimentation

We conducted an experiment to determine the average amount of training data required for "good" recognition. "Good" recognition means to achieve at least the hits rates reported by previous research works. The prototype implements the sign recognition model proposed in Sect. 3.

We used the Leap Motion for gesture recognition. The prototype was developed in Python 3. The SVM module was implemented using the library scikit-learn [9]. This library provides a one-against-one classification approach for multiclass classification. In one-against-one multiclass classification for SVMs, all possible two-class classifiers are evaluated, giving a total of n(n − 1)/2 classifiers [8, 10].

A factorial experiment design was selected using two design factors and k levels. The design factors are the amount of training signs of the SVM (4 levels) and the signs (10 levels). Hence, we selected 10 signs to be performed (see Fig. 4) and 4 configurations varying the number of training samples:

- 10 training samples for each sign (training set size: 10 × 10 samples).
- 100 training samples (training set size: 10 × 100 samples).
- 252 training samples (training set size: 10 × 252 samples).
- 1000 training samples (training set size: 10 × 1000 samples).

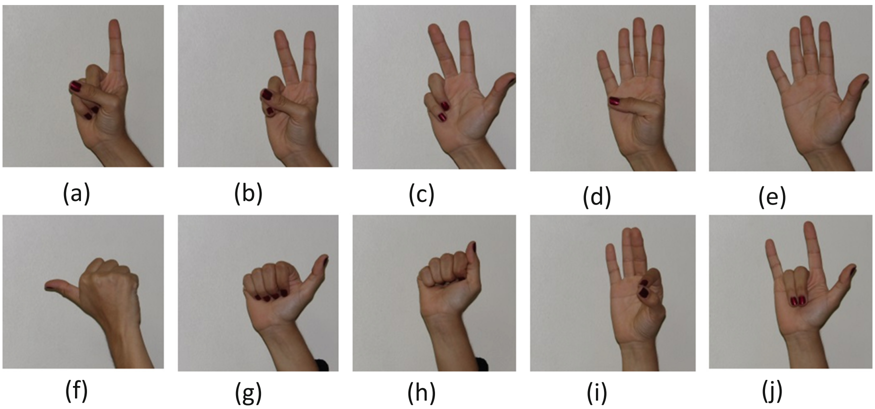


Fig. 4 Performing the letter W sign. **a** Number 1 sign; **b** Number 2 sign; **c** Number 3 sign; **d** Number 4 sign; **e** Number 5 sign; **f** Thumb to left; **g** Thumb to righ; **h** Letter A sign; **i** Letter F sign; **j** "I love you" sign

Table 3 Analysis of variance

Source	DF	Adj SS	Adj MS	F-value	P-value
Training	3	2.3263	0.77545	33.70	0.000
Sign	9	0.5326	0.05918	2.57	0.028
Error	27	0.6213	0.02301		
Total	39	3.4803			

The training was performed by two researches. The initial hand position was randomly generated, considering the device vision range. Constant factors were considered: The Leap Motion device, the desktop computer, the amount of light (400 lumens) and the value of the Y axis of thumb initial position. The Y axis was set at 200 mm because researches demonstrated a better precision between 100 and 300 mm [11].

The experiment execution provided the analysis of variance (ANOVA) shows in Table 3. The analysis was performed using the Minitab 17.0 tool. As shown, the sources of variability belonging to the amount of training and sign show a p_value < 0.05. Therefore, we can say that in both cases the null hypothesis is rejected (all means are equal). This implies that both the amount of training data (10, 100, 252 or 1000 training samples) and the sign (10 selected signs) have an effect on the results.

Moreover, determining the amount of training data used by each SVM configuration (10, 100, 252 and 1000 samples), the ANOVA showed that this amount has an effect on the percentage of correctly classified signs. To support this, see Fig. 5.

Figure 5 shows the system with 10 training samples per sign achieved a 50 % of successful classifications only in 3 signs. Meanwhile, the 100 training samples configuration, all signs exceed 50 % of successful classifications.

Additionally, Table 4 shows the Tukey's test results with 95 % confidence. These results showed how the amount of training data greater than 100 samples, are

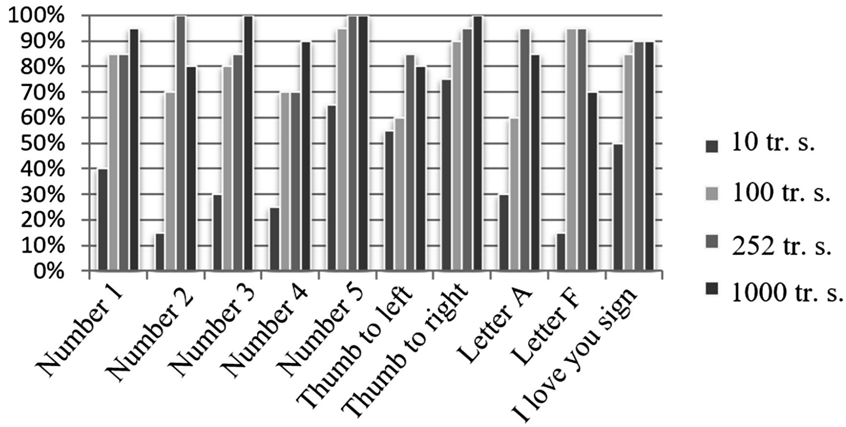


Fig. 5 Signs correctly predicts by the sign recognition model prototype

Table 4 Tuckey's test

Training set	N	Mean	Grouping
1000	10	1.27129	A
100	10	1.25982	A
252	10	1.11474	A
10	10	0.67688	B

statistically equal. Specifically, 100, 252 or 1000 training samples per signal thrown statistically the same results.

In addition to this experiment, the sign recognition model was evaluated using a second prototype. This prototype was implemented in C# using an Intel RealSense. The results are not ready. Notwithstanding, the preliminary results suggest better performance.

5 Discussion

The model proposed has proven to be a suitable method to recognize simple signs of a sign language. Using the direction vector and the fingertips coordinates is a worthy approach that could be used in many contexts where signs are needed.

The experiment results are useful training SVMs for signs classification. Only 100 training samples are enough to reach satisfactory predictions rates. Training a SVM using a large corpus could be a demanding task. Moreover, using only 100 training samples could help to diminish tough work.

There are many challenges that every day must overcome the deaf. One of those challenges is to communicate with hearing people (family, friends, teachers). We believe that the proposed sign recognition model using technologically innovative devices (3D cameras) should be encouraged. The goal of these research is proposing a comprehensive medium-term solution to the problems of communication between deaf and hearing people.

Much work remains to be done. It is necessary to extend the model so you can recognize not only simple signs, but complex signs (using two hands, by example). The model should have tested using a real sign language corpus (composed by thousands of different signs and gestures). This in order to make the necessary adjustments to continue improving the model. We hope future solutions be accessible to the Deaf Community.

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Analysis of Interaction Patterns in the Use of High-Tech Prompting Technologies by People with Intellectual Disabilities

Jeannie Roux, Dany Lussier-Desrochers, Yves Lachapelle, Bruno Bouchard and Julie Bouchard

Abstract Several "high-tech" assistive technologies are currently used in the field of rehabilitation to support the achievement of daily activities. These technologies have proven to be especially effective when used with persons with intellectual disabilities (ID). It is important, however, to consider the interactions between the technology and the people to determine which conditions to set up to optimize the impacts of this intervention method. This case study on using computerized guidance modalities in the performance of a daily living activity will help create a first schematic of the interactions between the users and their environment.

Keywords Intellectual disability · Prompting · Daily living activities · Technologies

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1 Research Context

Intellectual disabilities (ID) affect 1–3 % of the general population. More precisely in Canada, these conditions affect between 300,000 and 1,000,000 people [1, 2]. An intellectual disability is defined as an incapacity characterized by significant limitations in intellectual functioning and adaptive behaviors. These incapacities appear before the age of 18 years. [3] More specifically, this clientele may present limitations in terms of reasoning, planning, problem solving, abstract thought and understanding complex ideas, as well as the capacity to learn [4, 5]. These limitations make it difficult to accomplish certain daily living activities (DLA), such as complex household chores [4, 6, 7].

1.1 Using Prompting to Help Perform DLA

With the aim of helping persons with ID perform DLA, various intervention methods, including prompting, are being implemented. Generally, prompts are stimuli that are used to cause a behavioral response when the environment alone does not suffice for the behavior to appear. There are various types of prompts: (a) verbal stimuli, (b) models, (c) physical stimuli, (d) gestures, (e) photos and drawings, (f) textual stimuli and (g) other types of cues, or hints [8].

Recently, the arrival of information and communication technologies has provided new prompting possibilities, including digital photos, videos and audio messages. These technological modalities can now be used to help people carry out activities related to personal care, residential and community life, and professional life [9–11]. In this regard, studies conducted with persons with ID show that high-tech prompting (a) reduces the amount of human assistance required to carry out certain tasks, (b) increases the success rate of these tasks and (c) promotes learning of various adaptive skills [12–14]. Furthermore, studies comparing intervention methods that use high-tech prompting and low-tech prompting for clients with ID tend to demonstrate increased effectiveness of the interventions when high-tech prompting is used [15].

To be fully effective, high-tech prompting cues need to be presented in a particular way and consider environmental factors [8, 10]. However, current research does not show us precisely which application conditions will provide the most effective prompting with this clientele. In this regard, Lachapelle et al. [10] maintain that certain factors, which can be influenced by the characteristics of the user, of the task and of the technology, as well as by the support received, can influence the level of effectiveness of the prompting. It is thus important to deepen our understanding of the interactions (patterns) between the technology and the people to be able to determine which conditions to set up to optimize the impacts of the intervention method. Currently, few studies have focused specifically on understanding these interaction patterns.

2 Method

2.1 Objective and Research Design

This study aims at creating a first mapping of the interaction patterns that are present when computerized prompting modalities are used by persons with ID. To this end, two specific objectives are targeted: (1) describe the interactions between the person and his or her environment, which includes the technology and the people who are present while the task is being performed and (2) specify the levels of support to be considered while the task is being performed. Consequently, the elements to be considered can be documented during the development and set-up of the technological assistance.

Achieving the objectives requires a clear understanding of the interactions between the person with an intellectual disability and a prompting modality during the performance of a task. Given the nature of the research question, an exploratory, descriptive case study design was favored.[1]

2.2 Procedure

To gain a good understanding of the interactions and define their nature, a structured task is proposed to the participants. This task was derived from the Naturalistic Action Test (NAT) [16]. The selected task consists in preparing toast and jam as well as a coffee. The two other tasks proposed by the NAT were not retained: the first consists in preparing a school bag, which is not age-appropriate for the clientele, and the second one consists in wrapping a gift, which requires major adaptation of the materials because of the motor difficulties presented by several potential participants. This instrument was chosen to ensure continuity of the work carried out by Potvin [17], who, at the time, was looking into prompting for a clientele suffering from Alzheimer's disease. The selected task is performed in the smart apartment of the UQTR's Department of Psychoeducation. This test laboratory resembles on all points a regular apartment, consisting of a living room, kitchen, bathroom and bedroom. The experiment takes place in the kitchen, where participants are asked to set themselves up near the island on which all the required materials are located.

Four guidance modalities are tested consecutively, to support the person during the preparation of toast and coffee: general verbal, specific verbal, pictures, videos. The cues are transmitted on a screen located in front of the work station as well as through loud speakers placed on either side of the screen. During the experiment,

[1]This research is conducted thanks to financial support from the Fond de développement académique du réseau (FODAR) as well as the Institut Universitaire en DI-TSA of the CIUSSS MCQ and the national Consortium for research on social integration (CNRIS).

the tester gives starting instructions to the participant, who must then perform the task. Participants can perform the task in the order that they wish, as long as the order allows all the steps in the task to be accomplished. The essential steps to follow are defined in the protocol. If participants make a mistake or omit an essential step, they are sent a cue via a software program developed by the team at the Laboratoire d'intelligence ambiante pour la reconnaissance d'activités (LIARA). The cue is sent manually by a person outside the room who is watching through a ceiling-mounted camera. The experiments are filmed for the purposes of analysis.

Once the experiment is finished, a descriptive analysis of each test sequence is performed manually, which represents 254 min of video. To conduct the analysis, a first interaction schematic is created based on the experimental protocol, which is the basis of the assistance offered to the person to accomplish the task during this experiment. Next, each experiment is viewed and the behaviors observed are integrated into the schematic; at each step of the task, the cues and the person's behaviors are collated to produce a complete portrait of the interactions between the user, the technology and the people in the room, even if this requires the addition of new elements.

2.3 Sampling Method and Description of the Participants

The research design is combined with a judgement sampling method. This non-probabilistic method was selected because it allows potential participants to be chosen according to specific criteria. These criteria are intended to ensure that the participants: (1) present the basic skills required to perform the requested task; (2) need support to accomplish the requested task so that assistance can be provided and their reactions can be examined; and (3) do not present a concomitant autism spectrum disorder. Furthermore, potential participants must be between 18 and 45 years of age and not present any concomitant mental health or behavioral disorders, nor any major untreated sensorial deficit, or any motor difficulties that would prevent them from performing a simple task like making toast or coffee.

In total, five women with moderate ID who were receiving services from the Centre de réadaptation en déficience intellectuelle et en trouble envahissant du development de la Mauricie et du Centre-du-Québec institut universitaire (CRDITEDMCQ IU)[2] were recruited. Although limited, the number of participants made it possible to conduct a more in-depth analysis of the interactions between the participant and the proposed environment.

[2]The CRDITED-MCQ IU became the CIUSSS MCQ on April 1, 2015.

3 Results

An in-depth analysis of all the cases was carried out and each interaction was entered in the interaction schematic. Given the space available for this article, it is not possible to present a detailed description of each case.[3] Only the overall data from the experiments are presented here. Further to the analysis, the results of one of the participants had to be excluded because of the large number of environmental biases.

First, the results show that three of the four participants look for reinforcement in their environment. This search for reinforcement, which may be verbal or non-verbal, represents a request for confirmation of the quality of the task realisation. Figure 1 illustrates the number of these requests by experiment for each participant. While the number of requests decrease continuously for one of the participants, it fluctuates for the two other participants. Although this need for reinforcement differs from one person to the next, it is an element that should be considered and that enhances the initial assistance schematic.

Another dimension observed is the support offered by the assistant. As illustrated in Fig. 2, the data analysis shows that during the period where the technologies are being introduced to the participants, several human support must be offered. The number of human support then decreases gradually as the person grasps the technology. A combination of technological and human support is therefore needed during the integration of this type of prompting modality.

The in-depth analysis of the interaction patterns also shows us that the participants do not deal with the technology as initially expected. In fact, the pattern of interactions with the technology is far more complex than we had anticipated, since the initial assistance schematic provided for only two categories of behaviors, namely, did perform and did not perform the expected behavior. Consequently, the schematic needed to be enhanced to cover all the possibilities and behaviors observed during the individual analyses. In fact, the case analysis shows that participants may also seek assistance in the environment before they begin taking action. Figure 3 presents the interaction schematic that was produced further to the case analysis, which resulted in three interaction levels being defined. The three levels are distinguished notably by their degree of complexity.

3.1 Level 1: Performance of the Expected Behavior Without Technological Assistance

At this level, the person simply performs the expected behaviors to achieve the objective of the task without the need for technological support. One variable is

[3]Interested readers can consult the dissertation by Roux [18].

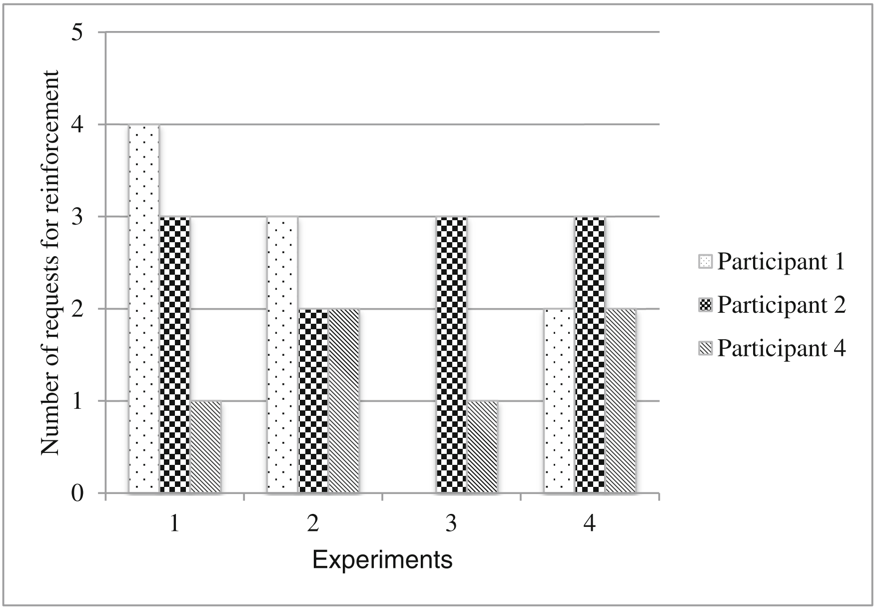

Fig. 1 Synthesis of the number of requests for reinforcement by experiment for each participant

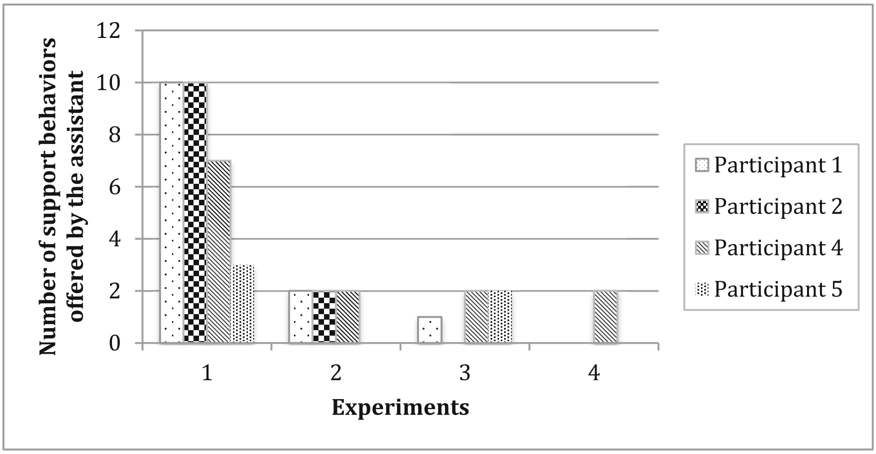

Fig. 2 Support offered by the research assistant during the experiments

introduced, namely the search for reinforcement. In fact, as mentioned in the first part of the results, some people will look to ensure the quality of the task realisation they are performing, even though they did indeed complete the requested step.

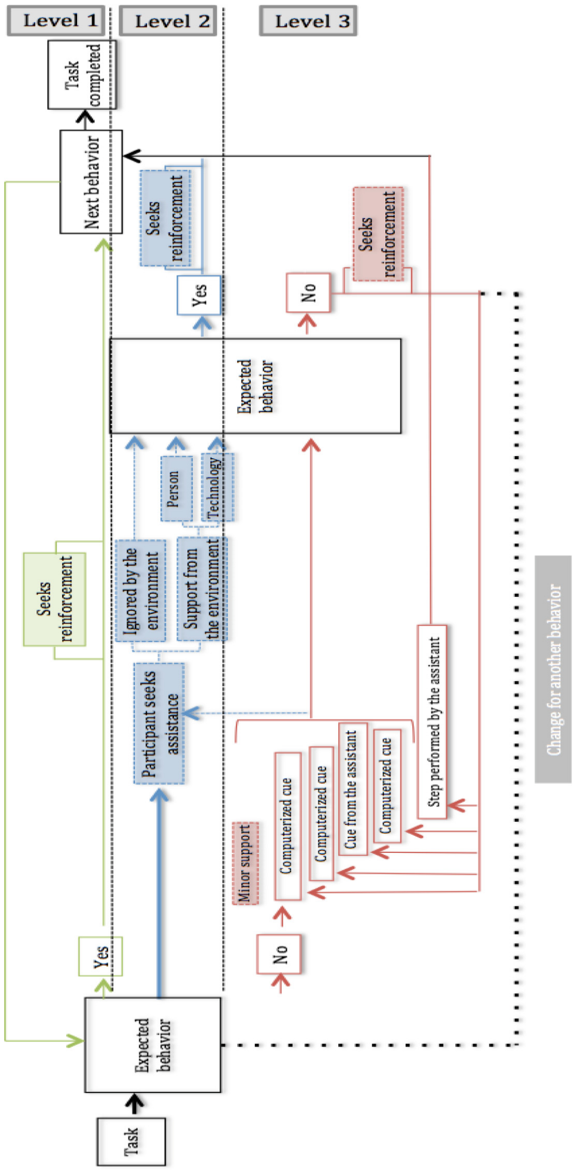

Fig. 3 New assistance schematic

3.2 Level 2: Search for Assistance in the Environment

At the second level, the participants sometimes seek assistance (human or technological) in their environment before performing the expected behavior. This request, which could be verbal or visual, may consist in looking to the assistant or the computer screen before taking action. We can see that the people search in their environment for hints to guide them in the performance of the task. In these circumstances, the environment may provide two responses: ignore the person's behavior and not provide assistance or provide human or technological support. Moreover, even at this level, we see that people who exhibit the behavior might subsequently seek reinforcement in their environment to encourage them to continue. In cases where the expected behavior is not exhibited, the participant enters into a loop of cues provided for in the protocol. This loop is represented by the third interaction level.

3.3 Level 3: Computer Support

To access this level, the person must not initiate or exhibit the expected behavior. At this point, technological assistance is activated. In this study, support is provided according to a predefined hierarchical level that consists in sending the computer cue a first time, and then a second time. If the person still does not exhibit the behavior, the assistant repeats the cue, and then sends it one last time. For the majority of the participants, these prompts lead to the performance of the expected behavior. However, we also see that some people are unable to perform the expected behavior after the computer cue is sent. In this situation, human assistance is required for the requested behavior to be performed.

The presence of minor human support was also seen in certain situations and was added to the assistance schematic. This support is different from the one in the "cue from the assistant" section because, instead of verbally giving the same cue as the one provided by the technology, the assistant directs the task without telling the participant what to do. This is a bias present in the experiment, but since it is systematic, it is included in the analysis. After the cue is given, the participant sometimes requests additional support. Therefore, an arrow pointing to the second level of support was added.

4 Discussion

The results analysis highlights a number of observations. It should first be noted that these observations must be considered parsimoniously, since the limited sample precludes them from being generalized. Before the experiments began, a first model for drawing a schematic of the participants' expected behavioral path was developed. The analysis of the participants' behaviors led to the addition of unexpected behavioral responses and to the identification of certain initially proposed expected paths. The assistance schematic presented in Fig. 3 demonstrates the complexity of the potential behavioral schematics and the relevance of conducting case studies to determine not only the cue to provide, but also the paths that may reinforce or inhibit certain behaviors. These elements are directly linked to the effectiveness of the cue supplied.

Furthermore, we notice that the participants' responses are heterogeneous, which suggests that the environment must be allowed to adjust to each person's characteristics, whether they be human or technological, in the set-up of computerized guidance modalities. Therefore, the technology must be capable of first including modalities to reinforce the person's behaviors and respond to the user's various requests for support. In fact, the search for reinforcement was present for the majority of the participants throughout the experimental process. Consequently, we must be attuned to this need to encourage and reassure the people when they are performing a task so that they will not give up. The research protocol is not exempt from these recommendations and it must also take into account the various paths that people might follow to perform the requested task. This is how technology will be able to accompany these people effectively in their performance of DLA.

At first, a technology may not suffice on its own to help the person. In fact, support from the assistant is needed and then decreases as the number of experimental sessions increases, for all the participants. A period of adaptation and learning is thus necessary and must be provided for when a new means of intervention is being used.

Finally, it is important for high-tech prompting technologies to be adapted to the person's basic abilities and to be capable of evolving at the person's pace. Several personal and environmental factors should be considered, whether they are directly linked to the technology used or to the way the surrounding people integrate this technology. The challenges encountered within this first schematization demonstrate the importance of continuing the research on the various interaction patterns. Once all these factors have been considered, computerized guidance will become a true facilitator for the inclusion and development of persons with ID.

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Accessibility of MOOCs for Blind People in Developing Non-English Speaking Countries

Mexhid Ferati, Njomza Mripa and Ridvan Bunjaku

Abstract Besides the globally popular MOOCs, localized MOOCs specific to a region or language are also emerging. These specialized MOOCs often aim to address specific needs that are typically unaddressed by the global MOOCs. Such example is Almooc that aims to address the needs of the Albanian-speaking persons who lack English proficiency. Despite the MOOCs adage to include and offer education to all people, research has shown that their interface is not accessible to people with disabilities, such as the blind. To evaluate the level of accessibility of Almooc, in this paper we report findings from three different methods: usability testing, automatic accessibility checking, and heuristic evaluation. The results indicate that Almooc is not currently accessible to blind people, however, we present recommendations to easily overcome the discovered issues.

Keywords Accessibility · MOOCs · Evaluation · Usability testing · Automatic accessibility checking · Heuristics

1 Introduction

Education has been traditionally received by instructions delivered in brick-and-mortar institutions, but lately the technology is contributing to making it more widely available. Many universities are offering online courses using Massive Open Online Courses (MOOCs), which are available to large audiences and are

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promising to fulfil learning needs to millions of people, regardless of their geographical location or personal abilities and disabilities [1].

Currently, in Kosovo, there are 86 blind and visually attending primary and high school education. However, this number is very low estimating that typically 3 % of people with disabilities (10 % of total population) is blind and visually impaired. Hence, the real number of people from this community should be over five thousand, and those attending schools should be higher [2]. We believe, the stigma associated with this community as well as the financial difficulties these families face, contribute to leaving most of the blind unrecorded. The only school for the blind in Kosovo is mitigating this issue by promoting inclusion on regular schools and sending teachers to blind persons' homes, although this brings a heavy load on the school, considering the low number of staff. Considering these issues, MOOCs could provide a platform to further alleviate the education process of the blind people.

Besides the globally popular MOOCs, such as Coursera,[1] Udacity,[2] Khan Academy[3] and EdX,[4] localized MOOCs specific to a region or language are also emerging. These specialized MOOCs often aim to address specific needs that are typically unaddressed by the global MOOCs. Such example is Almooc[5] that aims to address the needs of the Albanian-speaking people who lack English proficiency. Almooc (or Albanian MOOC) is an education platform that cooperates with distinguished Albanian teachers to offer free online classes to everyone. It started its activity at the end of 2013. Its vision is to offer a platform where everyone has access to qualitative education. Its purpose is to empower people with education that will improve their life and the community where they live. Currently, Almooc provides courses in Software Programming, General ICT, English language, Math, Physics and Chemistry. It offers over 70 courses with 16 instructors and over 47,000 students.

To evaluate the level of accessibility of Almooc, in this paper we report findings from three different methods: usability testing, automatic accessibility checking using available tools, and heuristic evaluation. The results indicate that Almooc is not currently accessible to blind people, however, we present recommendations to easily overcome the discovered issues.

2 Related Work

In a previous research, we identified many issues concerning education of the blind community in Kosovo and surrounding region [3]. One of the main obstacles identified was that blind people lack independent navigation. Inadequate basic road

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[1] http://www.coursera.org.

[2] http://www.udacity.com.

[3] http://www.khanacademy.org.

[4] http://www.edx.org.

[5] http://www.almooc.com.

infrastructure and classroom settings make it a challenge to provide accessible education for this community. Due to a lack of these basic school settings, blind students often do not receive training classes for navigation, as they will not be able to make use of such knowledge. Therefore, it becomes difficult for the blind people to attend schools, or even just go to class without a human escort when they live on campus dormitories [3]. Considering these issues, MOOCs are a great opportunity for the blind people who in this case are not able to engage in face-to-face learning. On one hand, educational institutions do not need to create accessible facilities, accessible equipment, accessible educational resources, or costly physical adaptations for this community. On the other hand, designing accessible MOOCs is technically and financially possible [4].

MOOCs have gained an impressive popularity, partly due its claim that they are open to everyone. However, their openness does not necessarily equate an access, as studies have shown that most MOOC websites do not fulfill minimum accessibility requirements [5, 6]. Hence, despite the MOOCs adage to include and offer education to all people, research has shown that their interface is not accessible to people with disabilities, such as the blind [7–9] or the elderly [10]. In spite of the opinions that in a single course MOOCs bring together diversity in ideas, cultures and regions, they currently exclude the disabled, which approximately comprise 15 % of the world population [7].

MOOCs, however, can overcome inclusion barriers if developed with accessibility in mind [11]. Various studies suggest improving their accessibility by implementing metadata [12], content adaptation [13] and following the Web Content Accessibility Guidelines (WCAG) [14]. WCAG are comprised of 14 guidelines, and within these guidelines, 65 checkpoints that describe how developers could adapt their web content in order to make it accessible. Although WCAG remain the best source when designing accessible websites [15], their impact on improving the accessibility of the Web remained quite low throughout the period of its use [16]. Some sites are making exaggerated claims about their accessibility, with 30 % of sites overstating their level of conformance to WCAG [8]. For the blind users, satisfactory level of accessing digital information is not guaranteed even when WCAG guidelines are followed [17].

Moreover, evaluating website accessibility against the WCAG guidelines is time-consuming task checking for compliance through the many guidelines. Instead of this, studies are being conducted evaluating web accessibility using IBM web accessibility heuristics, as these are more condensed and easier to work with [18]. We adopt such approach in this study when conducting heuristic evaluation of Almooc discussed in Sect. 2.3.

2.1 Usability Testing

Participants and Procedure. We recruited two blind individuals to help us uncover usability problems when using Almooc. The first participant has a master's degree education and works as a lecturer at a public university. He has decent experience in using computers with screen readers to browse information on the web. The second participant has a bachelor's degree and works as a journalist at a public broadcasting news agency. He rarely uses a computer and mainly relies on using his smartphone with its built-in screen reader. However, none of the participants had previously taken any online course before. Both participants were tested on a computer running Windows 7, using the Internet Explorer browser and JAWS screen reader. Participants were required to conduct the following tasks: randomly select a course, register it, watch two video lectures, take a quiz, and contribute to the class discussion and chat.

Findings. The testing of Almooc was very difficult considering the many problems participants faced when accessing its interface. As a result, the second participant gave up in the beginning of the testing. The first participant made it through most of the tasks on lecture twelve of Physics course. Some of the main issues and positive aspects include:

- Initially, the participant had issues registering for the course, as he could not locate the appropriate link. He succeeded only on the third attempt.
- The participant could successfully start lecture videos and listen to its content, but diagrams and images inside the video were not accessible. For instance, in cases when the instructor was explaining a concept and was referring to a diagram on his white board.
- Although the video playing speed was appropriate, a need for speed control was addressed by the participant.
- Navigating from a video to another video within a lecture was easy, however, going forward and backward within the video was difficult.
- Navigation from one lecture to another was easy.
- Access to a Quiz section as well as selecting and submitting answers was easy, but it was difficult to navigate from one question to another due to unlabeled buttons.
- The participant had issues accessing the Discussion page.
- The participant successfully navigated to the Chat section, he could read people's comments and provide his comment.
- Because of a lack of an appropriate labeling, the participant was unsuccessful in logging out of Almooc.
- The textual content across all pages during the entire session was accessible.
- Although the Almooc interface is in the Albanian language, many labels were still in English, which confused the participant.

These findings reveal that the majority of issues found are regarding missing or inappropriate labelling of links or buttons. These make the objects invisible for the screen readers and consequently unidentifiable and inaccessible for the participant.

2.2 Automatic Accessibility Checking

Procedure. To obtain technical evaluation insights of the Almooc interface, we conducted an automatic checking using the WAVE web accessibility tool provided as a chrome extension.[6] We randomly selected lectures and pages from two courses, Physics and English. For each course, we evaluated the webpages of two lectures. More specifically, we evaluated the Course Description page, the pages of two lectures containing the video recordings, and the Quiz page. Details of the two courses and their corresponding lectures is shown in Table 1.

Findings. The findings reveal that Almooc pages contain a high number of accessibility errors. The course description webpage, which contains information about the course and the instructors for all lectures, shows similar errors grouped into seven categories as described in Table 1. The majority of errors are associated with missing form labels.

Higher number of errors were also yielded for lecture webpages, which contained the video recordings and user comments concerning the lecture. Depending on the lecture, 37–49 errors were found, grouped into five different categories as described in Table 1. Same as with the course description page, most of errors were linked to missing form labels. Additionally, high number of errors were also recorded for missing alternative text and empty links. The quiz pages also yielded high number of errors, highest being concerning missing alternative text.

The similarity of errors found, in terms of numbers and type, shows that accessibility issues persist through the entire Almooc interface. This is also an indication that the issues are mainly related to the architectural structure of the site, rather than the content offered in individual web pages.

2.3 Heuristic Evaluation

Procedure. As a third evaluation method, we conducted a heuristic evaluation. Three evaluators have independently evaluated the Almooc interface following the nine IBM web accessibility heuristics.[7] Evaluators randomly selected a course and lectures from Almooc and made notes about the problems discovered. To evaluate Almooc's compatibility with assistive technologies, various screen reader software was used, such as: Non-visual Access Desktop (NVDA),[8] WebAnywhere,[9] and ChromeVox.[10]

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[6]http://www.webaim.org/extension.

[7]https://iwc.oxfordjournals.org/content/16/3/507/T1.expansion.html.

[8]http://www.nvaccess.org.

[9]https://webanywhere.cs.washington.edu/wa.php.

[10]http://www.chromevox.com.

Table 1 Number of errors found per category

Course	Physics							English						
Level	Webpage													
	6th Grade			12th Grade				5th Grade			Who is?			
Error description	Course description	Lecture 2	Lecture 10	Course description	Lecture 2	Lecture 5	Quiz	Course description	Lecture 2	Lecture 10	Course description	Lecture 2	Lecture 7	Quiz
Missing alternative text	2	15	14	2	15	14	13	2	16	14	2	6	6	13
Missing form label	12	14	14	12	14	14	9	12	14	14	12	14	14	9
Document language missing	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Empty heading	1	–	–	1	–	–	–	1	–	–	1	–	–	–
Empty button	1	6	6	1	6	6	6	1	6	10	1	6	6	6
Empty link	5	8	8	6	8	8	7	6	10	10	6	10	10	7
Empty table header	4	–	–	4	–	–	–	4	–	–	4	–	–	–
Total number of errors	26	44	43	27	44	43	36	27	47	49	27	37	37	36

Table 2 Cumulative findings from three evaluators using the IBM web accessibility heuristics

Heuristic	Cumulative findings
1. Provide meaningful and relevant alternatives to non-text elements	– Images and videos lack alternative description – Inaccessibility of videos with sentences on the board or slides that are not completely read by the instructor and it is expected that student will read them. Or, the instructor refers to a diagram or image on the board or slide without describing its details – Lack of alternative description of video controls, e.g., play, stop – Video lectures lack subtitles
2. Support consistent and correctly tagged navigation	– Partially tagged headings – No access to homepage from the video lecture page – No links to enable users skip to main content – No way to go to the next lecture without exiting the current lecture first
3. Allow complete and efficient keyboard usage	– Not possible
4. Respect users' browser settings	– Changing preferred colors on a website not possible – Page layout is responsive to text changes, e.g., text increase and decrease – No control to increase the text only
5. Ensure appropriate use of standard and proprietary controls	– Good, just some controls labels appearing in English, instead of Albanian
6. Do not rely on colour alone to code and distinguish	– Generally, the site has good contrast – When quiz answers are submitted, the results are indicated only using colours: red for incorrect and green for correct answer
7. Allow users control of potential distractions	– Not possible to change the speed of video lectures – Forward and Backward controls do not move through the video, instead enable moving through notes or comments students have posted at different times of the lecture
8. Allow users to understand and control time restraints	– The webpage never expires
9. Make certain the Web site is content compatible with assistive technologies	– No tab order for easy navigation using screen readers – Hidden controls and content that are not visible on the page (and not meant for the user), are read by the screen reader – In case of a pop up content, the screen reader reads the content of the page behind – Many empty elements

Findings. The results from the heuristic evaluation reveal numerous issues that break the web accessibility guidelines and therefore make the Almooc website difficult to access. List of found issues, categorized by the nine web accessibility heuristics, is given in Table 2.

3 Discussion and Recommendations

Three different evaluation methods discovered very similar accessibility problems with the Almooc interface. The relatively high number of accessibility errors found, considering the minimal textual content Almooc pages provide, is an indication that the issues are mainly related to architectural structure of the website. This is also an indication that the Almooc interface was designed and developed following a little or no attention to the accessibility guidelines. Moreover, issues persist through the entire Almooc interface and are not linked to any section in particular.

The majority of errors discovered during the three evaluations were related to missing or inappropriate labeling of objects on the website. Other issues that made the highest number of errors are regarding the missing alternative descriptions for images and videos. These issues make the objects invisible to screen readers and consequently unidentifiable and inaccessible to the participant.

Despite the high number of accessibility issues the Almooc interface has, the positive aspect is that these can be eliminated with minimal intervention. Most of Almooc pages are merely a replication of some template pages containing elements for a course, and making the template pages accessible will easily increase the accessibility for every course generated. This would affect the existing courses as well. Essentially, when the underlying system is re-engineered with blind users in mind, all content will become more accessible. However, this does not solve the problem of the course content. It is up to the instructor to have in mind accessibility for blind users when designing the course. This includes providing proper alternative description for images.

Another important issue discovered was related to video lectures content. Many were the occasions where the instructor referred to an object on their board or slide that expected the users to be able to see and follow instructor's explanation. Such issues can only be addressed by the instructors themselves who should have in mind blind students when preparing their video lectures. This would mean that they would need to explain everything they show on their slides.

To increase blind student participation within the class, Almooc should allow them to take part actively in discussions and other activities using their voice. For them talking through some interface is much easier than writing, which can improve their integration within the class.

4 Conclusion and Future Work

In this paper, we have presented the findings from an evaluation conducted to assess the accessibility level of Almooc, a MOOC platform dedicated to Albanian-speaking community. In order to get a comprehensive overview of accessibility issues, we conducted three different evaluation methods: usability testing, automatic accessibility checking, and heuristic evaluation. The findings indicate that Almooc has many accessibility issues and it is difficult to be used by blind people. However, on a positive side, Almooc's most accessibility issues can be easily fixed by making the general templates accessible, which in turn will increase the accessibility of every course generated, including those existing. What remains a challenge is making video lectures more accessible, which involves encouraging instructors to have blind people in mind when creating their videos. This will require from them to explain everything they present on their board or slides and not rely on students being able to see it themselves.

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An Eye Tracking Experiment on Strategies to Minimize the Redundancy and Split Attention Effects in Scientific Graphs and Diagrams

Azam Majooni, Mona Masood and Amir Akhavan

Abstract The focus of this study is investigating efficiency of coding and grouping methods in reducing split attention effect in scientific graphs and diagrams by applying local changes in the structure of scientific materials. The diagrams and graphs are regularly used in the structure of materials along with textual explanation to provide supplementary information and insight to the readers and is referred as redundancy principle. In some cases, the redundant presentation of visual and textual content could lead to split attention effect and cognitive overload. Although, multimedia learning theory claims that in order to enhance learning, information should be presented in multi-mode format the design and implementation of the multi-modal presentation is of great importance. Having incredible flexibility, if multimedia elements are not applied properly, they cause confusion and adversely affect comprehension of the readers.

Keywords Eye tracking · Redundancy principle · Split attention effect · Cognitive load theory

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1 Introduction

The extremely rapid growth in information technologies has been effectively responsible in the ever-increasing application of computers and handheld devices in all levels of education. However, application of multimedia instructional materials based on computers and tablets does not ensure effective and efficient learning [1]. Thus, the advantages and disadvantages of learning from multiple sources of information, such as textual and pictorial information, have been studied via multimodal theories in the past few decades [2].

There has been numerous research supporting the improvement in comprehension and memorability of illustrated texts and scientific diagrams on the readers [3]. Mayer examined the Learner's ability in optimally creating connections between presented information in the two modes when "the corresponding text and picture representations are actively held in memory at the same time" [4]. He concluded this connection could be achieved by presenting illustrations and text together on the pages and the annotated aspect of the illustrations could help the readers by acting as an elaborative cue. However, the presentation of the information using multiple sources (e.g. textual and pictorial) could lead to the split attention effect.

The split attention effect usually occurs when the learners have to split their attention between two or more essential sources of different information and mentally integrate them [5, 6]. The process of mentally integrating information from two or more sources obviously increases the extraneous cognitive load of the readers. The increase in cognitive load adversely affects the learning process of the readers. Tarmizi and Sweller [7] in an early research, investigated comprehension of the participants treated by materials on learning geometry. The results suggested that the negative effects of split attention can be eliminated by modification of the examples into "Integrated worked example" [7].

Following the experiments conducted by Tarmizi and Sweller, numerous studies were conducted in order to investigate occurrence of split attention effect in different conditions such as amount of interactivity of the information sources [8], text segmentation [9], mobile learning [10] and computer-based learning [11]. In almost all the split-attention examples, there exist one common issue: the physically or temporally separated sources of information. Meaning that no matter if experiment is conducted on computer or paper; it contains graphs, diagrams or charts; audio or text, the learner has to search and integrate between different sources of information. The extraneous cognitive load imposed to the learner due to the searching process between separate sources of information, reduces the learning efficiency [5]. On contrary, if the information (e.g. text and picture) is presented in specially integrated format, the learner is not required to split his/her attention between two sources. Implementation of such strategies in design could keep the extraneous cognitive load low and accordingly leave more capacity for the germane cognitive load and improve learning potential of the readers [9].

Regularly, in the scientific literature and technical textbooks, diagrams and graphs are integrated together with textual explanation in the structure of the material, chiefly in order to provide supplementary information and insight to the readers. In this study, the main goal is reducing split attention effect in scientific documents containing redundant graphs and textual information by suggesting and comparing different methods used in the design of materials. The effect of graphic design principles such as color hue and proximity is investigated in the experiments.

The quantitatively exploration of the effectiveness of each method is accomplished by eye tracking experiments. The cognitive load of the participants is measured by analyzing variations in the pupil dilation, duration of fixation, saccades length and blinks rate of the participants. In Sect. 4, the methods and procedure of the experiments is explained. The remaining sections of this paper are organized as follows. In Sect. 2, the present study is described. Section 3, provides the details regarding the hypothesis and variables. Section 5, summarizes the results of the experiment. Finally, Sect. 6 concludes the paper, and provides a brief discussion about the results.

2 The Present Study

In this study, an experiment containing four eye-tracking sessions is conducted on two groups of postgraduate students. Each participant is treated with instructional materials containing both text and the corresponding graph/diagram (redundant information). The experiments contained four types of combination of text and graph: (a) graph designed using harmonic color hue label coding (b) graph designed using random label color coding (c) label by grouping by proximity (d) label without grouping. In all the experiments, the text and graph were presented in one page and eye tracking methods were used to monitor the eye movements of the participants between different parts of the textual and visual source of information. Besides the eye tracking experiment, after each experiment the participants were asked to answer conceptual questions regarding the context.

3 Hypothesis and Variables

The graphs designed using harmonic label coding would require users to repeatedly search for the statements in text and legends of the graphs which is expected to increase the cognitive load of the participants. In contrast, the harmonic color labeling provides the required support for the readers to quickly locate and even remember the labels and consequently reduce the cognitive load imposed by searching and integration process.

Similarly, using the proximity between the groups of information in graphs reduces the searching process and consequently less extraneous cognitive load is imposed to the readers in comparison to the randomly presented labeling. The applied eye tracking methods provide several dependent variables that can be used for measurement of the split attention effect and variations of the cognitive load of the participants.

Table 1 The dependent variables of experiments

Dependent variable	Definition	Calculation
Comprehension (C_s)	Comprehension test scores	$C_s = \sum_{j}^{p}\sum_{i}^{q} R(i,j)$ $R(i,j) = \begin{cases} 1 & \textit{Right answer} \\ 0 & \textit{Wrong answer} \end{cases}$
Mental effort (C_L)	Integral of pupil dilation: the integration of pupil dilation demonstrates the percentage of increase in the pupil dilation per treatment for all participants. The value is then normalized using hyperbolic tangent (if required) to keep the ranges equal for the purpose of comparison	$\mathrm{SPD_{min}} = \mathrm{T} \times \sum_{i=1}^{p} \lVert PD \min(i) \rVert$ $\mathrm{PD} = \left\lVert \sum_{i=1}^{p} \int_{t=0}^{T} P\mathrm{dt} \right\rVert$ $\mathrm{IPF} = \mathrm{PD} - \mathrm{SPD_{min}}$ $C_L = \frac{\mathrm{IPF}}{\mathrm{PD}} \times 100$ where, $\mathrm{SPD_{min}}$ is the normalized minimum sum of pupil diameters for each participant PD is the normalized integral of pupil diameters of each participant during the experiment
Fixations	Dwell time for all participants	$S_f = \sum_{j=1}^{p}\sum_{i=1}^{n} T_f(i,j)$ where p is the number of participants and n is the number of all fixations in this Equation
	Number of all fixations for all participants	$N_f = n \times p$
	Number of long fixations for all participants	$N_{lf} = \sum_{j=1}^{p}\sum_{i=1}^{n} D(i,j)$ where : $D(i,j) = \begin{cases} 1 \text{ if } \mathrm{Dwell}_{i,j} > 250 \text{ ms} \\ 0 \text{ if } \mathrm{Dwell}_{i,j} \leq 250 \text{ ms} \end{cases}$
Long fixations ratio (LFR %)	LFR provides insight about difficulty of elements of context. Higher value means elements are harder to understand	$T_{LF} = \sum_{j=1}^{p}\sum_{i=1}^{N_{\mathrm{lf}}} T_f(i,j) \times D(i,j)$ $\mathrm{LFR} = \frac{T_{\mathrm{LF}}}{S_f} \times 100$
Vertical long saccades ratio $\lvert \mathrm{SLV_i} \rvert$	Ratio of the effort required for integration of textual and visual information *A threshold of 40 pixels differentiates between long and short saccades	$SR_{ver} = \left\lVert \frac{\sum_{i=1}^{p} \left\lvert \overrightarrow{\mathrm{SLV}_i} \right\rvert}{\sum_{i=1}^{p} \left\lvert \overrightarrow{V_i} \right\rvert} \right\rVert \times 100$ where, $\mathrm{SR_{ver}}$ stands for Vertical Saccades rate. The vertical vector and $\lvert \mathrm{Vi} \rvert$ is sum of vertical vectors of all saccades

In the current experiment, the vertically short and long saccades, suggest different meanings. The vertically short saccades in this experiment are defined as saccades with the length of vertical vector of the saccade shorter than distance between the internal elements of graphs. The threshold between short and long saccades is taken to be 40 pixels for this experiment. The saccades with vertical vector longer than 40 pixels are considered as the vertically long saccades and the remaining saccades are treated as short saccades. In addition, the fixations are classified into two set of short and long fixations based on the dwell time. The short fixations are the fixations with the duration of about 80–250 ms, and the remaining fixations are considered as longer fixations. When a long fixation occurs, higher mental effort is required by the reader to understand the elements in the gaze point, whereas a short fixation (less dwell time) means clarity of the content in the fixated point. In order to clarify the dependent and independent variables of the experiment some of the terms are described in Table 1.

In summary, the hypotheses in concern of this study can be listed as below:

Hypothesis 1. Using harmonic color hue labeling can reduce split attention effect imposed by searching and integration process.
Hypothesis 2. Using the proximity between the groups of information in graphs reduces the extraneous cognitive load and split attention effect.

In Table 1, *p* is the number of all participants in the experiment. In addition, the threshold for differentiation of long and short saccade is 40 pixels. The rest of the abbreviations used in the paper are defined in Table 1.

4 Methods and Procedures

In this experiment eight short scientific reading tasks has been assigned to the participant in two different groups. Each participant had to study four tasks, and answer to the comprehension tests after each task. Based on the redundancy principle, the graphs provided visualize information about the context. The gaze data of the participants is recorded during the experiment for further analysis of the cognitive load.

In the analysis phase of this experiment, the recorded gaze data (including the fixations, saccades, pupil dilations and blinks) were used to measure the variation of the cognitive load during the completion of tasks. In addition, AOI sequences, scan-path and dwell time (heat-map) diagrams were used to identify points of attention of the participant while studying the tasks. The quantitative analysis of the gaze data provides valuable information about the changes in the cognitive load and split attention effect of the participants. Nonetheless, the scan-paths and heat-maps reveal critical information on visual attention distribution and behaviour of the participants while dealing with redundant information.

As demonstrated in Fig. 1 the participants of each group go through the steps of the experiment. Each experiment contains, calibration, validation, treatment (gaze data recorded using eye tracking test), and comprehension test. Each experiment includes four phases, for each group of the participants.

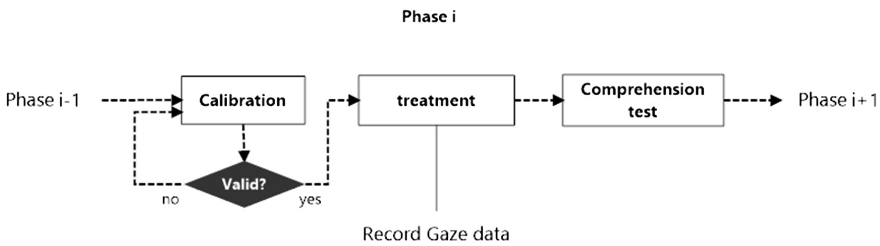

Fig. 1 Structure of each phase for both group A and B

4.1 Participants

In the conducted experiment, twelve doctoral candidates from Universiti Sains Malaysia participated. The participants were between 28 and 36 years old (Mean = 32, SD = 2.5). They were randomly assigned to one of the two groups of the experiments with each group containing equal number of participants. The structure of experiment contains seven sequential phases. Before the initiation of the experiment the participants were informed about the phases, also during the experiment the conductors of the experiment guided the participants when required.

Many of the participants had spectacles, therefore the calibration and validation of the Eye tracking device was tested before each phase of the experiment in order to minimize possible errors and achieve acceptable calibration accuracy.

4.2 Apparatus

Eye tracking device:

The eye tracking experiments are conducted using SMI Remote Eye Tracking Device (RED) with iViewX. The recorded eye tracking data for each experiment were saved for the further analysis using SMI Behavioral and Gaze Analysis software (SMI BeGaze™). In addition, the recorded gaze data were analysed using Matlab statistical toolbox.

Comprehension test:

After each experiment, the participants are asked to answer multiple conceptual questions regarding the presented context. The analysis of the results of each test provides complimentary information regarding comprehension of the participants. Classification of the comprehension test scores and the eye tracking data provides a new measure for estimation of the cognitive load of the participants [12].

4.3 Material

Experiment Material:

The materials designed for this experiment contained both text and the graphs visualized based on the information presented in the context. The stimuli were presented on the monitor screen with the average distance of 60–80 cm from the participants with the size 1680 × 1050. The stimuli were designed based on this resolution ratio. The context of each stimulus contained about 100 ± 8 words, and was about the results of a survey conducted in Universiti Sains Malaysia. All the graphs were designed to be the same size (width and height) to reduce other interfering variables.

The four stimuli (two for each group) were designed based on the gestalt law of proximity and color hue coding principles, and the other four were designed to control the effects of the first four stimuli. Thus, each group was treated with two experiment-sample and two control-sample.

The design of the materials was accomplished based on the hypothesis. As the two groups receive treatments with similar context but different design, therefore it can be claimed that material are randomly distributed between two groups (4 × 2).

Questions:

In the treatment phase, each stimulus is presented for almost one minutes (65 s) to the participants and after each experiment, four multiple-choice questions were asked from the participants. The questions are displayed on monitor one by one, and the participants had to pick one answer to be able to go to the next question. Meanwhile the eye tracking data of the participants while answering to the questions were also recorded for further analysis. The answers to the questions were later used for estimation of the comprehension score of the participants.

Blank page:

Just before starting the experiment, a blank white page was presented to the participants in order to estimate the pupil dimeter of the participant while the participants were not performing any task. This also provides information about the system lag and response time of each participant to sudden change of screen.

4.4 Eye Tracking Data Analysis

In the current study, the SMI BeGaze software is used to draw the scan paths and heat map diagrams for the fixations and saccades. However, the main variables concerning cognitive load of the participants, as mentioned in the hypothesis section, are the pupil dilation, blinks rate, long fixations and saccades. The number of the blinks and pupils diameter during the experiment are two measures that can provide means for estimation of the cognitive load [13–16].

Pupil dilation: Klingner et al. [14] have investigated effect of increase in cognitive workload on the pupillary dilation. They have concluded that subtle changes in the pupil diameter can be used to measure the cognitive workload.

Blinks: Blinks rate is also another measure used for estimation of increase in the cognitive load and fatigue [12, 14, 17–19]. In normal condition, when there is no cognitive load imposed, the natural blinks rate is between 3 and 5 blinks per minute (BPM). Based on the study conducted by [20], the number of blinks can even be more effective in estimating the increase in the cognitive load caused by the visual searching in comparison to the pupil dilation. As presented in Table 1, the dependent variables are measured for each experiment and the results are provided in Tables 2, 3 and 4.

Table 2 Scores of the comprehension test and cognitive load (average of both group A and B)

	Stimuli	DV	Result	SD
Hypothesis 1	With harmonic hue in labeling	Comprehension score	85 %	3 %
		Mental effort (C_L)	0.15	0.0006
	Without harmonic hue labeling	Comprehension score	67 %	5 %
		Mental effort (C_L)	0.19	0.0018
Hypothesis 2	With proximity in the design	Comprehension score	90 %	2 %
		Mental effort (C_L)	0.128	0.0006
	Without proximity in the design	Comprehension score	75 %	6 %
		Mental effort (C_L)	0.156	0.0008

Table 3 Pupil dilation ratio of all participants (for both group A and B)

	Stimuli	Average pupils dilation ratio	Result	SD
H 1	With harmonic hue in labeling (Treatment 1)	Long saccades	0.458	0.228
		Short saccades	0.351	0.194
	Without harmonic hue labeling (Treatment 2)	Long saccades	0.552	0.270
		Short saccades	0.691	0.242
H 2	With proximity in the design (Treatment 3)	Long saccades	0.340	0.13
		Short saccades	0.210	0.16
	Without proximity in the design (Treatment 4)	Long saccades	0.519	0.266
		Short saccades	0.482	0.189

Table 4 Blinks per minute (BPM) and long fixation ration of the participants

	Stimuli	Avg. blinks (BPM)	SD (BPM)	Long fixations ratio (LFR %)	SD (LFR)
H1	With harmonic hue in labeling (T1)	7.4	2.2	63	3.9
	Without harmonic hue labeling (T2)	9.5	3.3	84	4.5
H2	With proximity in the design (T3)	6.9	1.4	68	3.4
	Without proximity in the design (T4)	11.3	2.7	85	3.2

5 Results

In order to compare the results of the experiments, the dependent variables described in Table 1 are calculated for each one of the treatments. There exist two stimuli for each group to investigate each hypothesis (one sample for each group). Therefore, it is possible to compare the values and significance level using simple comparison of the results. The first set of results belong to the comprehension test results. The results of the comprehension test are provided in Table 2. As it can be seen from the results, both hypothesis one and two are confirmed.

In Table 3 the results indicate that average of pupil dilation value in the treatment 1 and 3 is much less than their control treatments (treatment 2 and 4). In addition, the results, indicate that increase in pupil diameter is overall more visible in longer saccades rather than in the shorter saccades. The longer saccades naturally are the sign of split attention effect, and having higher ratio of longer saccades with bigger pupil dilation provides insight to existence of increase in extraneous cognitive load imposed by searching process.

In addition, in order to compare the eye movements of the participants, between the textual context and the graphs, the normalized ratio of long vertical saccades is calculated for all the experiment sessions. Meanwhile, the results in Table 4 demonstrate the number and duration of long fixations versus all fixations (LFR). These variables provide information about the overall attention time. The longer fixations are sign of higher cognitive load, as it is assumed that during the fixation the participant is attempting to integrate the received information with prior knowledge.

The number of the blinks is another sign of increase in the cognitive load of the participants, as it can be seen from the results, the number of the blinks in treatments T1 and T3 are lowest whereas in treatment T4, this number is at its highest value.

According to the result presented in Tables 2, 3 and 4 it can be concluded that the results of the experiment confirm the suggested hypothesis of the experiment.

Figure 2 demonstrates a pupil dilation ratio of one of the participants when treated by materials designed to investigate effect of harmonic color-coding (Treatment 1) and arbitrary color-coding (Treatment 2) in split attention. As it can

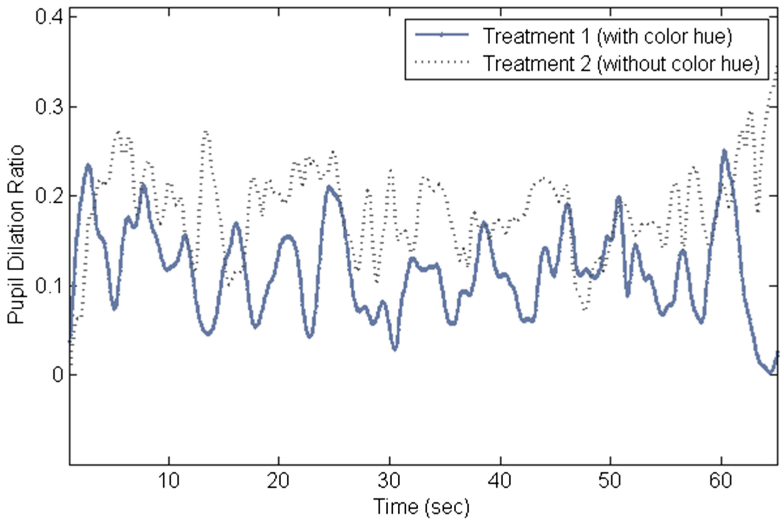

Fig. 2 The comparison between the pupil dilation ratio between two treatments (1 and 2)

be seen from the figure, the amount of pupil dilation ratio is lower compared to Treatment 2.

Similarly, Fig. 3 compares the effect of treatment 3 and 4, which investigates the effect of proximity in split attention effect. As it can be seen the result of grouping in implementation of treatment 3, has led to lower pupil dilation compared to treatment 4.

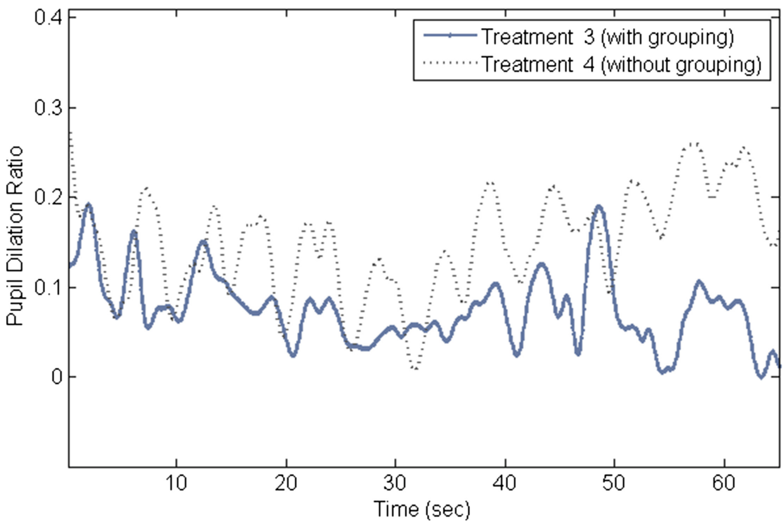

Fig. 3 The comparison between the pupil dilation ratio between two treatments (3 and 4)

6 Conclusion

Graphical elements can be used in powerful ways to enhance the meaning and clarity of diagrams, but these elements are effective only when applied properly based on design principles. There are numerous cases that the redundant presentation of information in the diagrams and textual content is inevitable and may lead to split attention and cognitive overload. Meanwhile multimedia learning theory claims that in order to enhance learning, information should be presented in multi-mode format.

The results of the study highlighted that the proper implementation of the graphical elements in graphs not only does not lead to split attention but also could be highly effective in improving formation of the mental model of the readers. Conversely, ignoring design principles could lead to information overload and split attention effect.

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Evaluation of Health Services Received by People with Autism Spectrum Disorders by Means of an Adapted iPad® Questionnaire

Dany Lussier-Desrochers, Nancy Milette, Valérie Godin-Tremblay, Jeannie Roux and Yves Lachapelle

Abstract Recent studies show that mobile technologies (e.g. tablets and smartphones) have positive effects when used with people with autism spectrum disorders (ASD). Aware of the potential associated with these mobile technologies, the Mauricie and Centre-du-Québec—University Institute wanted to evaluate the applicability of the iPad® as part of its service quality assessment for people with ASD. An iPad version of the questionnaire was therefore created for this study. The results indicate that the participants were satisfied with the electronic version. Moreover, participants reported that this tool made it easier for them to understand the questions and express their preferences. These findings show that the iPad may be an efficient tool for gathering information from people with ASD.

Keywords Autism spectrum disorder · Satisfaction · Questionnaire · ipad® · Electronic tablet

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1 Research Context

In Quebec, information and communication technologies are gaining importance in the field of intervention for people with autism spectrum disorders (ASD) [1–3]. ASD are characterized by cognitive, social, affective, intellectual, sensorial and language-related deficits. People with ASD have major disabilities in two areas of development, one being social communication and the other, restricted and repetitive behaviors [4, 5].

The interventions currently implemented with these people target notably social skills development, communication support, and structuring of the person's environment [6]. In Quebec, the principles of social participation and self-determination also guide the ASD programs offered by the Centres intégrés de santé et de services sociaux (CISSS) with respect to identifying intervention modalities that should be favored with these people [7, 8]. That said, concerning the principle of self-determination specifically, there is social and scientific recognition of the need to use intervention modalities that allow people to act on their lives and to perform actions that are minimally influenced by the environment [9]. The principle of self-determination also highlights the importance of offering people opportunities to make choices, but also to express their preferences. Unfortunately, difficulties relating to social communication and to restricted and repetitive behaviors significantly limit the opportunities offered to people with ASD. However, the mass introduction of several technologies into the market could contribute not only to diversifying the intervention modalities, but also to supporting the achievement of new rehabilitation objectives.

The miniaturization of technologies and the development of such peripherals as multi-touch screens help provide ergonomic technological solutions better suited to the needs of people with ASD. In this regard, there is a marked progression in the use of smart phones and electronic tablets by these people [10]. These mobile technologies offer, among other things, the option to configure accessibility parameters to meet these people's particular needs (synthetic speech screen reader, larger font size, voice control, etc.). Moreover, touch screens are proving very effective when used with people with ASD [11]. Indeed, the results of the first studies suggest that using the iPad® contributes to the development of academic skills and knowledge [12, 13]; the management of challenging behaviors [13]; the development of certain communication-related dimensions [14, 15]; the development of play-related skills [16, 17]; and the teaching of vocational tasks [18]. It appears also that these mobile technologies have positive impacts for children [13, 16, 17, 19], adolescents [12] and young adults [18] alike.

These early results suggest that digital tablets contribute to the expression of choices and preferences and to the development of certain components of self-determination. This dimension will be examined more closely in this study through an evaluation of the satisfaction of adults with ASD as regards the iPad version of a questionnaire aimed at improving the quality of social services.

1.1 Using Technologies to Help Improve Service Quality

Aware of the potential associated with these mobile technologies when used with people with ASD, the Mauricie and Centre-du-Québec—University Institute (CIUSSS MCQ) wanted to examine the applicability of the iPad® in a process of service quality evaluation for people with ASD. This was part of an accreditation process, that is, *[Translation]* "a process of self-evaluation and external evaluation used by public and private health and social services institutions to assess the quality and safety of their care and their services" [20]. In Quebec, this process is repeated every three years [21].

1.2 Process of Adaptation and Computerization of the Data Collection Tool

As part of the accreditation process, users have traditionally been asked to complete a paper version of the "Customer Satisfaction Questionnaire". The content of the questionnaire was first adapted to meet the particular needs of people with ASD and to ensure optimal comprehension of the questions asked. The adapted version of the tool is divided into three parts: Part (1) Customer satisfaction assessment; Part (2) Sociodemographic questions; and Part (3) [meant for the attendant] Validation of how well respondents with ASD understand the statements. It should be noted that this tool has not been validated.

Once the Customer Satisfaction Questionnaire had been adapted, the CIUSSS MCQ had a computer version of this tool made. This new electronic version, which was more accessible, appealing and interactive, was developed by Omnimedia design + solutions Web in Trois-Rivières. Features of the computer version include: (a) a progress bar indicating the duration of the questionnaire; (b) video clips to introduce and conclude the questionnaire and to establish a personal connection with the respondent; (c) brief, specific instructions (audio and textual) to facilitate comprehension; (d) the option to go back and hear the instructions again; and (e) direct access to the relevant content through filter questions. Finally, the accessibility parameters of the iPad® can be adjusted according to the needs of respondents with sensorial limitations (e.g. brightness and volume adjustment).

2 Method

2.1 Research Objective and Design

This study aims at learning the opinion of people with ASD who fill out the adapted, computer version of the “Customer Satisfaction Questionnaire” (previously described). This research uses a quantitative, exploratory, descriptive design. The subsections below describe the process, data collection tool and sampling technique.

2.2 Process

Participants’ opinions are compiled immediately after the “Customer Satisfaction Questionnaire” is completed. To ensure harmonization of the research design with the satisfaction evaluation process and to avoid confusing the respondents, a complementary section was added at the end of the questionnaire. Therefore, once respondents have completed the “Customer Satisfaction Questionnaire,” they are invited to participate in this research. They are thus given the option to answer complementary questions concerning their experience with the computer version (user-friendliness, clarity of the information provided, relevance of the video clips presented, etc.). Using a filter question, respondents indicate whether they want to participate or not in the research and thus answer these questions. If they do not want to, a thank you message appears. If they do, the research questionnaire is displayed.

2.3 Data Collection Tool

Visually, the research questionnaire is similar on all points to the questionnaire already completed by the respondents. For the sake of harmonization and continuity with the existing questionnaire, the research team also used the same rating scales as those used in the “Customer Satisfaction Questionnaire.” Figure 1 presents an example of a question from the research questionnaire.

Furthermore, since the first part of the questionnaire already contained 46 questions, the number of complementary questions was restricted, to help keep the person’s interest throughout the process. It was agreed that the addition of seven questions was justified and that this number would limit experimental mortality.

The data entered by the participants are sent to a secure database. These data are then analyzed using SPSS Version 19.0.

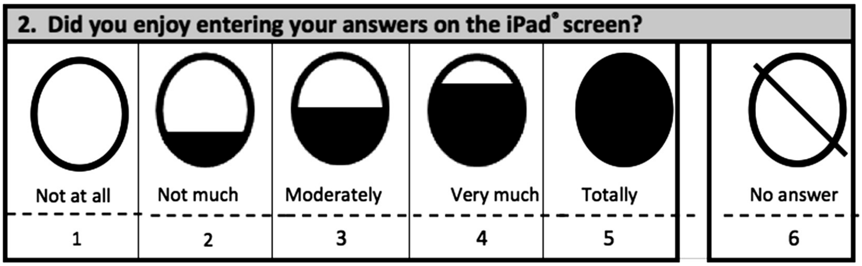

Fig. 1 Example of a question used in the research

2.4 Sampling Method

Participants who are eligible for the research component are those already selected to answer the "Customer Satisfaction Questionnaire." These participants then decide freely and deliberately whether they wish to continue with the research. To properly situate potential participants, it is important to specify the sampling method used by the CIUSSS MCQ to select participants for the "Customer Satisfaction Questionnaire."

First, participants are selected using a judgement sampling method. Potential participants are chosen by caseworkers at the CIUSSS MCQ based on the following inclusion criteria: (a) present an autism spectrum disorder; (b) be over 18 years of age; (c) be receiving rehabilitation services from the CIUSSS MCQ; (d) have the necessary receptive skills to understand the questions (ability to read simple sentences, capacity to respond autonomously to questions); (e) present the on-task endurance needed to fill out the entire questionnaire; (f) present the motor skills required to use an iPad®; and (g) present a specific level of tolerance for the unexpected in case of technical problems during the experiment. Participants meeting these inclusion criteria are contacted by phone and are invited to fill out the "Customer Satisfaction Questionnaire" either at home or at the offices of the CIUSSS. On the day of the experiment, participants are offered the choice between the paper or the computer version of the questionnaire. The research assistants remain on site to support the participants.

3 Results

3.1 Description of the Participants

In total, 41 people, namely 32 men and nine women, filled out the computer version of the questionnaire. French was the first language of 85 % of the participants. The majority of the participants (68 %) were between 18 and 25 years old. Those from

26 to 40 and from 41 to 64 years of age represented 24 and 5 %, respectively, of the group. A minority (2 %) were aged 65 years or over. Slightly less than two thirds of the participants (63 %) lived in their natural environment. The others lived in a family—or intermediate-type resource (12 %), a supervised autonomous apartment (7 %) or an assisted-living residence (2 %). Five participants said they lived in another environment, but did not specify which kind. Finally, the participants were from seven territories in the Mauricie and Centre-du-Québec regions: Trois-Rivières (29 %), Centre Mauricie and Mékinac (22 %), Drummondville (10 %), Haut St-Maurice/Maskinongé (12 %), Bécancour/Nicolet Yamaska (10 %), Cap-de-la-Madeleine/Des Chenaux (10 %) and De l'Érable (2 %). Two people did not indicate their region.

3.2 General Satisfaction

Regarding the participants' general appreciation of the iPad® as a means to fill out the "Customer Satisfaction Questionnaire," they almost all reported totally enjoying (74 %) or very much (15 %) enjoying this technology to answer the accreditation questionnaire. Few participants (n = 1) did not enjoy or moderately enjoyed (n = 3) using this type of device. Regarding the touch screen, 89 % of the respondents said it was easy to indicate their answers on the screen. Only one participant reported finding this operation difficult.

Some questions aimed also at comparing the iPad with other electronic (e.g. desktop computer) or traditional (e.g. paper version) data collection instruments. The questionnaire then asked respondents to identify the technology that they would like to use if they had to answer the questionnaire again. A large proportion (77 %) of the participants said they would use this technology again. Conversely, only one participant would prefer to use a laptop computer. However, 21 % of the respondents reported preferring to use a desktop computer with a keyboard and mouse. Finally, regarding their potential interest in using the computer version of the questionnaire as opposed to the traditional one, 67 % of the participants said they preferred the iPad to the paper version.

3.3 Satisfaction with the Presentation of the Information

The satisfaction evaluation aimed also at verifying whether the information presented on the iPad® screen was easy for the people to read. In this respect, 88 % of the respondents said that the text was legible. Only one participant seemed to have had difficulties in this regard. One of the advantages of the iPad is that multimedia content can be added to help people's comprehension. The experiment conducted in this study was designed to also check the relevance of using a video to present the information. Eight out of ten respondents liked this presentation mode (59 % totally enjoyed it and 27 % enjoyed it very much). Additionally, 88 % found the video easy to understand. A minority of the participants did not much like this presentation mode (n = 2) or did not like it at all (n = 1), and 9 % said the information presented was difficult to understand.

4 Discussion

This research was but a first, exploratory study on the iPad® as a tool for people with ASD to express their preferences. It provided an opportunity to examine the possibility of using an electronic version of a questionnaire for people with ASD, but also to check how satisfied they were with this means of expressing their preferences. These results show that the participants enjoyed filling out the questionnaire and that the touch screen makes it easy to enter the answers. The majority of the people would like to use this version of the questionnaire again and prefer it to a paper version. The participants also liked the use of multimedia to introduce the various sections of the questionnaire. Nonetheless, although the team was careful to not add too many questions so as to not make the process cumbersome, not all the participants answered every question. Between two and seven pieces of information are missing for each of the questions (the participant selected the “no answer” box). Unfortunately, there is no way to know whether this response was chosen by the participant or the attendant. Our analyses show that, paradoxically, the last two questions obtained the highest response rate. This fact should be considered in future studies. It is also important to specify that the exploratory nature of this research limits the possibility of generalizing the results. Therefore, conducting this research with a larger sample is recommended. This would allow more in-depth analyses and chi-square analyses, for example, to be performed. In this study, polarization of the results precluded these types of analyses. Moreover, the use of a scale that was predefined by the Conseil québécois d’agrément restricted the kind of information that could be gathered from the participants. It would have been relevant to obtain the comments of the people accompanying the participants while the questionnaires were being filled out. Triangulation of the data would have provided a more accurate portrait of the difficulties these people may have encountered and could have informed us of the technical issues that may have occurred. Finally, more in-depth studies with more rigorous methodological designs would help provide a good understanding of all the factors that influence people’s satisfaction. In summary, further research on the subject is recommended. The first data obtained here seem to show that people with ASD are interested in using this technology to express their preferences.

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Part XI
Dissing the Dis—The Swedish Concept

A Design Research Lab—An Integrated Model to Identify Conscious and Unconscious Behavior in the Design Process

Morteza Abdipour, Lena Lorentzen and Håkan Olin

Abstract To understand how different design solutions affect users, designers traditionally use different evaluation methods that mainly rely on conscious feedback from the users. However, the complexity of human behaviour, where a large part is unconscious, point to a need for an extended tool box addressing the part not accessible to human conscious knowledge. Here, we describe a design research lab where traditional methods are complemented with tools to measure physiological signals influenced by emotional and sympathetic responses. These tools include galvanic skin response (GSR), electrocardiograph (ECG), and electroencephalograph (EEG). Typical sessions with acquired data of conscious and unconscious user reactions are described. The large body of data collected, which also require non-design expertise for interpretation, suggest that a further development towards simplified output data of the unconscious reactions is needed to allow wider use within industrial design work.

Keywords Design methods · User studies · Design pedagogy · Design research

1 Introduction

Designers traditionally use evaluation methods that are based on conscious feedback and observations, to understand how different design solutions affect user experiences [1]. Subjective self-report methods are a commonly used tool in design research and a number of techniques have been developed to quantify and qualify user-product interactions across the broad field of industrial design [2]. However, a

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large part of human behaviour is unconscious [3], which suggest that methods like interviews, which are probing the conscious experience, need to be complemented with methods targeting unconscious reactions. Some users, with cognitive limitations, can have difficulties to express their feelings.

There is thus a need for design researchers to move beyond the limitations of subjective conscious user interpretations of design solutions and explore the use of new tools and multi-modal methods to reach objective measurement of human experience [4]. To get a deeper understanding of the experiences that affect the user's behaviours, psychophysiological measurements might help researchers in the design process. There are variety of tools or methods to measuring and evaluating user's behaviours. In general, only a limited number of studies have collected both neural (cognitive and emotion) data and preference data [2].

Here, we present a design research lab where traditional design evaluation methods are complemented with equipment for measuring psychophysiological signals that probe emotional responses. The physical lab, evaluation methods, and processes are described. The initial results show that it is possible to measure these unconscious reactions. However, the large body of data generated as well as the time consuming work to interpret the data, suggest that further development is needed for simplify data output.

2 Methods

To understand which data is necessary to acquire and which method that can be utilized in the design experiments, we used several methods. 'Design for All' [5] has been used as a conceptual framework to evaluate if the method support the needs of a diversity of users. An experimental constructive design method has been applied to see how the integration and relation of different evaluation methods can correlate with each other. In addition, quantitative and qualitative methods were used to evaluate the experiments.

2.1 Mixed Methods to Understand Hidden Emotions

Design framework. In the Design for all process people with different disabilities and abilities are involved in a different phases of the development to secure usability and accessibility of the result [6]. During the test are Design researchers try to catch and fulfill the needs of the different user groups.

Constructive Design. Constructive design research is a grounded in imagination and is also reflected in how researchers understand their contribution [7]. Methodology of constructive design research is primarily shaped by offering different options rather than pushing reality.

Qualitative and Quantitative methods. By employing a mixed-methods strategy and using both quantitative and qualitative approaches, depending on what phase in the design process. Each of these approaches provides a “distinctive kind of evidence” that when used together can offer a “powerful resource to inform and illuminate” the designers practice [8].

Quantitative methods, based tools focus on data collection, are usually used in the beginning of a project. Qualitative based tools, designed to collect data from a small number of participants, are more common during the development interacting with and giving feedback on a model or prototype [9].

2.2 Design of the Research Lab

The Design Research Lab (DRL) was planned to allow a variety of user studies using a virtual reality environment integrated with several measurement tools.

Virtual environment. Our world is increasingly dominated by information technologies [10] and virtual reality provide a way to simulate different design situations. The lab has a powerful visualization system and provide an integrated technological system to evaluate design ideas [11].

Physical space of the Lab. The Design Research Lab (DRL) has two parts: one user stage and one control room with several measurement tools that could be utilized in the studies Fig. 1. The Lab is physically located in the Department of

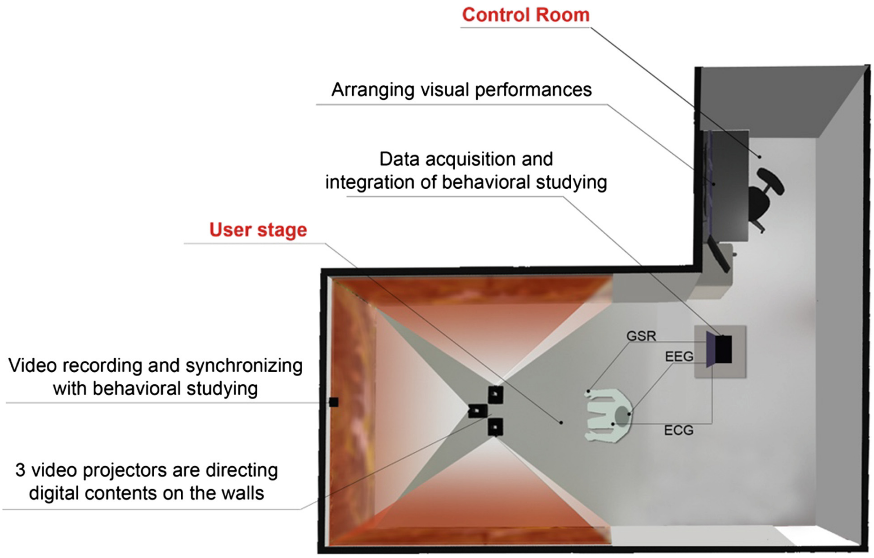

Fig. 1 Top view of the design research lab presents the main two sections, control stage and user stage

Industrial Design at Mid Sweden University in Sundsvall, Sweden. Accessibility have been considered for participants and researcher with different levels of abilities and disability.

A. **User stage**. The user stage is a cubic room to evaluate design concepts while studying user participants in virtual space. Three video projectors direct digital contents on three walls of the cubic space. Virtual contents could be a combination of images, videos, animation or other visual data. In addition, audio and smell stimulus could be applied. In the user space, designers might bring tangible mock-ups or models to complement the virtual reality.

B. **Control stage**. From the control room the test leader can control the visual on the different wall of the user stage, audio presentation as well as video camera capturing of the study. Here, also the physiological measurement data is collected.

2.3 Physiological Measurement Tools

There are a variety of methods used to measure response to emotional stimuli in psychological research studies; skin conductance (Electrodermal response, EDR or Galvanic Skin Response, GSR), cardiac function (Electrocardiogram, ECG), heart rate (HR), respiration, blood pressure (BP), facial musculature (Electromyogram, EMG) and more recently, gastric myoelectric activity (Electrogastrogram, EGG) [12]. Here, we arranged a system using EEG, ECG and GSR that also allowed integration with the other components of the Design Research Lab. We were aiming at collecting simple data signals, such as changes in a level or a sequence of some particular signal, and not to replicate the sophisticated measurement procedures that can be found in neuroscience studies. We tried to use simple methods that still provide data of value in the design process (Fig. 2).

EEG (**Electroencephalography**). EEG [13] register brain activities from the scalp and is used in clinical and research studies. We used the XELE-CM01 Brainswave cap, Medium 20 cm with the 4 channel EEG system feature (Noldus, Netherland).

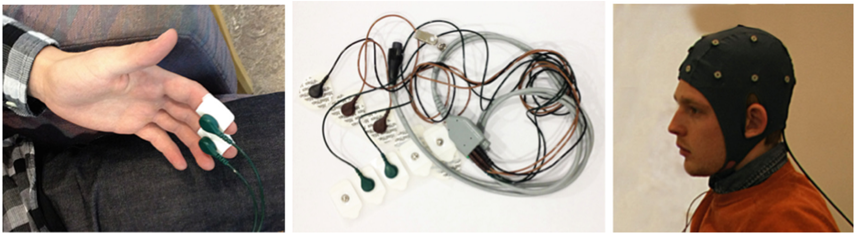

Fig. 2 GSR connections, ECG and EEG Cap, using 3 different solutions in the design lab to register emotional reactions of users

ECG (**Electrocardiography**). ECG register the activity of the heart. ECG is of importance in psychophysiological studies for several reasons. First, at least some its parameters, like heart rate and blood pressure, are readily observed and quantified. Second, the cardiovascular system is a rich and intricate physiological system with multiple regulatory subsystems that are subject to central and peripheral autonomic controls and humeral influences. Consequently, it is sensitive to neuro-behavioral processes [14]. We used the Touchproof (Mindware Technology LTD, USA).

GSR (**Galvanic skin conductance**). GSR is a measurement of the electrical conductance of the skin, which is directly influence by moist of the skin. Since the sweat glands are controlled by the sympathetic nervous system, GSR is of importance to measure the level of arousal [15]. We used the Touchproof 40 inch (Mindware Technology LTD, USA).

2.4 Data Acquisition

Procedure. User involvement formulates an important part of the design process. In the Design Research Lab, the sessions is mostly run with one user applicant at a time, but there is also possibilities to evaluate a design subject as a group session study with up to four participants. The level of sessions and arrangements of each study are different depending on the aim. Each session usually takes approximately one and a half hour. The operator of The Design Lab arranges the requirements and facilities in advance. Measuring the stress of participants is a part of user study. When participants come to the Design Lab they might have different feelings and they might be nervous. In the beginning of each test session the Lab operator gives a 20 min' introduction of the lab and test procedure also showing some unrelated content to bring the test person to a calm starting point as a baseline for the study. Installation of the measurement tools (EEG, ECG, GSR) usually takes 20–30 min for each applicant, due to that instruments must be installed very gently and comfortable (Fig. 3).

Acquired data of EEG, ECG and GSR were collected by the software Mind Ware Bio Nexline [16]. Which has been customized for The Research Design Lab, digital events are capture by the software BioLab which also is capable to organize and display artefacts and synchronize the acquisition data.

The flexibility of the hard- and software allows diverse researching like; assessment of behaviours, observation of users, evaluation of concepts, estimation of user experiences, capturing reactions of simulation. In addition as a solution to record diversity of human behaviours through observation studying we have installed The Observer XT [17] (Fig. 4).

Fig. 3 Experimental set up, installing of EEG cap, ECG and GSR measurement tools and integrating with observation system in the design research lab

Fig. 4 Demonstration and evaluation of concepts of environment design, behavioural observations are integrating with psychophysiological reactions of user applicants

2.5 Research Sessions and Typical Results

Pre-plan for test sessions: Running a test session needs considering a good time planning and preparation arranging several tools and facilities. Mixed method research questions are usually broad, calling from both in depth, emergent qualitative data and focused and pre-planed quantitative data [18].

Data analysis. This model of design lab presents variety of tools and test combination. Hence, analysing the data depends on how many tools have been employed during each session. Grounded theory uses three sets of coding procedures that help the analyst break down the original data, conceptualize it and re-arrange it in new ways [19]. Before analysing the data begin, researchers need to accomplish some preparation because in this model of research lab usually huge number of data is acquired. The first step is sorting the data according the test plan and available data. This might take a lot of time but it will give a clear picture about what data has been obtained. The next step is filtering the data; researchers need to see and choose the most valuable data in order to use analysing table. The main goal of problems tracking is to identify any problem of obtained data and validate the accuracy of data.

Integration of data. The integrated system consists of hardware and software that has been designed to do promote experiments in a wide range of behavioural studying with design research proposes. It is clear (and has been widely recognized) that one cannot understand a technology without having a functional understanding of it is usage [20]. Figure 5 presents the framework of data acquisition of the design lab. Physiological values, such as brain activity, heart rate and hand sweat, can be measured and registered carefully showing emotional reactions by sensitive and reliable measurement tools. The whole session is captured by video cameras and photography. For example, observation is often used to describe settings,

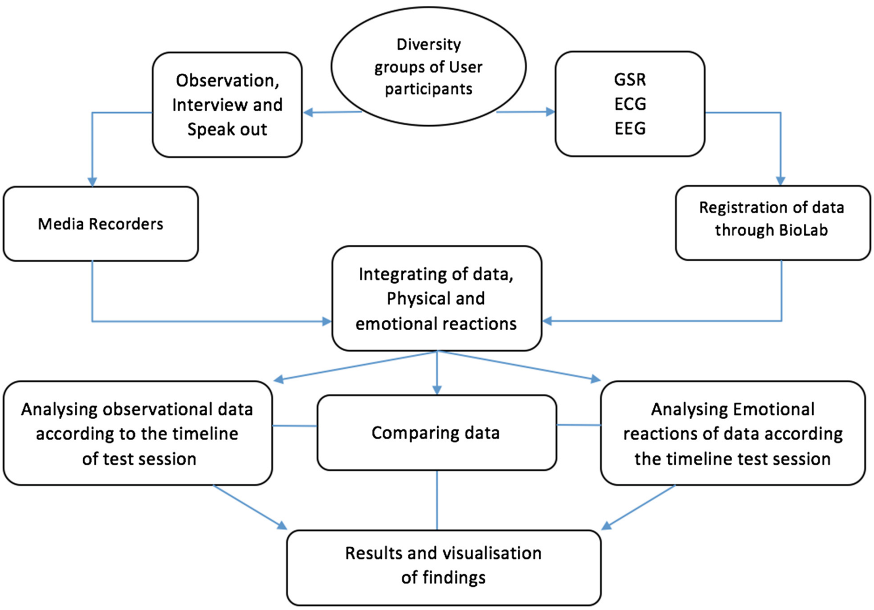

Fig. 5 The overview of the design research lab. This system has been established in a physical lab which provides virtual environment by using audio-video contents that directing on large screens of the lab

behaviour, and events, while interviewing is used to understand the perspective and goals of the users [21]. Simultaneously physical measures are recording emotional reactions by physical reaction. The analysis of data is exposed by selected videos and software for psychophysiological measures and compared with interviews, questionnaire and other components of observation studies.

3 Results and Discussion

Each test session provides wide range input of experience paradigms like video recording of behavioural and data of psychophysiological reactions. Acquired information needs to be interpreted with flexibility to choose and combine specific data to analyse. Figure 6 shows how collected data from BioLab and video recordings are merged as a synchronized sequence of the session (Table 1).

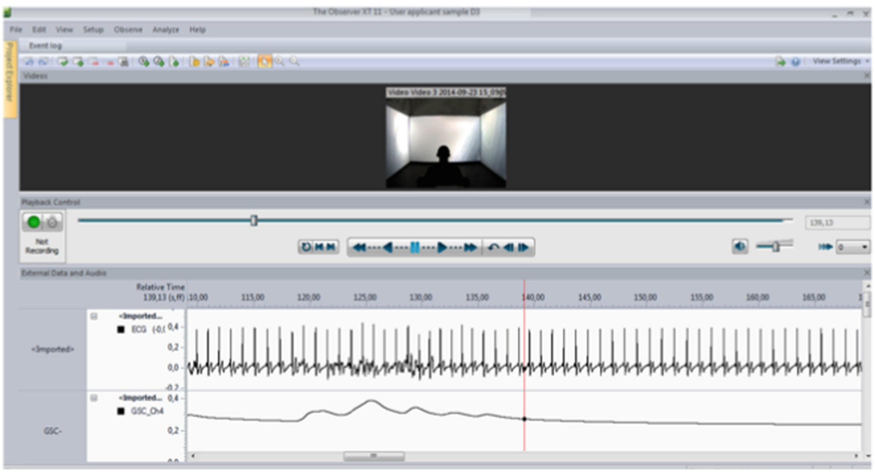

Fig. 6 Integration of observation and behavioural studies in software ObserverXT

Table 1 Multi dimensional observation and measurements

Goal/design inputs	Conscious experiences	Both conscious and unconscious	Unconscious reactions
Target	Perspective, goals etc	Behaviour	Physical and psychological reactions
Methods	Interaction	Observation	Measuring
Tools	Interviews, speak out questionnaire etc	Video, photos, Tobii glasses etc	EEG, ECG, GSR etc

Simulation can be used to combine virtual lab facilities with evaluation of design concepts while doing behavioural studying assessment of other dimension of users during the interaction.

We can compare and see what happen when several users experience different design solutions with the same purpose. It is important to visualize what the data look like [22]. So that we can target the scale of variables showing cause of the error (while using the design) and the effect on the user.

An example of results from the lab is a study concerning large displays that are more and more frequently used to run commercial movies or slide shows in public places. To be able to design environments for a population characterized by a diversity of people with variation of psychological ability and disabilities we need more knowledge about the impact of this development.

In that set of sessions, we evaluated and compared emotional reactions of users with and without Attention Deficit Hyperactivity Disorder (ADHD). The test group consisted nine people, that two people with ADHD and seven people without. The tests were made individually in a lab where the user was surrounded by three different commercial film clips projected onto three walls. Galvanic Skin Response (GSR) was used to measure the psychophysiological reactions of the user participants. After each session, an interview was made to find out the conscious experience of the participant. The result of the GSR data showed that people with ADHD had significant higher emotional reactions compared to none-ADHD people. The interviews indicated that this difference in emotional level was due that the people without ADHD were able to focus on a single screen, while the participants with ADHD lacked this focus and tried to look at all screens simultaneous. This small study indicates that we need to further investigate the impact of large-area screens and how they are placed in public places to be able to design an inclusive society.

Two important recommendation from this study are:

Firstly, provide equal test conditions for diverse groups of users with different abilities. The second is interpreting and reflecting data about conscious and unconscious reactions of users. This combination of data help design researchers to understand what user participants are looking at and what makes them to show specific behavior. The results can be present with variety of visual methods such as bar or graphs that researchers determine which method is appropriate.

4 Conclusion

We have designed a Designed Research Lab using a virtual reality user stage and utilized several methods including psychophysiological ones, with the aim of complementing standard conscious data with unconscious data. We used simple procedures of the psychophysiological signals, still the large amount of data collected, which also require non-design expertise for interpretation, suggest that a further development towards even more simplified output data of the unconscious reactions is needed to allow wider use within industrial design work.

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(In)spectors—Presentation of Education, Training and Professional Practice of Professional Test Persons

Lena Lorentzen and Klas Tviksta

Abstract This paper describes a pilot project education in Design for All and usability evaluations for people with different disabilities. The concept "(in)spectors" began as a vision to create a platform where people due to their disability, can be a resource for companies, organizations and governmental agencies in the development of an accessible society with easy to use and attractive products, services and environments. By educating (in)spectors in how to design, organize and participate in usability testing and accessibility analyses they could be an exclusive resource in development and planning, thanks to the combination of knowledge and their disabilities. The vision of the (in)spectors would thereby lead both to that people with disabilities are utilized as an important resource and that they through this creates conditions for inclusion of more people with disabilities into society and employment.

Keywords User studies · Design for All · Participatory design · Inclusion · Expert users · Accessibility studies · Social invention

1 Introduction

The requirements for inclusive solutions in Europe, specially for public places, education and working environments, are increasing due to legalisation deviating from UN declarations against discrimination [1] and from cooping with the demographic changes towards and increased amount of elderly in the population [2] even if "the recent surge of immigrants to the European Union introduces an element of uncertainty to the region's demographic future" [3]. In a Design for All process it is essential to involve the most demanding user groups in the process to

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secure an inclusive result [4] “the tougher and more demanding the customers are in their requirements, the better and more robust the designs will be” [5]; “when designers engage directly with real people then there is a richness of information that cannot be obtained through more indirect design research methods alone” [6]. Often the most demanding users equal people with disabilities. How inclusive the result will be is due to the designer’s knowledge about what limitations follow different diagnoses and how to put together test groups that cover usability of the actual item. The test people are often only actors in a test situation without any influence on the layout.

Unemployment among the persons with disabilities is as high as 80 per cent in some countries. [7]. In Sweden, many people with disabilities are facing a situation where unemployment and exclusion is a part of their every day life. The solutions for this group are often constructed compensatory tools, which aims to even the discrepancy between a persons abilities and the tasks that should be done. The diagnose is defined as a limitation that needs to be compensated for the person to be able to get employed. Despite extensive political actions and insistent work from different actors there is still need for creative solutions and alternate viewpoints to find ways where the competences and knowledge, the abilities, of disabled people is considered. Social innovations to prevent alienation are needed and encouraged by the Swedish government [8].

What if people with disabilities could use their limitations as the unique selling point in their CV while solving the gap in most designer’s knowledge in conducting user studies for inclusive design, if they were educated to design and run user test as well as giving really professional feedback to designers and other developers? That could lead both to that people with disabilities are utilised as an important resource and that they, through this, creates conditions for inclusion of more people with disabilities into society and employment.

This vision was the starting point for a pilot project called [in]spectors run by the nonprofit organisation Unicum - Nordic Design for All Centre [9] in collaboration with and funded by The governmental employment service, Arbetsförmedlingen [10], in Sweden.

In the project people with different disabilities were educated in:

- The Design for All philosophy
- Arguments for Design for All.
- The Design for All process and what kind of user feedback designers need during the process.
- Methods to measure usability and accessibility.

The intention was that the group, when the project was finished, should start a Cooperative company [11] to run a business and that every aspect of that business should be designed based on the philosophy of Design for All. Therefor the education was divided into two parallel tracks; one about Design for All and the other about how to start and run a cooperative company.

This paper presents the methods that were used, the process, problems that occurred and findings for further development of the [in]spector concept. An unexpected result was findings about how to make people with psychosocial problems to get into the job market.

2 Method, approach and treatment

By inviting unemployed people with some kind of impairment to a hearing about the project they could apply to join the education. From this group ten people with different kind of disabilities was picked by Arbetsförmedlingen.

The education was divided in two parallel sections; half time studies in Design for All and half time in group dynamics and how to start and run a company.

All participants in the [in]spector project had either physical or cognitive limitations. The goal was that every person should be able to participate in the education 100% of the individual capacity. To fulfil this goal following factors were used:

Design for All in pedagogic practise. Learning by doing [12] was the main pedagogical approach. All actions and practicalities within the education should work for the entire group of participants. Because of the diversity of educational experiences and ability to focus within the group, an instant sensitive approach to the needs of each participant was required, questioning traditional methods of teaching, to enable all participators to consume the content of the education. The needs and their character were changing in different situations and over time. The requirement of flexibility and creativity of the teacher leading to an inclusive approach bridged the distinction between student and teacher leading to a collaborative exploring way to gain knowledge. This approach also gave an opportunity for the knowledge to internalise and consolidate in an individual and deep level.

An allowing and receptive environment. To be inexperienced in an education situation could be stressful, worrying and fearful, more likely if you already have a vulnerable situation. Consequences of divergent ability, sicknesses, social and economical problems were affecting the every day life of the participants during the education.

The method was to not only adjust to the participant's situation but also, in a methodical and conscious way, try to establish long term conditions encouraging improvement and empowerment. Morning meetings where every person got attention were an important contributor in this case. To be able to share problems and other circumstances that could influence the working ability while listing to the others were contributing to a compassionated working climate and gave the teacher an opportunity to adjust the design and distribution of daily tasks.

Inclusion, participation and contribution were key concept of the policy, influencing growth of self-esteem and the informal learning processes.

Adjusted working environment. The working space was adjusted according to physical and psych-social need of every participant. Each working station was adapted with technical aids such as height-adjustable tables and ergonomic working chairs. Working time, mode of operation and where the work was carried out was designed to fit every individual's needs and wishes. The level of individual adjustments, flexible learning, continuous coaching and acceptance of each persons situation implicated an increasing productivity beating all expectations. Absence due to illness did hardly exist at the same time as the self-esteem increased during the project. Citation from a participant: "This is the first time in my life I don't feel foolish. I have gained self-confidence and know that I am good enough."

Health maintenance. Health maintenance was a core ingredient in the ambition to stimulate every individual's personal development with a goal of higher quality of life, increased empowerment, and wellbeing. Inspired by the salutogenic perspective by Antonovsky [13], was research about the heritage of heath and heath bringing factors core idea about heath maintenance. Opposite to the pathogen view that states health as absence of illness, the salutogenic approach defines health on a continuous scale between totally healthy and totally unhealthy. By improving the conditions for a person you can start moving towards the healthy end point gaining more and more health. Except giving social support and adjusting the requirements to the capacity of each person, there was health backup consisting nurse, physiotherapist, and occupational therapist. The participants were also offered to try different kind of exercise and treatment methods to find out what would improve their body contact and state of health.

Personal development. During the whole project there was a full time support person from the governmental employment service, called SIUS "Special introduction and follow-up support". This person was a behaviour scientist that supported the participants individually as well as a group, so that they could manage to focus on the education. Normally a SIUS is supporting people with disabilities to find, get and maintain employment. To use the SIUS-methods to work with a group of individuals in an education situation was a new and unexplored situation even if the purpose was mutual to traditional work, nursing personal resources and finding sustainable solutions for each person.

Supported employment. Supported employment [14] is an evidence based work rehabilitation method inherited from US and applied in Sweden since a couple of years. The method is a cluster of different actions with a goal to lead and support inclusion for people with disabilities. The method is built on own will and individual motivation to get work. The goal is that disabled people who want to be employed shall get support to find, get and keep employment in the regular work market. The method has been used primary to support participation in the education but also to reach long-term employment as a result of this project. A big amount of the support has been focused to ease the contact with other actors such as The Swedish Social Insurance Agency, social assistance, health systems and hospitals. The aim was to support each individual's development towards faith to their own resources as well as being able to focus on the education.

3 Results

The vision of the (in)spectors was that the project should lead both to that people with disabilities are utilised as an important resource and that they through this creates conditions for inclusion of more people with disabilities into society and employment.

The goal was also to start some kind of a social company based on the philosophy of Design for All in all aspects of the business.

To evaluate the vision a pilot study was initiaded and run by Unicum—Nordic Design for All Centre in collaboration with Arbetsförmedlingen in the small town Bollnäs in Sweden. Three people ran the education, one industrial designer specialized in Design for All, one social scientist from Arbetsförmedlingen and one business developer specialized in social business. The industrial designer was responsible for the core education in the topic. The social scientist was supporting the participants considering personal issues both regarding economy, handling administration and personal psychological development. The business developer was educating the group in how to start a social company whiles' merging the group.

The participants consisted of ten people with different kind of limitations; six people with physical limitations, two with a combination of physical limitations, cognitive limitations, panic disorders and psychosocial problems, one with severe physical limitations in combination with cognitive and psychosocial problems and one with big cognitive and psychosocial problems related to former addiction to drugs. During the project four people with physical limitations and the participant with severe physical limitations in combination with cognitive and psychosocial problems left. The people with physical limitations gave following reasons to leave; need of a secure income offered employment somewhere else, frustration about the pace in the education due to the participants with cognitive limitations, frustration about the behaviour from people with psychosocial problems. The participant with severe physical limitations in combination with cognitive and psychosocial problems had to hard time to follow the education and was offered another occupation.

The group merging and self-developing activities had a great impact on the participants with cognitive or psychosocial problems. They gained an increased self-esteem and managed tasks that were way beyond their comfort zone when the project started. For example could a participant panic disorder, so severe that she could not attend public places, enter the scene and give a short speech to the Swedish government.

During the education the group was applying the knowledge they gained in real projects. It turned out that the most efficient way of doing this was to collaborate with designer specialised in Design for All. Together they were running projects evaluating products, packaging and environments. The [in]cluders could focus on the evaluation while the designers could give feedback to the job requestor in how to make improvements. Both groups found this collaboration very fruitful and stimulating.

4 Discussion

The purpose of this project, to educate professional [in]spectors, was to advance for the participants with cognitive or psychosocial problems. This kind of problems led to a very slow learning process and problems concerning independent work. Another problem was that they, because of their unstable mode, the participants did not trust each other enough to start a company together.

To solve the aim of making the group work in the field in witch they were educated we made a collaboration with industrial designers and an architect. Together they made several successful evaluation projects.

This project was run as a pilot study by a non-profit organization and is therefor lacking academic stringency. The paper is written on base of observations from two of the leaders.

5 Conclusion

The learning from this pilot study is that

- it is important to start an [in]spector group with people who do not have severe cognitive or psychosocial problems.
- focus in the education should be on the core of the business idea, Design for All, usability and accessibility.
- the individual help from a SIUS, or similar competence, that can support contacts with governmental organisations, concerning economy and individual support, is crucial for the participant to be able to focus on the education.
- easy to use tools for evaluation of usability an accessibility must be developed.
- the framework for the [in]spectors must be provided since it is not realistic to expect a group of people who have spent several years outside the working environment to start a company.
- Courses in self-development and group dynamics could be a great tool to get people with cognitive and psychosocial problems back to employment.
- collaboration between [in]spectors and designers is very fruitful.

The vision of including the experience of educated people with different impairments, i.e. [in]spectors, in the process of developing accessible and barrier free services, products and environments would need to be evaluated in a new group consisting of people without severe cognitive or psycho-social problems. The goal is for this concept to be adapted in several countries. To be able to spread the concept a manual for future educations needs to be developed parallel while running a new group. New software or apps needs to be developed for easier conduction of tests and to secure the quality. A distance course in Design for All for designers and others that want to run [in]spector educations should be developed.

An international collaboration in developing and spreading the concept so that local preferences could influence the results of evaluations is under development.

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How the Swedish Rheumatism Association Uses the Design for All Tests to Approve Easy to Handle Packages and Products

Lena Lorentzen and Johan Eklund

Abstract Swedish Rheumatism Association has for many years fought for accessibility of products and services for their members. One tool in that struggle is a method to certify products and packaging as “easy to use”. This paper describes the development of the latest version of that test. It relies on people experiences and puts value on user satisfaction. The result is a powerful tool in inclusive design. Performing calibrated product testing by test groups of persons with reduced functions in their hands is now used as a product development and, if approved as a marketing tool.

Keywords User experience · User evaluation · Design for all · Design thinking · Inclusive design · Usability · Accessibility · User friendly · Packaging design · Product design · Easy to use · Easy to open

1 Introduction

Handling products and packaging can be difficult and annoying for us all. People with reduced function in their hands can experience a handling step that for others requires some extra effort and patience, very difficult or even impossible.

What or who determines whether a product, service or environment is easy to use or not?

It can easily be measured by testing if a person can manage a task or not if the concept of “using” is equalled to “perform”. The scale is binary and, depending on the outcome, the answer will be either yes or no. It will be easy to quantify how many people can handle the task. A problem with this approach is that the

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assessment is determined by the ambient expectations. Criteria are set for what it means to manage a task. Those are not necessarily consistent with the user experience.

If the concept of using instead is equated to manage what you want, the measuring situation becomes more complex. The person's experiences and feelings in the moment of use become critical. That the user is satisfied with the product becomes the target, regardless of the ambient expectations. For example, it might not matter that it takes time to open the package to access the content if the user is satisfied without discomfort in the form of pain or feeling of failure. If the user is satisfied, the product is good.

The method discussed in this paper is therefore based on the use of people with reduced function in their hands as instruments to judge how difficult or easy the handling steps of different types of products and packaging are. This means that the test persons perceived judgement comes as a measure of how well the product's design makes it easy to use. This approach means that it is necessary to also assess the hand function of the test persons.

Between 2003–2005 The Swedish Rheumatism Association [1], in collaboration with Unicum—Nordic Design for All Center [2] and Spenshult's Rheumatism Hospital [3], developed a method to test the handling of packagings. A reference group consisting of several consumer organisations, industry organisations, companies and governmental organisations s were following the work giving inputs.

The method was based on test group of 16–20 people with different kind of reduced hand function where the participants assessed kind and level of their limitations in their hands. Grip force was measured using Gripit [4] and dexterity was measured using the Grip Ability test [5].

The tests were performed in four groups of approximately five people. Every handling step of the packaging or product was judged on a scale where 0 = impossible, 1 = extremely difficult, 2 = very difficult, 3 = difficult, 4 = rather difficult, 5 = neither difficult nor easy, 6 = rather easy, 7 = easy, 8 = very easy and 9 = extremely easy.

Since different test people participated in each test occasions, every test group was calibrated to make the results fair. As calibration tool we used a bottle (Fig. 1) that has been evaluated by a reference group of hundred people with reduced hand function. The average value of the judgement of the bottle by the actual test group was then compared to the average value of the reference group. If the actual group considered the bottle more difficult to handle than the reference group their judgement of the product or packaging to be evaluated was adjusted accordingly higher and vice versa if the actual group judged the bottle higher (easier to handle than the reference group).

The weak point with this method was that it was relying on a bottle that could stop to be produced at any moment. It was also hard to spread the method internationally since the bottle was produced in Sweden and not available in other countries. The method was also hard to make applicable to evaluations of environments and services, where people with limitations in other parts of the body or cognitive limitations should be used as a test group.

Fig. 1 The bottle that was used as a calibration tool and a glimpse of the questionnaire

Other weak points were that the scale was to detailed which made it confusing for the test people and that the questionnaires were printed implicating a lot of work compiling the results.

The following sequences of this paper will show how the method was developed to target these problems and how The Swedish Rheumatism Association is using the method to approve easy to handle products and packaging.

2 Development of New Method—The Design for All Test

The main inspiration in development of "The Design for All Test" was the old method from the Swedish Rheumatism Association that was built on Quality Function Deployment (QFD). QFD is a product and production development method developed in Japan and used all over the world, especially in the car industry. The product development part involves that you gather needs from different stakeholder. The importance of needs or benefits for the costumer is recorded on a scale from 1 = Not at all important to 5 = Of highest importance. By comparing the score of the needs with consumer satisfaction of current product or service, on a scale from 1 = very poorly to 5 = very well, you get a clear picture of the improvement ratio [6]. Since no chain is stronger than its weakest link, The

F10.4 How much are you bothered by any limitations in performing everyday living activities?

Not at all	A little	A moderate amount	Very much	An extreme amount
1	2	3	4	5

Fig. 2 Example of question and scale used by WHOQOL to measure quality of life

Swedish Rheumatism Association decided that all handling steps of the product or packaging should be scored at least "neither difficult nor easy" in average by the test group to be approved.

2.1 Subjective Method

To avoid the week points using a reference bottle we were investigating the possibility of using the test person's self-assessed abilities as a calibration tool. Since this method is built upon subjective judgements of a product or package ease of use, also affected by the test person's attitude, it made sense that the assessment of the persons abilities also should be subjective. It was the test person's own experience we were trying to catch since that is the only thing that counts for each individual. An example of subjective measurement is the WHOQOL-SRPB field test instrument by WHO [7]. It is used to measure people's experience of quality of life by putting questions to be answered on a five grade scale. For example: (Fig. 2).

Donald Normans describes the significance of measuring experiences from a design point of view [8]. Using a product includes seven stages; A person is forming a goal, forming the intention, specifying an action, executing the action, perceiving the product, interpreting the product and evaluating the outcome. In the Design for All Test the stages can look like this; The person wants to reach to the product inside the packaging, forming the intention is to open the packaging, the person is planning how to open it, the person opens the packaging, the opening procedure gives experiences (e.g. pleasure, frustration or pain) that needs to be interpreted. When finished the person will evaluate the process of opening.

2.2 Assessing Hand Function

When assessing the abilities of the hand two parameters are used; the function of the hand and the ability to use the most common grips. This combination of different aspects was chosen to give clear design input. The design solution would be totally different if problem to perform a task that require a certain grip heritage from reduced muscle force than from pain or numbness.

To measure the function of the hands we use a combination of the International Classification of Functioning, Disability and Health (ICF) [9] by WHO and results from deep interviews about every day problems with representatives from different disability organisations. To measure the ability to perform different grips we used the six first defined most common grips from Sollerman: 1. "Pulp pinch: the object is held between the thumb and the index or the middle finger, or both. 2. Lateral pinch: the object is held between the thumb and the radial side of the index finger. 3. Tripod pinch: the object is surrounded by the thumb, index and middle finger. It may (but need not have) contact with the web of the thumb. 4. Five-finger pinch: the object is held between the thumb and the four fingers together. It has no contact with the palm. 5. Diagonal volar grip: the object is held with the thumb against the four fingers. It has contact with the palm and its axis is diagonal to that of the hand. 6. Transverse volar grip: same as 5, but the axis of the object is transverse to that of the hand." [10].

2.3 *The Scale*

According the scale the experience from the nine level scale was that it could be experienced as confusing with to many choices. Earlier we also tried to use a VAS-scale [11]. The result from that was that the test people tended to not score in the end of the line e.g. They did not score 0 even if they could not open the packaging. The fact that a a Likert scale is preferable to a VAS-scale is also found by H van Laerhoven, HJ van der Zaag-Loonen and BHF Derkx; "The Likert scale scored significantly higher on both preference and difficulty, followed by the numeric VAS and the VAS" [12].

The scale was changed from ten to five grades to better correspond with the scales of ICF and WHOQOL as well as the QFD-scale. An extra grade "X" was added to equal "no function" assessing hand abilities and "impossible" judging the handling steps of the product.

Since the Design for All test also is covering cognitive issues we needed to develop a scale according to people with intellectual disabilities. S. L. Hartley's and W. E. MacLean's research shows that "Likert-type scales should include pictorial representations of response alternatives, a single set of one or two word response descriptors, clarifying questions, and pretests, and are best used with adolescents and adults with borderline IQ to mild ID" [13] In the focus group discussions with adults who had different cognitive limitations they considered average smileys as "childish". Therefor a more adult-like pictoral representation with more details, like eyebrows, angle of head, wrinkles etc., was developed in co-creation with these groups.

2.4 Calibration

To be able to reduce the required size of a test group a reference test was made with i.e. 120 people with reduced hand function. Using a reference product the level of implication of reduced hand function on handling a product or package could be established.

By comparing the actual test group's level of hand function and abilities to use the most common grips with the reference group adjustment of the test results could be done. The certainty of the test results depends on the size of the actual test group. Therefor the requirement of the judgement of the product the smaller the test group gets (Fig. 3).

To verify the Design for All test several pilot tests was accomplished together with companies and designer (Fig. 4).

3 Result: Description of the New Test Method

3.1 Test Procedure

After agreement on the implementation of the test, the company supplies a copy and any instructions for the products or packaging to be tested to the test manager.

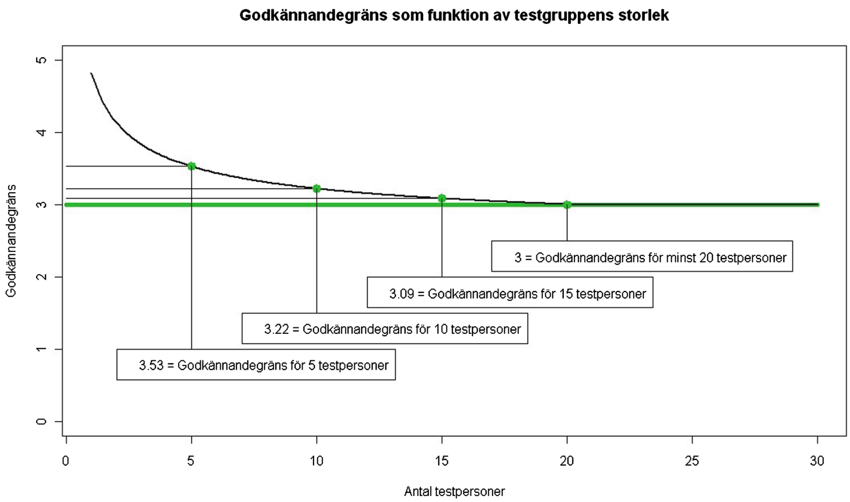

Fig. 3 The graph shows the connection between the size of the test group and the calibrated average value of judgement of each handling step required to be approved by The Swedish Rheumatism Association

Fig. 4 Pictures from pilot test mugs and mobile phones with Myra Industrial Design and Veryday

After an activity analysis [14], the test leader makes a draft questionnaire to be approved by the company. This is to ensure that all handling steps are covered and correctly perceived.

At least a week before the test, the company shall deliver the products or packaging to be evaluated. If the product or the packaging features are destroyed during the test, the number of samples should be equal to 1.5 times the test group size. Surplus products are used for test people who want to repeat a handling step and for analysis. Otherwise, the number of needed products will be discussed between the company and the test leader.

At the time of testing a maximum of six products or up to 30 handling steps are gathered together from different companies. This means that representatives from the company, for confidentiality reasons, can not be present at the time of testing if they do not fill or pay for an entire test themselves.

Time between test booking and test implementation is usually around four weeks.

After the test is completed and analysed the results are compiled in the form of a simple report. The company can use the report for further negotiations with the Swedish Rheumatism Association on use of the merited label.

The report is usually delivered about three working weeks after the test.

3.2 Test Implementation

By responding to a standardised form each test person starts by performing a subjective assessment of his or her hands abilities. Then the test leader gives instructions about the conditions of the test and introduces the test group for the product to be judged. Since it is only manageability that is measured, exactly how the product is supposed to be used is explained carefully. Each test person judge individually all handling steps involved in the use of the product on a scale from 0 = Impossible to 5 = Very easy. They are also encouraged to motivate their judgement in the comment field that follows each question. The results are collected and compiled for analysis.

3.3 Assessment of Function in Their Hands

By answering a questionnaire with 28 questions regarding function and grip, each test person evaluates their hands. The first 16 questions will determine how individuals perceive their own functions. The following estimates are made for both the left and the right hand:

- Dexterity
- Muscle power
- Sense of feeling
- Numbness
- Coordination
- Pain
- Shaking or involuntary movement

The last twelve questions concern the individual's ability to use the most common grips. The following estimates are made for both the left and the right hand:

- Ability to use the tweezers grip
- Ability to use key grip
- Ability to use five-finger grip
- Ability to use force grip
- Ability to use hold grip
- Ability to use pencil grip (Fig. 5).

The test persons themselves assess their functions such as mobility on a six-point scale where 0 = no ability, 1 = very reduced ability, 2 = rather reduced ability, 3 = neither nor, 4 = rather good ability, 5 = very good ability. In some cases, the scale is used to assess problems e.g. pain. Then the scale is 0 = total, 1 = very severe, 2 = rather bothering, 3 = moderate, 4 = light, 5 = no problems. The assessment scale 0-5 is used in all cases. Each scale point is linked to a picture to

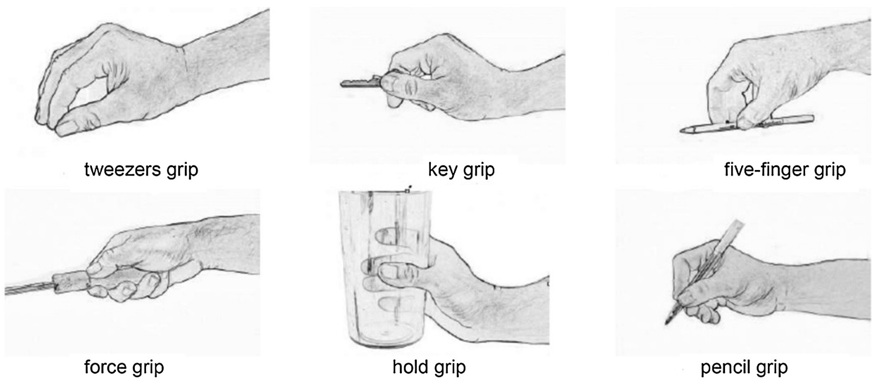

Fig. 5 Each grip is illustrated by a picture to make the questionnaire easy to understand

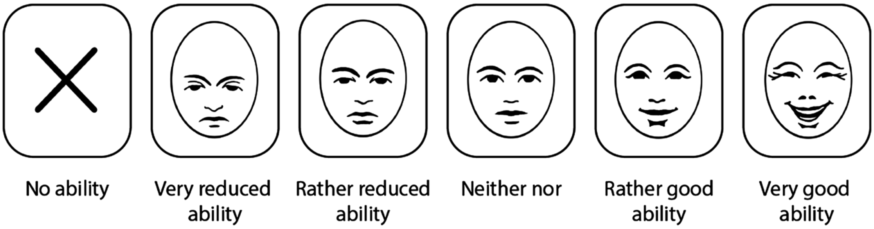

Fig. 6 The scale used to assess the ability to use different grips

clarify its meaning. Verdict choices are shown in the table below. The answers connected with the numbers are adjusted to match each question.

The answers are used to characterize the test person's degree of ability (Fig. 6).

3.4 Judgement of the Product or Packaging

The product is tested and judged on the basis of pre-defined handling steps according to a prepared questionnaire. Each handling step is judged individually and the tests group's collective opinion counts as the evaluation of the product's manageability. The method is based on QFD methodology, with the difference that this method does not allow the persons themselves to decide the importance of the various needs/usage steps. Instead, the approach to the product judgement is that all handling steps are equally important and must be judged as either "neither difficult nor easy" or "easy" by the test group. No chain is stronger than its weakest link and it is not acceptable if a product contains any handling steps that are perceived as difficult and exclusive. Each handling step of the product is judged on a similar scale as the self-assessment of the hands, but where 0 = Impossible, 1 = Very hard, 2 = Rather hard, 3 = Neither nor, 4 = Rather easy and 5 = Very easy (Fig. 7).

3.5 Calibration of Test Results

To reduce the effects of the test group's composition, a calibration of the judgements of the products handling steps is carried out. This is done on the basis of the

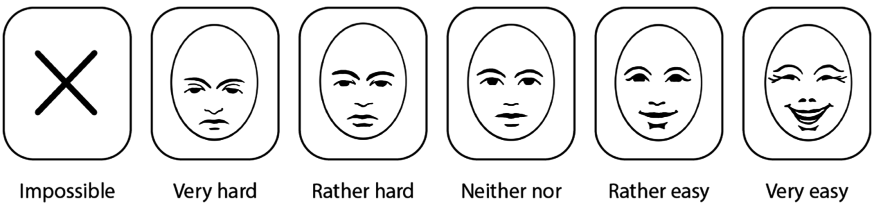

Fig. 7 The scale used to judge each handling step of the product or packaging

Fig. 8 The label a company can use for an approved product or packaging

test group's reduced hand function and a reference group of over a hundred people with reduced hand function.

At the creation of this method, extensive testing was conducted with the reference group to describe how the level of reduced hand function impacts the assessment of the various handling steps. By analysing the gathered data, a quantitative correlation between hand function and product judgement has been established. This correlation is linear which means that the calibration is proportional to the difference of assessment of hand function between the test group and the reference group.

Generally, to be approved as a test person, you need to have responded assessment option 2 = little impaired or lower, on at least one question about your ability in the hands. The test groups average may only deviate a maximum of 0.5 from the reference group average.

The result of the product assessment is compiled by calculating the test group average assessment of each handling step.

The test group's judgement is calibrated proportionately to the correction factor calculated for hand function of the test group. The calibration is calculated by:

Calibrated judgement = Judgement – Reference value * Correction Factor

Approval. If the product or packaging is approved in every handling step the company can make an agreement with the Swedish Rheumatism Association in how to use the label (Fig. 8).

4 Discussion

It is hard to claim that the The Design for All test method gives true results since the interactions between different aspects of people are so complex. Still subjective evaluations of people's experiences are the main input to be able to develop design solutions that people appreciate.

The Design for All test method used by the Swedish Rheumatism Association to approve product or packaging that are easy to handle has turned out to have an impact on how companies look at usability issues. Despite from for the label, many companies use the method in their product development.

5 Conclusion

The aim while developing The Design for All test method was to find a way for companies and designers to be able to make user studies with disabled people easier and get more reliable results. The labelling from the Swedish Rheumatism association is a way to encourage companies to develop products and packages that are easy to use. In interviews with several companies they claimed that developing a measuring method with a label and producing guidelines is the way.

The method is built upon the relationship between experienced (dis-)ability and experience of handling the product or packaging. Both consist of an individual attitude that is a part of the relationship. Using expert s or tools to measure the abilities would miss that relationship.

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How to Categorize Users from a Design Point of View?

Lena Lorentzen

Abstract It is important for designer to know the body functions and abilities of the test persons involved in the user tests performed during the design process. Otherwise they have no control of who is going to be able to use the product and not. This paper presents a new method to categorize the users from a design point of view that does not require any knowledge about diagnoses or disabilities.

Keywords User studies · Categorization of users · Categorization of abilities · Categorization of disabilities · Universal design · Design for all · Inclusive design

1 Introduction

Since development is about people and not about objects [1], why do designers insist on frustrating users? [2] In a study of designers a clear observation was that developers underestimated the diversity of users [3]. As Grudin describes the situation, developers may have a market in mind, but the actual users of a product are not known until the product is bought [4]. One aspect of diversity could be limited abilities due to diagnoses or age. Currently around 10 % of the total world's population, or roughly 650 million people, live with a disability [5] and world is ageing rapidly. People aged 60 and older make up 12.3 % of the global population, and by 2050, that number will rise to almost 22 % [6]. According to UN declarations about discrimination of people with disabilities [7], inclusive design is not any longer an option—it is a must!

To be able to create inclusive design direct user participation in the design process is a strong tool. Promoting diversity as a continuum encourages companies to think how their mainstream products might be improved to provide a better user experience for more people, in more situations [8]. Interaction with a diversity of

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users, including elderly and disabled people, is developing empathy and make the designer understand the users needs [9]. User involvement is often seen as “time consuming,” “complicated” and “difficult to organise and there for not a part of the design process [10]. It is also hard to understand that focus on small groups is needed to reach a broad market [11]. Even if evaluations are particularly important in inclusive design there is a lot of traps during the design process that can end up in excluding solutions. One of them is is inadequate testing [12]. One problem is that user studies primary are conducted as field-based studies with “anekdotic” direct verbal user feedback or observations. There is a lack of a systematic and comprehensive tool-kit to assess and judge if design is universal [13]. This implies that the reliability on the result from user test are week. According to Zitkus, Landin and Clarkson there are two research conditions that enhance the assessment, the sample selection and the data collection process. Firstly, the diversity of participants in a representative range of age and capabilities enhances the resulting accessibility and usability data [9]. But if the do not have a simple way to categorize the abilities of the persons participating in the user tests they will never be sure who we include and not.

This paper presents the development of a new method to categorize users from a design point of view. The method is a part of the Design for All Test, a reliable tool to evaluate usability in small user groups using calibration to a reference group of over hundred people within each categorization field [14]. Since the demand of accessible design solutions is increasing and many designers are not familiar with diagnoses and disabilities the goal was to develop a tool to categorize users with impairments that did not required any knowledge within the field.

2 Method

The work started by investigating existing methods. The most efficient way to categorize the users would have been if to use the International Classification of Functioning, Disability and Health, ICF [15]. It is well known and has a nice approach looking at people in a context where the body function, structure and abilities interact with the environmental factors to decide the participation and activity of the user.

The first limitation was that ICF only contains a negative scale when judging the body-functions and body structure. You can never have any skills. Also there is no possibility to design products that make the everyday life of people judged to reach a higher level than “no problem”. That feels as a very low level as a goal for design that targets a high quality of life. If we go into details ICF is also focusing on patients and their activities while designers are looking at user and their experiences.

To interview people with different kind of diagnoses and disabilities was a way to get a better understanding of their estimated problems and experiences. The method used were focus group discussions conducted with different handicap organizations. In each group there was at least one representative from the most common diagnoses. The question we put to them was:

- In what situations do you experience problems? In what way?
- Are there any special products that are hard to use?
- What problems do you experience within the information field? (E.g. web sites)
- Are there any situations that cause problems for you?
- Do you use any tricks to get around the problems?
- Do you use any aids? Which?
- How would you want it to be? Any special wishes?

The survey ended up with a long list of limitations and problems in their every day life. Next step was to put the key words into post-its and group them. The problems and experiences were related back to ICF to see if there was a way to combine the result of the interviews and the frames of ICF. The result was confirmed with physiotherapists and ended up defining categories including body functions, structure, abilities and aids.

3 Result

Other categorization tools for designer, such as the Inclusive Design Toolkit, are built on the capability of the user [16]. The body function or structure is not considered although both the capacity and the solution are affected by these components [15].

For example might body function strength affect the capability dexterity in a totally different way than what shaking in the hands would do. Simplified might the solution for low strength be a light product while it for severe shakings might be heavy product. The generalization of the capability is also an issue. The design solution to meet different fractions of dexterity capability, e.g. tweezers grip versus holding grip (transversal volar grip) is also different.

Also the need for and use of aids could affect solutions. For example could an evaluation of an environment be affected by if the test person is using a manual or electric wheelchair. In this categorization are all these aspects considered (see Appendix).

The categorization is dividing the users into ten groups:

Senses: Eyesight and hearing

Body parts: back/neck, arms, hands and legs

Cognitive functions: memory, structure, communication and learning

Only two senses got their own groups since taste and smell is not that relevant in design evaluations and sense of feeling is considered as a body function in all parts of the body. Reach and stretch functions where shoulders are involved are considered within the group “Arms”.

Designer are always working with people’s subjective experiences. Nothing else counts in the end since they will not buy a product that they do not like even if some expert tell them that it is beautiful and easy for them to use. Since the experiences are subjective [1] the suggestion is to let the test people make self-assessment of their functions and abilities. The self-assessment is a core value of the method since it gives information about the subjective experience of the situation. At the same time the test people assess their functions and abilities they are also going to give feedback and judge ideas and design suggestions. In both cases it will be a combination of physical, cognitive and psychological experiences where the attitude will affect the results.

3.1 The Scale

A Likert scale is used for assessing functions and abilities since VAS-scales are considered more difficult to use [17]. It consist of five levels and an extra level “X” that was added to equal “no function” or “no ability”. One difference between this scale and the ICF-scale is that it consists of both negative and positive levels since diversity also include skills. Hoskin, Waller and Clarkson found that “Promoting diversity as a continuum encourages companies to think how their mainstream products might be improved to provide a better user experience for more people, in more situations” [18].

Since the categorization is covering cognitive issues we needed to develop a scale according to people with intellectual disabilities. To make it intuitive and easy to use we decided to use a combination of faces and text [19]. The pictures are developed to fit all user groups and were evaluated during the user interviews (Fig. 1).

3.2 The Questionnaire to Categorize the Users

All questions for categorization of users are available in Appendix

About the questions. During our work we found out that the cognitive issues concerned almost all test persons in one way or another. Therefore we always put this questionnaire to all test persons. Since the mood of the test person can affect the answers we start the questionnaire with the question How are you today? The questions about balance and dizziness are connected to several diagnoses and can as well be perceived to originate from the ears as from the legs. Therefore we were forced to put them on the first page so that everyone will answer them. All the

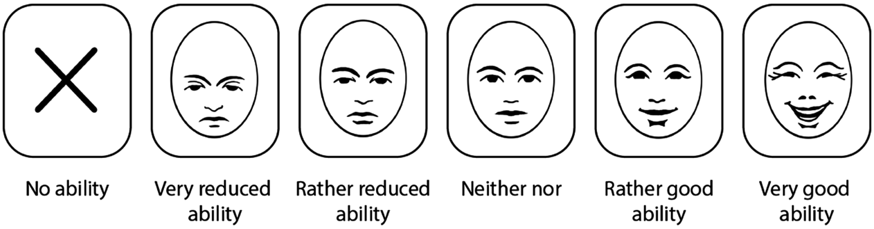

Fig. 1 The test persons themselves assess their abilities on a six-point scale where 0 = no ability, 1 = very reduced ability, 2 = rather reduced ability, 3 = neither nor, 4 = rather good ability, 5 = very good ability. In some cases, the scale is used to assess problems e.g. pain. Then the scale is 0 = total, 1 = very severe, 2 = rather bothering, 3 = moderate, 4 = light, 5 = no problems. The assessment scale 0–5 is used in all cases. Each scale point is linked to a picture to clarify its meaning

questions about functions in eyesight, arms, hands and legs are put separately for the left and right eye. Some questions are clarified with pictures to avoid misunderstanding.

3.3 How to Use the Questionnaire

Since the questionnaire is used to categorize the users and consists of many questions it is recommended to encourage the test persons to only answer the parts where they have any limitations.

After designing the categorization a reference tests, with about a hundred people within each group, was conducted. The result from the reference test is used for calibrating small test groups with our reference groups to receive more reliable results. Without the reference group calibration "one should run as many users of varying experience levels and abilities as possible" [18] to get reliable results.

4 Discussion

This tool for categorization can be used together with a similar way of judging the ease of use of a product, service or environment; using the same six level scale. That process is described in another article [5].

No subjective or objective method could cover the complexity of human functions and abilities. The intent of this method was to deliver fairly reliable results from small user groups in a tool that is easy to use.

5 Conclusions

The contribution from this project is a tool to categorize users that consider the interaction between body functions and structures, abilities and use of aids since all of these components affect who will be included in the design solution.

Some indications has occurred that peole with injury in the left part of the brein can have difficulties in judging on a scale. This needs to be futher examinated.

6 Appendix: Questionnaire for Categorization

Cognitive abilities

Memory

- How is it to remember things that happened long time ago? (More than one year)
- How is it to remember things that happened recently? (During the last week)
- How is it to remember parts while you are doing something? (Working memory)

Structure

- How is it to plan activities and events?
- How is it to keep track of activities and events?
- How is it to carry out projects?
- How is it to focus on one thing at the time?
- How is it to do several things simultaneously? (E.g. cooking and get everything ready at the same time)
- How is it to deal with unexpected incidents?
- How is it to deal with pressure?

Communication

- How is it to read a short text? (E.g. these questions)
- How is it to read a long text? (E.g. a book or an article in a magazine)
- How is it to calculate and understand numbers?
- How is it to interpret images? (E.g. to see what a photography depicts)
- How is it to interpret symbols? (E.g. road signs or other signs)
- How is it to interpret other peoples expressions of feelings?
- How is it to relate to other peoples feelings?
- How is it to orient yourself in different environments?
- How is it to express yourself by speaking?
- How is it to express yourself by using sign language?
- How is it to write a short text? (E.g. a text message on the cell phone or filling out a form)

Learning

- How is it to learn new things by reading?
- How is it to learn new things by listening with your ears?
- How is it to learn new things by listening to sign language?
- How is it to learn new things by watching others?
- How is it to learn new things by doing?

Other questions for all

- How do you feel right now?
- How is it to keep your balance?
- How often do you feel dizzy?

Eye sight

Eye sight functions

- Photosensitivity

Visual acuity

- Close-range visual acuity
- Distance visual acuity

Field of sight

- Central vision due to macular degeneration
- Peripheral vision (to the sides) due to glaucoma
- Patchy vision because of diabetes or retinal detachment

Eye sight abilities

- Ability to see and read text in a book without glasses
- Ability to see and read text in a book with glasses
- Ability to perceive contrast
- Ability to distinguish colours

Which of these aids do you use?

- Glasses
- Magnifying glass
- Magnifying device
- Magnifying software in computer
- Braile printer
- Computer speech synthesis
- DAISY digital talking player
- Other. What?

Hearing

Hearing functions

- Hearing level
- Sound sensitivity
- Tinnitus

Hearing abilities

- Ability to identify origin of a sound
- Ability to follow a group conversation
- Ability to converse in noisy environments

Which of these aids do you use?

- Hearing aid left ear
- Hearing aid right ear
- Hearing loop for television
- Blinking lamp for telephone
- Blinking lamp connected to door bell
- Vibrating alarm clock
- Sign language interpreter
- Other. What?

Back and neck

Back and neck functions

- Mobility
- Muscle power
- Sensation
- Hypersensitivity
- Pain

Back and neck abilities

- Ability to sit
- Ability to bend down forwards
- Ability to twist the body

Complementing ability questions

- How far down can you reach? Thighs, Knees, Shins, Top feet, Floor, Other
- How High can you reach with your left hand? Side of thigh, Navel, Chest, Neck/Throat, Face, Top of the head, Higher, Other. What?
- How High can you reach with your right hand? Side of thigh, Navel, Chest, Neck/Throat, Face, Top of the head, Higher, Other. What?

Arms

Arm functions

- Mobility
- Muscle power
- Sensation
- Numbness
- Coordination skills
- Hypersensitivity
- Pain in your arm
- Tremor or involuntary movements

Arm abilities

- Ability to lift your arm straight out to the side
- Ability to lift your arm straight forward
- Ability to reach the upper part of your back with your arm
- Ability to reach the lower part of your back with your arm

Body structure of arms

- Impaired alignment of left elbow
- Impaired alignment of right elbow
- Impaired alignment of left shoulder joint
- Impaired alignment of right shoulder joint
- Missing part left arm
- Missing part right arm
- Other What?

Hands

Hand functions

- Mobility
- Muscle power
- Sensation
- Numbness
- Coordination skills
- Hypersensitivity
- Pain in your hand
- Tremor or involuntary movements

Hand abilities

- Ability to use the tweezers grip
- Ability to use the key grip
- Ability to use the five-finger grip
- Ability to use the force grip
- Ability to use the hold grip
- Ability to use the pen grip

Body structure of Hands

- Impaired alignment of left wrist
- Impaired alignment of right wrist
- Impaired alignment of fingers on the left hand
- Impaired alignment of fingers on the right hand
- Part of finger on the left hand missing
- Part of finger on the right hand missing
- Finger on the left hand missing
- Finger on the right hand missing
- Other. What?

Legs

Leg functions

- Mobility
- Muscle power
- Sensation
- Numbness
- Coordination skills
- Hypersensitivity
- Pain in your leg
- Tremor or involuntary movements

Leg abilities

- Ability to stand on one leg (left/right)
- Ability to walk short distances (5 meters indoors)
- Ability to walk longer distances (hundred meters on level ground)
- Ability to descend stairs with handrail
- Ability to climb stairs with handrail
- Ability to sit down on a kitchen chair without armrest
- Ability to rise from a kitchen chair without armrest

Body structure of Legs

- Impaired alignment of left knee join
- Impaired alignment of right knee joint
- Impaired alignment of left ankle, Impaired alignment of right ankle
- Impaired alignment of toe joint on the left foot
- Impaired alignment of toe join on the right foot
- Part of toe on the left foot missing
- Part of toe on the right foot missing
- Toe on the left foot missin
- Toe on the right foot missing

- Part of left leg missing
- Part of right leg missing
- Left leg missing
- Right leg missing
- Other. What?

Do you use the following aids indoors

- One cane
- Two canes
- Crutches
- Walker
- Manual wheelchair
- Electric wheelchair
- Electric scooter
- Other. What?

Do you use the following aids outdoors?

- One cane
- Two canes
- Crutches
- Walker
- Manual wheelchair
- Electric wheelchair
- Electric scooter
- Other. What?

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Vital Minutes—Cardiac Arrest and the Essence of Time

Lise Johansson, Ana Popa, Hanif Bahari, Muzammil Aslam and Sanna Amjadian

Abstract The vision with this project is making people working with cardiac arrest, both bystanders and paramedics, use the time and act correctly. Research about cardiac arrest was performed in order to find further focus areas to answer the question: How can we reduce time in emergency situations with cardiac arrest outside the hospital? A user study was made and two questionnaires were given to the Sundsvall ambulance and SOS workers. Different needs were subjected into a brainstorm. The user study and questionnaires gave ideas about what needs should be considered in the ideation. The ideas created were: (1) application for cardiac arrest (information about emergency situation, guidelines etc.), (2) redesign pre-filled syringes package (3) cardiac arrest kit for pre-filled packages (bystanders and paramedics). The purpose was ultimately to reduce mortality in cardiac arrest. Further studies need to be carried out to find a way to make lifesaving efforts more efficient.

Keywords Pre-filled syringes · Cardiac arrest · Time · Adrenaline · Stress · Education

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1 Background

Out of hospital cardiac arrest is very common, approximately 400,000 people suffer from cardiac arrest every year. The survival rate remains low, less than 10 % survives after an out of hospital cardiac arrest as reported by *Offcial Journal of the European Union* (2012).

As noted by Lyon [1] the survival from cardiac arrest rely upon few factors, such as (a) early recognition and searching for help, (b) early CPR (cardiopulmonary resuscitation), (c) early defibrillation and (d) advanced post-resuscitation care. Every element it is crucial for patients, and they can improve the survival rate.

Knowledge about CPR needs to be improved in Europe where the survival rate is poor, only 7 % in patients out of hospital. 55 % of the Swedish population knows basic CPR but the survival in SCA is only 3 % in out of hospital cardiac arrest. If the affected person is not resuscitated within 10 min the possibility of medical sequel like brain damage is impending.

An ambulance worker at Sundsvall hospital [2] informed that in medical care while working with cardiac arrest, time is the only thing that has been proved to cause less fatal outcome. Studies done by Rittenberger et al. [3] have shown that injection of Adrenaline might be administrated too late and could be the reason why it's not so efficient when treating cardiac arrest patients out of hospital.

Working under time pressure is very stressful, both for medical personnel and bystanders. During stress people use different coping mechanisms such as avoiding decision-making, favoring a certain solution and see no other way. This kind of stress for paramedics can lead to wrong estimates while handling drugs along with frustration which leads can lead to more stress. Bystanders have little or no medical education and stress for them in this situation could be paralyzing and make them avoid interference. This is the time when they are needed the most.

Weisfeldt and Becker [4] proposes a model with three phases of CPR for patients in VF (Ventricular fibrillation) or VT (ventricular tachycardia), to show the importance of time in resuscitation process.

1. The first phase is called "electrical phase", it begins from the collapse until nearly 4 min. In this phase the defibrillation in comparison with CPR, can lead to the best results. A good example of effectiveness of defibrillator during the first stage is the "Implantable cardioverter defibrillator (ICD)". The proceeding of early defibrillation in electrical phase increased the surviving approximately 50 %.
2. The second phase is "circulatory phase" it starts from nearly 4 to 10 min of cardiac arrest. The most lifesaving treatment during this stage is to start the CPR. Firstly, is needed to provide oxygen delivery after chest compressions and ventilation followed by defibrillation. As noted by Neimann et al. [5] after 7.5 min of untreated cardiac arrest, the best choice is to do 5 min of CPR and epinephrine, it has better results compared with immediate defibrillation (64 % vs. 21 % survival). In contrast, using the CPR before 5 min has failed to provide results over immediate defibrillation.

3. The third phase is "metabolic phase" is starts after 10 min of cardiac arrest. In this stage the immediate defibrillation and CPR are both in the same level efficient, but it decreases fast and the survival rates are becoming poor. In this phase circulating metabolic factors can lead to additional injuries.

As noted by Rittenberger et al. [3] the time from the patient's collapse until the first drug is given will influence the effect of every medicine given. In animal laboratory studies of CA, the medicine is often given early and in an exact time, that can probably increase the efficiency of drugs. However, in the usual situation of out of hospital cardiac arrest (OOHCA), drugs are usually given late or via the tracheal tube. Their hypothesis is that the drugs given late are limiting their effectiveness.

On average, nearly 18 min are passed until the patient receive their first dose of drugs, but in cases the cardiac arrest is not witnessed, it could be longer. Thus, the medicine seems to be ineffective. Animal model studies inject drugs nearly 7–10 min after a cardiac arrest. Those studies have shown a big advantage in return of spontaneous circulation (ROSC) even the use of many cardiac arrest drugs. Based on these published reports, the drugs in cardiac arrest resuscitation are injected too late. Before to conclude that the drugs are ineffective, the administration time should be shortened.

Miller [6] argues that in a moment of stressful decision making under time pressure people tend to use three basic coping mechanism. These coping mechanisms help them to handle the situation and actually reduce the time pressure of that person. They make the people in these stressful situation decide in a some sort of organized way. All of these are more likely to be used when the threat of a possible negative outcome is stronger than the actual fact of not considering all information.

Acceleration. Meaning that the person that is placed in a stressful environment process information much faster than he normally would.

Avoiding making decisions. Meaning that the person is don't want to make decisions. This may be shown trough the person making random choices or making choices trough what stands out in the environment.

Filtration. Meaning that the person filters all the information that passes him/her by in this situation.

Bolstering. Montgomery and Svenson [7] argues that inside the filtration part is another part as well, "Bolstering". Meaning that a person in a stressful situation want to choose an alternative that is better than another or equally as good. In order to do this people tend to restructure information in an angle that makes that choice look superior to other choices. Janis and Mann [8] argues that "bolstering" might also be used as a mechanism for "defensive avoidance" to use when a conflict occurs. Meaning that if a conflict in decision making occurs in a stressful situation the person use "bolstering" instead of comparing the different choices objectively towards each other. This kind of work in a stressful situation can both end up good and bad. Good if the person makes the choice very fast and it turns out to be of use, this often happens in the early stages of the situation. But can also turn out bad if the person makes a choice that turns out to be wrong and then end up not being able to function due to the time pressure it has put itself in.

The long and short-time effects of stress impact the wellbeing of health care personnel in and outside of work. This lays as a background to mistakes made during stress in a stressful situation which then becomes a cascade effect and could put affected persons in a spiral of stress.

According to Karkar et al. [9] around 75 % of the nurses experienced a mild level of stress and ca 40 % a moderate level of burnout. The most common stress factor was technical breakdowns of machines (15.9 %).

This is relevant while considering how people behave in an acute situation where decisions need to be made correctly and fast. Root causes of errors in a pre-hospital emergency is described by Lammers et al. [10] where clinically important themes were tended to such as incorrect estimates of weight, faulty recollection of doses, difficulty with calculations under stress, unit conversion errors and inaccurate volume measurement. Underlying causes of dosing errors, which was occurring in almost half the cases, were found in four domains: cognitive, procedural, affective and teamwork errors (crosschecking, i.e. communication). Most struggled to locate essential equipment, three found broken or inoperable masks resulting in delayed ventilation. Some mistrusted their intraosseous injection gun device; others used it incorrectly. Some even used the wrong end of pre-filled syringes.

According to a research that conducted by *School of Health and Social Sciences,* University *of Dalarna* (2009) to show the impacts of education in cardiopulmonary resuscitation. This was done by looking at cardiopulmonary resuscitation teaching programs in Sweden for 25 years and correlate those to alterations in the quantity of patients with out of hospital cardiac arrest who obtain bystander CPR. Statistics were taken from the Swedish CPR training registry settled in 1983 and contains most of Swedish education programs in CPR and (second) the Swedish Cardiac Arrest Register settled in 1990 and now consists circa 70 % of ambulance domains in Sweden.

CPR training in Sweden operates based on a cascade principle (instructor-trainers trains instructors, then they train rescuers in CPR). Since 1989, 5000 instructor-trainers have educated more than 50,000 instructors who have educated circa two million of Sweden's population of adults (9 million) CPR. This is tantamount to one new rescuer per 100 residents each year in Sweden. Since 1989 there are 51,000 new saviors in Advanced Life Support, since 1996, 41,000 new Basic Life Support saviors with Automated External Defibrillation training, and since 1998, there are 93,000 new saviors in child CPR.

The outcome is an increasing number of bystander CPR attempts for out of hospital cardiac arrest in Sweden from 31 to 55 % from 1992 to 2007. By operate a cascade principle for CPR education circa 2 million saviors were trained in Sweden (9 million residents) in the period of 1989–2007.

The vision with this project is to make people working with a cardiac arrest, both bystanders and paramedics, use the time and act correctly. The vision is ultimately to save lives. The goal of this project is to reduce time in emergency situations with cardiac arrest outside the hospital and to present our results using either physical or rendered models, a presentation and written report. How can we reduce time in emergency situations with cardiac arrest outside the hospital?

2 Method

A user study was made with five people inside a research lab and was carried out to get an understanding of how people react in a stressful situation. It included simulation with observations, interviews and questionnaires for ambulance and SOS personnel.

Five test persons where put in a situation/environment of having a person with cardiac arrest in front of them. The environment was set in a lab with projectors showing a street environment with a lot of peoples and a car accident. The sound of people talking and cars passing by came out of speakers to add to a more real situation. During the simulation observations were made and following everything was a interview about how they felt in this simulation.

A questionnaire was handed out to five paramedics at Sundsvall hospital. It included questions about treating patients having a cardiac arrest, like handling the drugs and different steps they carry out in this instance. Another questionnaire was made for SOS personnel including questions about how they help people in stressful situations and which kind of advice they are required to give in cardiac arrest situations.

A brainstorm was held within the design group regarding eight areas considering the needs that emerged after our background and user study. The areas where: early drug administration, support, defibrillator, keep track of time, knowledge, avoid stress, keep track of actions and interface.

3 Results

The user study resulted in different findings leading to different directions. The first reaction of the test people was to check the vital signs of the patient in correct order: breathing, pulse, awareness. Average time of calling SOS was 20 s to receive help and more detailed information about what to do next. Two persons refrained from moving the patient because of the surroundings in the simulated accident situation. All test people knew how to perform CPR but only one recognized the symptoms of a cardiac arrest. The stress level varied among the tests people, two persons were aware of the circumstances but the rest showed elevated signs of stress.

When they were asked in the interview about the recognition of the symptoms, they were unsure whether the patient had fainted, was bleeding or had a concussion. They acted more on instinct than knowledge and mostly in the correct way. All of them had undergone CPR courses in school and one of them had taken extra courses and had knowledge about performing compressions but no training with defibrillator.

Most had problems remembering the rate and ratio between compressions and ventilation. The test people also couldn't recall their actions and whether it was done in the correct order or not, and forgot to report some of the actions altogether.

Even though they knew the importance of time, 4 out of 5 test people recalled and estimated the time they were in the emergency situation in double the amount.

They needed help in order to get further instructions; otherwise they wouldn't use the defibrillator. It was helpful talking to a professional since they felt insecure, and they didn't know the correct procedure, not wanting to do more damage. All of them could understand the instructions and use the defibrillator in a correct way. A few got lost among the steps and images, a few preferred to listen rather than reading the instructions. Others needed more time to think and couldn't hear the instructions well.

Most of them didn't even notice the first aid kit and the one who saw it didn't know what it was used for since it was black and had unclear text. In this stressful situation, many were comfortable in giving the patient an injection if necessary, provided they would have previous knowledge.

In the opinion of ambulance workers, 3 out of 5 thought it could be possible for a bystander to inject adrenaline, intramuscular, before the ambulance arrives. Legislation allows adrenaline to be used in the muscle similar to the injection given for allergic reactions. An emergency doctor pointed out that intramuscular injections, in theory, are not efficient in cardiac arrest since the blood circulation is reduced.

In average it takes the paramedics 1–2 min from SOS alarm to departure from the station. It takes 15–20 min for the ambulance to arrive within Sundsvall and the goal is to reach 90 % of the population before 30 min, which means the chances of survival are poor.

Increasing the survival rate is also dependent on other factors such as receiving SOS alarm, ambulance dispatch, medical history of patients, arrive to the location, assess if the working conditions are safe, check patient, priorities, open the acute bag, carry out treatment, evaluate, transport of patient, drop patient at emergency ward etc. In this chain of events from SOS-alarm until the ambulance leaves the patient at the hospital, time is crucial for the patient's survival in every step.

The SOS are required to give practical suggestions about which vital signs to check on a patient in an emergency situation. There was a dissent among the respondents whether it was possible to do compressions and ventilation inaccurately and thereby worsen the condition in cardiac arrest. According to the paramedics the feeling of stress depends on the situation and your own wellbeing, but entering an acute situation gives more focus. It is always more or less stressful and puts a lot of emotional strain. In an acute situation it's time consuming to brake ampules so most of them would prefer using pre-filled syringes.

From the eight different needs that emerged from the brainstorm different ideas were shaped, such as redesigning the defibrillator for a better function and understanding, an automated compression-machine, a smart watch that could detect your pulse and changes, a drone to transport the necessary equipment to the scene of emergency, a smart floor to deliver the defibrillator kit, an application that would keep track of what actions were taken, a package for the syringes etc. A discussion within the design group was made to find out what areas could be possible to implement within the near future. The areas that emerged were divided into:

Application for cardiac arrest (quick information in the emergency situation, education and guidelines). The pre-study shows that people need support in a stressful situation in terms of keeping track of time, seeing informative pictures, getting auditive instructions etc. Since the smartphone is always available for people it's very easy to reach a large group, people have their own smartphone and personal settings which makes the application more suitable for them.

Package for pre-filled syringes (redesigning for a better use). The actual package for pre-filled syringes is unclear and not user friendly and the shape of the syringe doesn't inform as how to be opened.

A cardiac arrest kit containing the pre-filled packages (both for bystanders and paramedics). One study shows that adrenaline is administered too late so the main focus is to enable quicker access to the vein and give an injection of adrenaline intravenously. The kit contains most of the things that people with basic medical education could understand and handle.

4 Discussion

The given assignment was simply to develop a storage case or bag for pre-filled syringes. This kit may save 1 min or two but looking more closely, the problem lies before that time frame. When the ambulance arrives the vital minutes for resuscitation usually have passed and the survival rate is only 2 %. Therefore the core issue should be to reduce mortality in case of cardiac arrest. The aim of this project was then converted to solve the basic problem which is ultimately to save lives.

The results and the solutions are lifesaving and easily implemented in society today. Further studies need to be performed on intramuscular administration of adrenaline during cardiac arrest, since circulation is not optimal. The test group was small and the results might not be generalized into a larger population.

Another category of patients that could benefit from an epinephrine (adrenaline) pen at home, except patients with previous anaphylaxis, is those with previous life-threatening asthma. It could also be interesting at health care centers, health clinics at schools, company health care etc., where it could be easier to have pre-filled pens/syringes available to administrate in life-threatening conditions.

The application could also be suitable in these emergency situations which would prepare ordinary people and facilitate to help a person in emergency. The new package of pre-filled syringes should be intuitive and easily understood. The kit could be used for more pre-filled syringes and thereby make the work of professionals and bystanders even more efficient. Moreover, a new syringe kit could be time saving in other life-threatening situations like bleeding, thrombosis, pneumothorax etc.

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Part XII
Design for Inclusion in the Living Environment and Ageing Population

CampUS: How the Co-design Approach Can Support the Social Innovation in Urban Context

Davide Fassi, Laura Galluzzo and Annalinda De Rosa

Abstract This paper describes how the co-design approach can facilitate the development of new community gardens in an urban context by using the "campUS" research project of the Politecnico di Milano. This is the second stage of a complex and structured path that started four years ago with the creation of Coltivando—the convivial garden at the Politecnico di Milano—founded by a group of professors, researchers and graduates of the Department of Design. Its main objective is to connect two spatial and social realities that co-exist but have no meaningful communication with each other—the university campus, and its surrounding neighborhood. After more than three years, the garden is a thriving hub of community activities. So, how can the success of this project be replicated in another green space of Milan? This question is at the core of one of the initiatives planned by the "campUS" research project, financed by the Polisocial Award, a prize for social innovation research projects at the Politecnico di Milano.

Keywords Social innovation · Urban agriculture · Service design · Spatial design · Communities · Co-design

1 Introduction

"CampUs" is a two-year long, funded interdisciplinary research project developed by the design department together with the architecture and engineering management departments at the Politecnico di Milano, Italy. The project's main goal is to use the university campus as an incubator for social practices to be developed through design skills and to be transferred into the neighborhood as independent actions. It is based on

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the results of three previous successful design activities on the “Bovisa” campus of the Politecnico di Milano during the last four years: “C’è spazio per tutti/There is room for everyone”, “Coltivando” the community garden on the campus, and PlugTV, the social web TV for the neighborhood.

The first was a one-day event organized in 2011 and 2012 as part of a design course called “Temporary Urban Solutions” where postgraduate students were asked to develop design activities that could be immediately prototyped after a five-day workshop to open up the campus to the neighborhood. The “Bovisa” campus is an important site in the Bovisa neighborhood of Milan because it was the location of a former factory where most of the local people were employed until the 1970s and because of its large, open green areas, which are very unusual in that part of the city. “Coltivando” was one of the design activities developed in the 2011 “C’è Spazio per tutti” event that was implemented in a long-term project to be established on the campus. Today it is a 1000 m^2 community garden run by a team of local citizens together with the university community. PlugTV is a web social TV designed by a team of researchers (ImagisLab) in the design department that is built on the connection with the community developed by the previous two projects.

The “campUs” research project benefitted from this network of actions and is attempting to establish a more structured way of developing design for social innovation solutions by using a combination of: the skills and competences of the researchers and students; spaces on the campus; and a network of local associations and informal groups. The project is organized into four main work packages, one per goal to be achieved:

- the development of a new community garden on common land close to the campus;
- the implementation of the web social-TV involving “neets” (young people who are “not in education, employment, or training”);
- setting up a mobile pavilion in the neighborhood to host activities by different associations in a four-month period during spring/summer 2016;
- developing an economically sustainable model to support the long-term life of the three previous goals.

Within the design department, this research has been developed by the Polimi Desis Lab.[1] In 2010, the process of creating a Living Lab on the university campus located in the district of Bovisa began, which would allow local residents to discover and use it, and would allow students to come into contact with real life problems and opportunities. Research activities are thus developed through educational ones: it is a form of action research that engages students in parts of the projects, asking them to generate ideas that contribute to the work in total. It is well documented that experiential education—in particular, through hands-on, project-based learning—facilitates student success [1], and conducting research through design [2] allows a continuous process of implementation of the results.

[1]www.desis-network.org.

The prototyping of the solutions is the core of the research since making the ideas immediately tangible, and by having the local people at the center of them, allows for exploration of many ideas in parallel [3]. At the same time, the role of the designer in these processes of people engagement and social innovation development has to be understood in terms of timing in order to make the initiatives self-sufficient and the community 'competent' [4]. This approach lets the team focus its research on the public space as a complex system to be investigated in its embodied features of resilience through the use of design tools and methods.

2 When Design Meets Social Innovation

Design for social innovation has dealt with many local projects in recent years to help communities develop solutions for a better quality of life. Innovations in, for and with society occur when social needs are met in order to create new social relationships or collaborations [5]. Design plays an important role in supporting this process, due to the approach, tools and methods being rooted in the discipline.

The connection between social innovation and design has been supported in many design departments by DESIS—the Design for Social Innovation and Sustainability Network that includes more than forty labs around the world. Ezio Manzini established this network in 2008, after years of research and didactic projects connected with the improvement of society adding value to emerging practices, to triggering people's design potentialities and to implementing grassroots initiatives. According to Manzini [6], "social innovations are solutions based on new social forms and economical models. They are those social changes towards sustainability when they can reduce the environmental impact, regenerate common goods and social fabric". The "campUS" research project deals with design for social innovation due to the strong connection in the local context illustrated by the relationship with several stakeholders (associations, local public management, informal groups) and a direct geographical contact (campus location). Moreover, the importance of having innovative solutions is highlighted in the emerging needs related to urban agriculture, skills/knowledge exchange, sharing of culture and training for those groups of people most in need of it. Here the attempt is to include other disciplines such as architecture and engineering management in the process of developing these solutions and thus enable the projects to last longer and be self-sustainable.

3 When CampUS Is Going to the City

In October 2014 "campUs" began its research activities with two main events: an "Ideas sharing stall" at "Coltivando's" 3rd anniversary; and a meeting with representatives from local associations at "Jodok", a space within a meeting place in North Milan that is very well-known to local citizens. As they are both open systems, "the ties between cities and universities take place around 'spaces of interaction' with social networks (based on mutual trust or social capital) playing a critical role" [7] spaces with a key role in the local social realm were chosen or both the activities (workshops) and the presentations.

The "Ideas sharing stall" was a way of promoting the campUS goals and a road map to the citizens along with some advertising materials (flyers, postcards etc.) and by involving them in a small co-design activity related to three out of the four main outputs. The stall itself was tested in 2011 in a previous project developed by Polimi DESIS Lab [8], where it was conceived as a window to enable discussion between designers and city dwellers, creating tangible connections between the researchers and the people who would become users of the services to be implemented.

The three main questions related to the co-design activities asked them to complete the following sentences:

- "In the neighborhood garden I would love to cultivate…"
- "On the local social TV I would tell this story…"
- "I would like the pavilion to host…"

This was felt to be an interesting way of collecting feedback and suggestions of how to start the activities in the near future based on grassroots input. More than 100 suggestions were collected, including:

- garden: people did not limit their suggestions to vegetables or fruits, but also wrote about "friendship", "skills", "harmony", and "best practices";
- social TV: some suggested specific stories related to personal memories connected with local places; others focused more on the present poor conditions of abandoned areas or on the misbehavior of some young people towards common areas; while others told stories of people who help to improve the quality of the neighborhood;
- mobile pavilion: since the pavilion would host activities organized by associations, the results would be quite diverse depending on the variety of the services provided by the associations. People's suggestions ranged from gym activities to theatrical ones, from public readings to handicraft workshops (Fig. 1).

Two weeks after this event, "campUS" was presented at the "Jodok" space during a "communities meeting". It was an open meeting for representatives of the local associations and of the informal groups (i.e. inhabitants of local co-housing, ethical purchasing groups etc.) to introduce the research program and to collect ideas about how to develop the three main activities. The meeting was useful in strengthening the connection between the local network of people and the university and in starting a robust collaboration for the following two years and beyond. The meeting was divided into three parts: a presentation by the coordinators of the research program; then, people were split into three groups according to the three main research outputs to generate suggestions relating to them. The last part of the meeting focused on sharing the results of the parallel sessions with the other participants.

Fig. 1 "campUS kick-off": the "Ideas sharing stall" to present the four main goals of the research and to provide small co-design activities

Results differed slightly from the previous event of two weeks before, due to the more intimate setting and because the participants were more motivated and involved. The findings were that:

– the garden is more than a place to cultivate vegetables and fruits; it has to be a place to gather competences and skills for urban gardening so as to share them later with the community garden network in the city.
– social TV needs to be a collector of memories for future generations and to teach skills such as how to produce content (video-editing, etc.) to young people.
– the mobile pavilion was considered to be an interesting way to circulate culture within the neighborhood and not just a place where activities happen. They even suggested finding a place after it has completed its journey and to leave it as a permanent public place for residents.

4 When Gardening Is Not Only About Cultivation

After the 'kick-off' activities, we moved into a more practical phase by focusing on specific work packages. Each department involved in the research is in charge of one work package and involves experts from the other departments to ensure an interdisciplinary approach. The activities connected to the "Garden" work package are described in the following paragraphs.

In 2013 the city of Milan launched a public call ("Coltivami") stating that an association could request the use of an abandoned public area (among those listed by the council) for free if they would use it as a community garden for the following six years. This produced an incredible response due to the increase in requests by citizens for places to grow their own vegetables.

The call included some basic rules: use the area predominantly as a community garden; organize small public events to promote its activities; design and build fences around the area; do not use the existing soil but plant the vegetables and fruits in raised garden beds on top of the existing soil (i.e. boxes, crates, new soil etc.); and do not run any activities for profit. These rules aimed at guaranteeing correct use of a public commons by increasing a sense of responsibility in future users and, at the same time, creating some opportunity for design—such as how to build garden beds, how to create a layout for the area and how to initiate and strengthen a community by taking care of the garden.

As a design school and research team dealing with social innovation we saw design challenges in the limitation of using the existing soil, building fences and strengthening a new community of citizens: a "hardware" challenge (i.e. building something physical) and a "software" challenge (i.e. designing the intangible). We focused on these two main activities in the following months, involving post-graduate students as part of their curriculum and for the development of their final project.

Thanks to the "communities meeting" held in October 2014, we contacted the "9 × 9" association who had been successful in the "Coltivami" public call. They had been recently assigned a 5000 m^2 area in the "Bovisasca" neighborhood of north Milan not far from the Politecnico campus. They were going to start their garden activities and they asked for collaboration with the "campUS" team. This was a very interesting opportunity for the research team to work on a real context by combining the research goals with those of the association. The "hardware" and "software" actions taken are described below.

Software and the garden: how to get people aware about community gardens In January and February 2015, together with the "9 × 9" association, we scheduled three indoor workshops to explain the meaning of community gardens and to promote the opening of a new one, to develop and share the garden rules and "manifesto", and to define the spatial layout. According to the "campUS" proposal, the workshops were held in the Politecnico campus spaces, to utilize university facilities and areas as an incubator for social practices. Each workshop was promoted through the research team's mailing list and contacts from "9 × 9" and the local council administration; flyers and posters were also placed in local shops and supermarkets.

Based on Meroni's [9] approach, "participating in designing and innovating brings enjoyment and a sense of sharing of the objectives", the following activities were designed to increase awareness of the community garden and to trigger unpredictable interactions among people previously unknown to each other by using design tools.

Workshop 1: "**What is a community garden?**" This 3-h long event was held on January 31st, 2015 with the participation of twenty-eight local citizens. The "campUs" project was presented at the opening of the workshop and the goals were introduced. "What is a community garden?" was then explained using some best practices as examples and by involving the participants of "Coltivando"—the convivial garden at the Politecnico di Milano—telling their experience of the garden over the previous three years. Then the participants were asked to create two teams—experts and beginners—to take part in an icebreaker activity. The two teams spent 20 min getting to know each other by sharing their backgrounds and motivations for joining the garden. Then they briefly presented the results of their conversations to the group as a whole.

A brainstorming session followed using different colored Post-its and a sheet of cardboard to display them on. Three central questions were asked: "What would you take into the garden?" "What would you like to find in the garden?" and "What would you not like to find in the garden?" Participants were divided again into three small groups to allow for a more effective exchange of ideas and were then invited to stick the Post-its onto the cardboard. The research team arranged the Post-its into key categories highlighting the main issues. The answers to the first question were mostly about "knowledge", "skills", "enthusiasm" and "time". "Friendship", "fertile soil", "garden tools" and "experts" were answers to the second question. The third question provided a variety of reactions that included: "conflicts", "too many people" and "disorganization". The workshop ended with an invitation to the following one two weeks later.

Generally speaking, the participants were interested in the presentation of the research activities and there was good feedback on the interaction with the "Coltivando" gardeners due to their close connection with a similar experience. Discussion among the participants was made easier and interaction was positive thanks to the examples and best practices shown and because of the small team activities. Unfortunately, the time used for discussion after the first presentation was too long and impacted the following activities. Therefore, debate management was seen as a priority for the following workshops. Some participants left the workshops before the team activities because of the amount of sharing in the project; these people were not interested in the community concept of the garden but only in having an individual plot. Consequently, this was a stronger and more motivated group than the previous one.

Workshop 2: "**Roles and rules: the manifesto**". The second workshop was held on February 14th, 2015, with the participation of sixteen citizens.

To design this workshop we collected the results of the previous brainstorming activity, starting with the clustered Post-its. We found it very interesting that, despite concerns about the idea of a community garden, which led to the abandonment of the co-design process by some participants, expectations and wishes were expressed about the realization of a harmonious space to make new friends and reinforce existing relationships. We grouped the Post-it statements relating to the three questions to generate five main points for a draft manifesto. Together with the "9 × 9" association, we later connected to each point specific questions about the management and care of the garden that would define future regulations. In order to give continuity to the activities and having noted the importance for some gardeners (especially the elderly) to know in advance what the workshop would be about, we prepared a presentation for the beginning of the second workshop, which showed clearly that the whole process would be used to achieve the presented results and the following actions to be taken. In addition, due to the difficulties in the first meeting with the management of micro-groups of gardeners, we thought of a collective interaction method that would be easy to manage. Therefore, we provided a voting system to answer questions about the regulations: providing three possible answers for each question, we defined the opportunity for all the gardeners to register their preferred options simultaneously. We prepared flags for voting and decided on a specific time for a short debate at the end of voting, in order to make the participatory activity individual during the vote and collective at the final decisions.

The positive feedback on this second workshop was an influential part in the decision-making process by future gardeners, aided by some of the design tools previously mentioned. Therefore, some issues that were discussed were not wholly defined and the final decision was postponed to a later time.

Workshop 3: "**Layout**". The third workshop was held on March 28th, 2015 with the participation of thirty-three citizens.

This workshop was designed to produce an initial layout of the 5000 m^2 area of the garden. Following the second workshop, we assessed the results and summarized them in twenty rules to be shared with the gardeners. At the opening of the third workshop, we provided a report to each participant, allowing everyone to comment and add their own ideas and wishes regarding every rule.

Then we started the layout activities. Before the workshops, several meetings about the layout had been held with the "9 × 9" association. The issue was to decide which part of the garden would be the focus of the workshop since the city council call allowed for both the community area and the individual parts with only one restriction: those with a private allotment will have to join in and assist in the care of the community garden. Finally, we decided that the participation of gardeners would extend only to the co-design of the shared areas of the layout, in order not to create conflict and opposing views in the spatial definition of individual allotments. The results of the previous workshop relating to regulation defined that 70 % of the garden would be dedicated to individual areas, and 30 % to the community garden. Thus, following these guidelines we developed a map with about fifty individual parcels of two sizes (25 and 50 m^2), and two areas for the shared vegetable garden (about 300 m^2 each). Accordingly, we prepared two scale models of the space, one of which represented the whole area (scale 1: 200) while the other was used to represent the community garden (scale 1: 100). The latter was used as a tool during the workshops. Some small pawns were designed, representing different activities that could take place in the garden: lectures on gardening, an open-air dance hall, fitness area, butterfly oasis, greenhouse, herb orchard, relaxation area, picnic tables and playgrounds for children. The activity of placing the pawns on the model triggered a very useful debate among the participants.

Fig. 2 Workshop 2: “Roles and rules: the manifesto”. Voting for the development and sharing of the vegetable garden rules and manifesto

Finally, each participant was given some A3 sheets printed with blank garden maps to take note of the discussed layout and the size and positioning of the pawns. This allowed them to customize their own personal layout within a previously decided general framework.

The horseshoe set up of the classroom was very useful in focusing everyone’s attention on the physical mock up in the center. It also encouraged interaction and discussion among the participants. Participants highlighted the lack of information about the size and cost of the services to be put in the shared area so we provided quotes for these in subsequent meetings (Fig. 2).

4.1 Hardware and the Garden: “Il sabato della Bovisasca”

After the second workshop, we focused on the outdoor activities to involve future gardeners in-the-field in a co-creation session to have, as Sanders and Stappers state, “an impact with positive and long-range consequences” [10]. In March 2015, the research team led a workshop at the School of Design at the Politecnico di Milano to develop some design solutions for the Bovisasca garden. This workshop was part of the Temporary Urban Solutions master class and involved more than 50 international students. They were briefed with goals based on the city council's call and specific needs of the area: designing low-cost fences and participatory activities; finding solutions for water collection; designing the logo and name of the garden; and implementing a sense of community among future gardeners.

"**Piantastorie/Planting stories**". This is a red wooden bench where people were invited to tell stories connected to key local places, and, using the toolkit supplied, to create short video interviews. The kit included a picture of one of the local places and a seed to be planted in the garden to leave a memory of the interview. This activity became a web-series and it is now shown on PlugTV, the neighborhood social TV station.

"**Che ortista sei? Which gardener are you?**" In this design activity to make the citizens feel part of the garden identity, we started collecting insights about the Bovisasca area. Interviews, historical clues were developed as a fertile background for brainstorming, enriched with ideas and values related to the future: a community growing in parallel with the new vegetable garden. These were translated into three different styles of brands, as well as three respective "psychological profiles": "The Convivial", "The Explorer" "The Intellectual". The participants could discover their profile by answering a simple questionnaire based on a selection of printed colored cards. The player chooses one of the two garden types depicted for his/her particular profile, then plants it in the new vegetable garden soil. For this, handmade, recycled-wooden shovels were provided, on which the players could write their name and attach their chosen sticker. Along with the personalized shovels, three different kinds of flowers could be planted, to actually give root to the players' profiles. Thus, the garden began to be filled with flowers and this marked the start of the planting activity (Fig. 3).

"Beyond the boundary" A project to develop a border to delineate the community garden's area. The area is 5000 m^2 wide and the "fence" will be 500 m long, so a low- or no-budget solution is the most appropriate. For these reasons, the ready availability of a large quantity of material has to be taken into consideration. The construction of the fence itself aims to involve the future growers, stimulating their participation in the manual process: in this way, the collective activity starts from the very beginning and creates a bond among the co-growers. Plastic crates from the local fruit market are used to create the fence by joining them with connectors, and the set-up is explained via visual instructions for the participants to follow during the event (Fig. 4).

5 Conclusion and Future Steps

These activities resulted in the creation of the Bovisasca garden, which was aligned with the "campUS" research project timeline and supplemented the set of design tools to be used for the "Garden" work package for future activities.

Fig. 3 "Che ortista sei?", a design activity during "Il Sabato della Bovisasca" to start planting the garden with flowers and herbs

The first six months of the research project (Oct 2014–Mar 2016) were dedicated to the development of a strong relationship between the research team and the future gardeners' community through workshop activities. This allowed the in-the-field activities in the garden area to begin and design skills and competences to be shared with the participants. Using the campus facilities for the indoor workshops eased the incubation process for the community: getting to know each other, coming to shared decisions, defining environmental/spatial issues. After each workshop, the research team collected feedback on the activities to make adjustments for subsequent workshops and to define a better set of tools that would be shared later.

After the "hardware" and "software" activities, the research team completed a handbook composed of the various tools used in the workshop: from the brainstorming to the voting, from the spatial layout to the fence construction. This can now be downloaded from the "campUs" official website (www.progettocampus.polimi.it) to help future community groups begin the process of creating a community garden.

Fig. 4 "Beyond the boundary", a design activity during "Il Sabato della Bovisasca" to build garden fences by using second-hand plastic crates (used to sell vegetables and fruits) from the local market

The "campUs" research project is still ongoing. After the activities described above, the "9 × 9" association decided to spend the following months developing the private allotment part of the garden instead of the community one. This caused a delay in the construction of the shared areas, which is now forecast for Spring/Summer 2016.

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The Digital Crystal Ball: A Service Recommendation System for Designing Social Participation Experiences Among the Elderly

Koji Kitamura, Yoshihisa Shirato, Mikiko Oono, Yoshihumi Nishida and Hiroshi Mizoguchi

Abstract Social participation contributes to a higher quality of life for the elderly. However, an effective way to promote social participation has not been fully established. Conventional technologies for service recommendations have several limitations, such as a lack of or limited consideration of lifestyle, health status, physical capabilities, and desired experiences of the elderly for a recommended service. In this study, with the objective of promoting social participation among the elderly, we developed a service recommendation system called the "Digital Crystal Ball" through the establishment of two functions. The first function is to recommend social services based on the subjective experiences that the elderly want, and the second function is to suggest available transportations in order to utilize the recommended services in consideration of the physical capabilities of the elderly. Here we describe the details, experience, and usefulness of our service recommendation system in Minamisouma, a city in Fukushima Prefecture in northern Japan.

Keywords Daily life · Social participation · Service recommendation · ICF

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1 Introduction

Japan is currently trying to cope with the rapid aging of its population. Several different types of social services aiming to promote healthier lives among seniors, such as adult day care and exercise programs, are available. However, only 10 % of seniors aged 90 years and older live independently. About 20 % of male seniors require some type of support or care from others by the time they reach 60 years of age, and this increases to more than 70 % by the time they reach 70 years of age [1].

Social participation, such as interpersonal interactions and participation in community activities, contribute to a higher quality of life for the elderly. The health risks among isolated elderly who do not engage in any social activities are equal to those of individuals who smoke or drink daily [2]. Recent epidemiological studies have shown higher levels of social isolation among the elderly are associated with worse unadjusted survival curves [3]. Moreover, elderly individuals who engage in higher rates of social participation report having better subjective feelings of happiness than the isolated elderly [4].

One way to promote social participation among the elderly is to develop a new technology capable of recommending available services, places, or social events based on personal needs and preferences. However, conventional service recommendation technologies have several limitations, including a lack of or limited consideration of one's lifestyle, feelings, or health status, such as suffering from a back pain or a disability, as well as a lack of transport arrangements for a recommended service. Therefore, a new technology for recommending appropriate and attentive services for the elderly is needed.

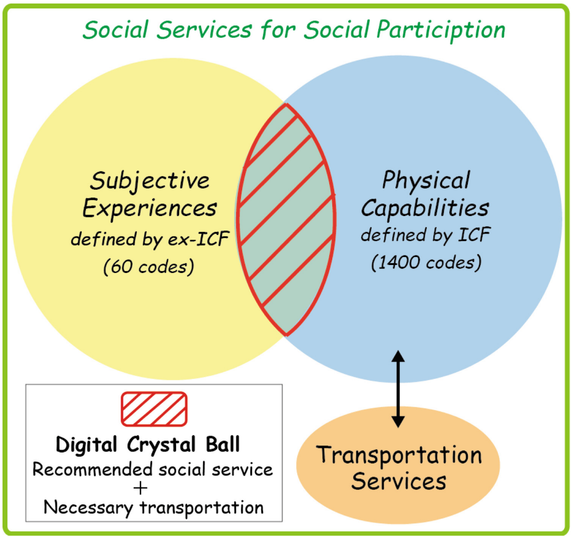

Fig. 1 Study overview

In this study, we developed a service recommendation system called the "Digital Crystal Ball" through the establishment of two functions. The first function is to recommend social services based on one's subjective experiences and physical capability, and the second function is to suggest available transportations in order to utilize the recommended services in consideration of one's physical capabilities (Fig. 1). To evaluate the usefulness of the developed service recommendation system, we tested it in Minamisouma, a city in Fukushima Prefecture in northern Japan.

2 Proposed Service Recommendation System

2.1 Outline of the Integrated Regional Service Recommendation System

In this study, in order to recommend good social services available in the region to the elderly, we developed a service recommendation system with the following two functions: proposing social participation based on one's experience, and proposing integrated services. The configuration of the proposed service recommendation system is show in Fig. 2.

The function for proposing social participation based on one's experience uses two databases: an experience database and a social services database. The experience database accumulates the subjective experiences of service users, while the

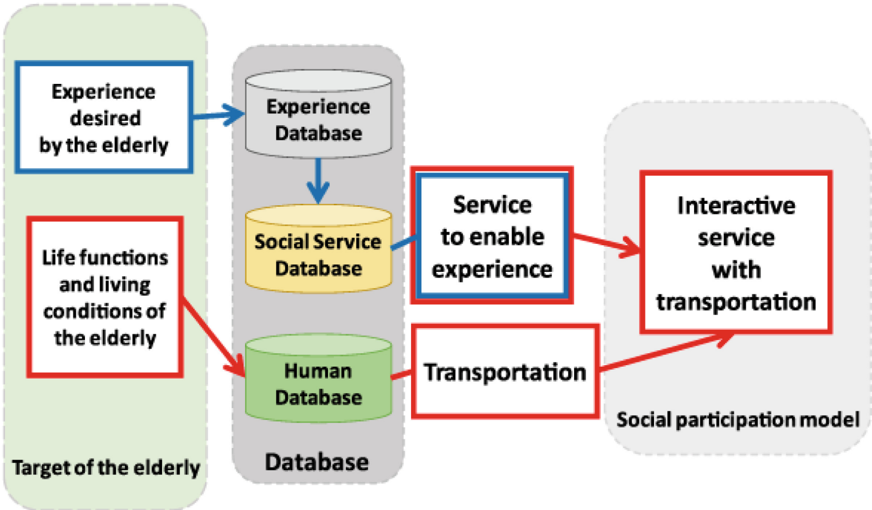

Fig. 2 Configuration of the service recommendation system

social services database accumulates the social services available in the region. The discrepancies between actual and expected experiences with social services are then calculated and the recommended services are provided.

The function for proposing integrated regional services identifies and compares the skills needed to utilize a service and the skills possessed by the user. This function suggests social services one might be interested in and provides information on the types of transportation necessary.

2.2 *Functions of the Proposed Social Participation Based on Experience*

To recommend social services based on one's feelings, it was necessary to develop a system that can choose possible social services based on subjective experiences. Our system consists of an experience database and a social services database.

After using social services and engaging in social activities, seniors have different experiences and opinions. In this study, we used the World Health Organization's (WHO) International Classification of Functioning, Disability and Health (ICF) [5] and its extended codes of subjective experience developed by the National Institute of Advanced Industrial Science and Technology [6] to classify social services and subjective experiences among the elderly regarding their use of social services.

The ICF, which is part of the WHO's family of international classifications, focuses on health and functioning rather than on disability. There are over 1400 indices, and the ICF is utilized in the insurance, nursing, welfare and education fields [7].

The Experience database accumulates the subjective experiences of service usage classified by the ICF based on feelings and actions. For example, if one has the experience of "*Being delighted to finish in second place in the community golf championship*", this will be classified as "*ex.331.1: Being admired in the community*" from the perspective of one's feelings, and "*a5702: Maintaining one's health*", "*a445: Hand and arm use*", and "*a450: Walking*" from the perspective of one's actions.

Similarly, the social services database accumulates ICF-based social services that can be used by the elderly in their daily lives. For example, "*a restaurant*" is classified as "*a550: Eating*" and "*a630: Preparing meals*".

We developed a function that calculates a data-based similarity coefficient (the Jaccard similarity coefficient [8]) between ICF codes for actual experience and the expected experience from social services and then recommends matches. The elderly enter their desired experience and then the related content as defined by the Experience database is displayed, as shown in Fig. 3. The output recommends services that enable the elderly to more easily engage in social participation.

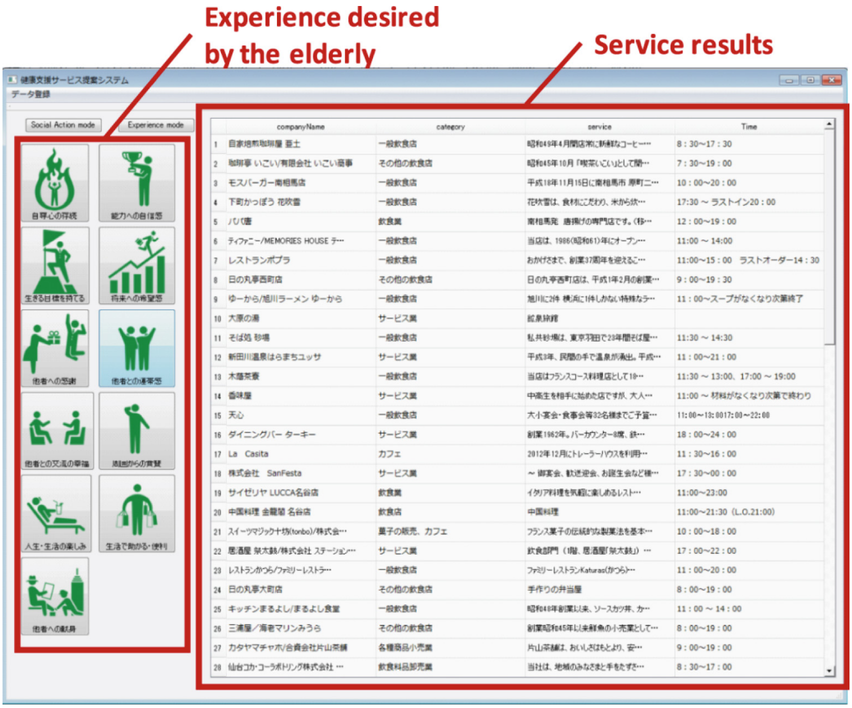

Fig. 3 Desired experiences of the elderly and service results

2.3 Functions of the Proposed Integrated Service

The services that promote social participation among the elderly are then applied to a social participation model. This model combines multiple services to promote social participation. When the elderly wish to use a certain service or visit a certain location, such as stores, restaurants, or other facilities, they need to know what types of transportation are available for access. This function suggests both social services one might be interested in and the available forms of transportation necessary to utilize them.

When suggesting available forms of transportation, it is essential to consider the lifestyle, health status, and skills of the potential user. Therefore, this function uses a human database that compiles the results from two questionnaire surveys: the Medical Outcomes Study 36-Item Short-Form Heath Survey (SF-36) [9], which assesses overall health, and the Instrumental Activities of Daily Living (IADL) scale, which is commonly used in field of nursing to assess daily living skills.

The way in which this function suggests and ranks the transportation needed for services is shown in Fig. 4.

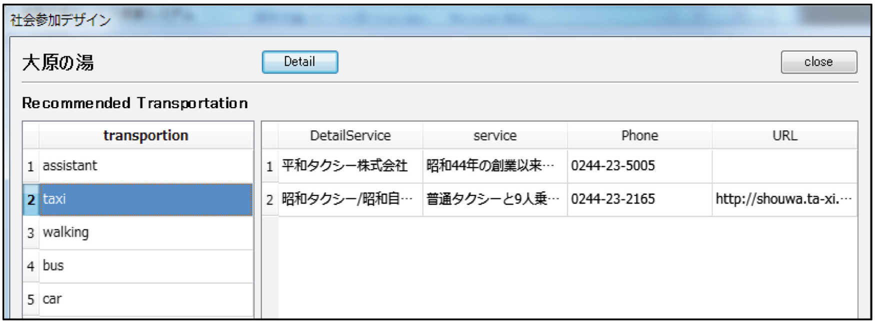

Fig. 4 Types of necessary transportation available for selected services

3 System Application to Support the Elderly in Minamisoma

In order to evaluate the feasibility of the developed system named “Digital Crystal Ball”, we entered data from 14 elderly persons aged between 76 and 91 years regarding their experiences in daily life. These experience data were collected through interviews. In addition, we conducted the SF-36 and IADL surveys to measure their health status. We also registered 367 social services available in Minamisouma City into a social service database. The registered social services included restaurants, cafes, supermarkets, bakery, bookstores, transportation services, day care centers, beauty salons, and NPOs. We created a map that indicated locations of the registered social services (Fig. 5).

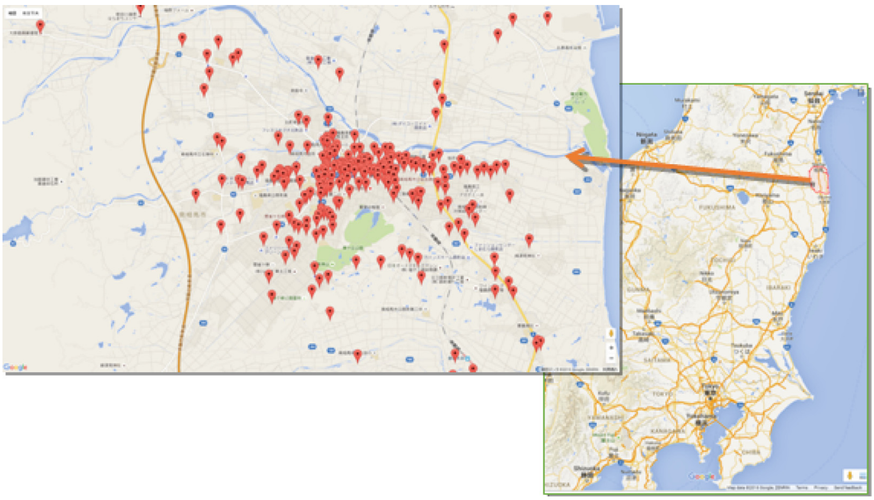

Fig. 5 Social service location map

Here, we will discuss one sample result obtained by the Crystal Ball. Among the 14 elderly persons, there was 81 years old woman who looked for a place where seniors could go and enjoy talking with friends. We classified her wish as "*ex.314: feels one gets along well*". When we chose this experience code in the system, the system searched past activities that other elderly persons had in the past based on the experience code. As a result, the system found matching activities such as "*Going on a trip to the hot springs*", "*Talking and laughing with friends at a restaurant*", and "*Talking on the telephone with my friend for hours*" and showed the following 67 social services: 27 restaurants and cafés, nine types of lessons and social events, seven supermarkets, five hotels and hot springs, and others including amusement parks, karaoke facilities, and bowling alleys.

From our interview, she has a physical issues such as "*cannot walk long distances*", "*has blurry vision*", and "*has shaky hands*". The Crystal Ball indicated transportations necessary for social participation in consideration of her physical functioning. Taxis and other transportation services with an attendant were ranked higher than buses and walking due to her limited mobility.

4 Conclusions

Engaging in social participation is essential to ensure a higher quality of life for the elderly. Therefore, we proposed a new integrated regional service recommendation system based on the health status of the users. We developed three databases: a social services database that can search for social services based on the WHO's ICF; an experience database that accumulates subjective experiences of service use based on the extended ICF; and a human database that accumulates results from two questionnaires (the SF-36 and the IADL). In this system, which we named the "Digital Crystal Ball", service recommendations are provided based on subjective experiences and available services. Based on results from entering data on elderly residents of Minamisouma, a city in Fukushima Prefecture in northern Japan, the usefulness of the system was confirmed. In the future, we plan on testing the system on the elderly in other communities and investigating whether it leads to improvements in their level of social participation.

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Handrail-Shaped IoT Sensor for Long-Term Monitoring of the Mobility in Elderly People

Yoshihumi Nishida, Yusuke Takahashi, Koji Kitamura and Hiroshi Mizoguchi

Abstract Cognitive and physical functions gradually decline because of aging. To support healthy and safe living of elderly individuals, a system that can monitor their activities of daily living is needed. This paper proposes a handrail-shaped sensor as a new Internet of Things (IoT)-type sensing system for long-term monitoring of the mobility of elderly people. The handrail-shaped sensor detects changes in mobility using information on movement velocity and the degree of dependence on the handrail. To evaluate the effectiveness of the sensor, we first assessed the accuracy of estimating the position of the load applied to the handrail in our laboratory. We then field-tested the handrail sensor in the home of an 88-year-old woman. The experimental results show that the handrail sensor can estimate the walking speed as well as the grasping position of an elderly person in an actual daily living environment.

Keywords Iot sensor · Handrail sensor · Healthcare · ADL monitor · Location sensor · Walking speed monitor

1 Introduction

Cognitive and physical functions gradually decline because of aging. Supporting healthy and safe living of elderly individuals requires a system for monitoring their activities of daily living. Internet of Things (IoT) sensors [1] have the potential to

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detect changes in an elderly individual's physical abilities, which could ultimately facilitate providing the necessary interventions and treatments. The market for smart homes, with sensor-supported healthcare, as well as home safety and security, is projected to increase over the next 10 years [2].

However, conventional sensing systems have the following drawbacks: wearable sensors need to be worn and turned on and off manually, and camera-based sensors are plagued with personal privacy issues.

The Japanese Ministry of Health, Labour and Welfare [3, 4] recently created a "basic checklist" to assess a person's necessity of support by checking activities of daily living (ADL), and one item of the checklist pertains to the use of a handrail. However, handrail use in Japan is currently determined by paper questionnaire or web-based survey. Detection of subtle changes in handrail use via long-term monitoring is essential for early detection of declines in physical function.

Thus, we proposed a handrail-shaped sensor as a new IoT-type sensing system for monitoring the mobility of elderly people. This IoT-type sensing system does not require user's efforts like on-and-off switches and can protect privacy, namely it does not have any of the drawbacks of conventional sensing systems. This paper describes the development of the handrail-shaped IoT sensor and presents experimental results showing its effectiveness.

2 Development of the Handrail-Shaped IoT Sensor

2.1 Configuration of the Handrail-Shaped IoT Sensor

Figure 1 shows the configuration of the sensor, and Fig. 2 shows the actual handrail-shaped IoT sensor. The sensor comprises an ordinary wooden handrail, iron plates with attached stain gauges, a data collection device, and a personal computer (PC).

When the user leans on or grasps the handrail, the iron plates bend slightly. The strain gauges attached to the front and back of the iron plates detect this slight bend, and the software on the PC uses the signals from the strain gauges to determine the location and magnitude of the load applied to the handrail.

Load calculation. The developed sensor calculates the perpendicular load applied to the handrail. The sensor can also indirectly assess a user's walking ability by measuring the degree of dependence on the handrail quantitatively because the measured load reflects how much the user depends on the support of the handrail to walk. As mentioned previously, the degree of dependence on a handrail is an important indicator of independent living. Our sensor can measure this degree of dependence directly and quantitatively, which is difficult to do using other sensors, such as cameras.

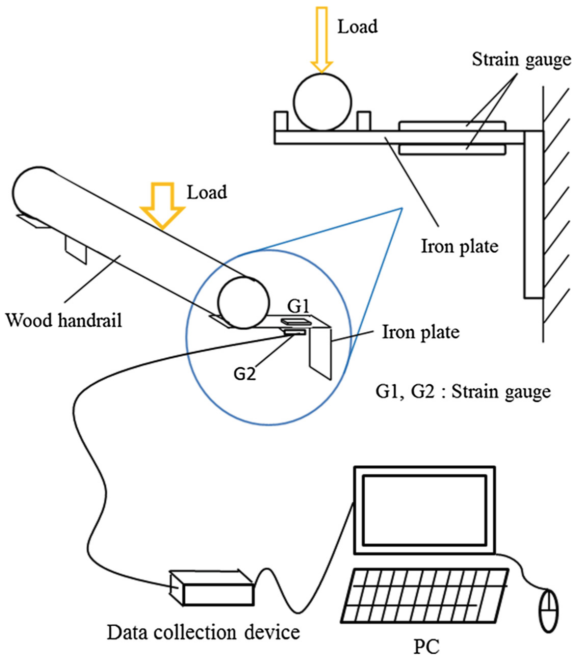

Fig. 1 Configuration of the handrail sensor

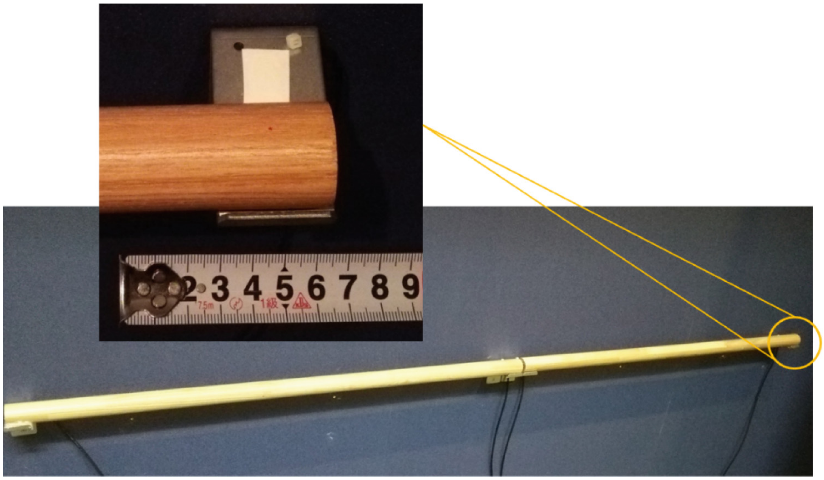

Fig. 2 Picture of the handrail sensor

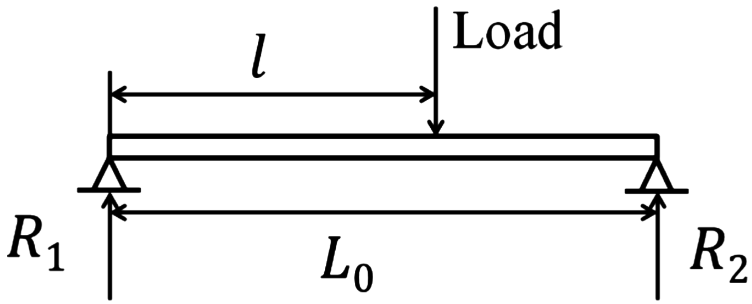

Fig. 3 Proposed handrail sensor modeled as a simply supported beam

Grasp position detection. To detect the user's position and estimate his or her walking speed, the handrail sensor was developed based on the theory of a simply supported beam. Specifically, the handrail can be modeled as a simply supported beam with two points of support, as shown in Fig. 3. Consequently, the distance from one end of the handrail to the position of the applied load can be calculated using the forces at both ends, as show in Eq. (1).

$$l = R_2 L_0/(R_1 + R_2), \tag{1}$$

where l indicates the distance between the position of the applied load and the right edge, R1 and R2 are the applied loads at the edges, and L_0 is the length of the handrail as shown in Fig. 3. The walking speed can be calculated from the change of the position of the applied load and its time difference.

3 Evaluation of the Handrail Sensor

We conducted an experiment to confirm the position estimation function of the handrail sensor by comparing the estimated and actual values for the grasping position.

3.1 Method

In this experiment, we asked a volunteer aged 22 year-old to walk along the handrail and grasp it with one hand at positions P1, P2, P3, and P4, as shown in Fig. 4, and then estimated the grasping positions using an estimation algorithm. We marked positions P1–P4 on the handrail using 10 × 10 mm stickers.

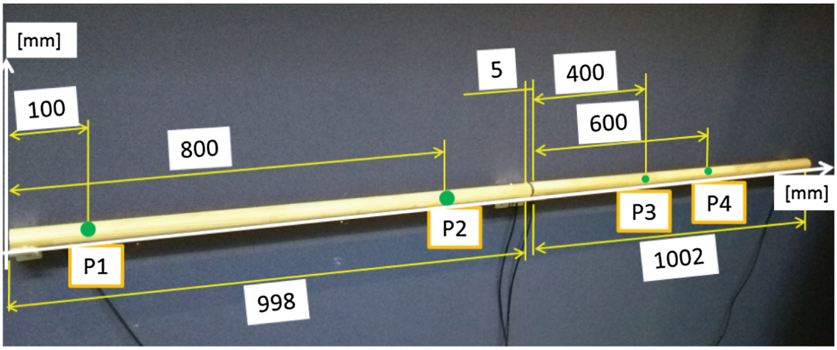

Fig. 4 Experimental condition

3.2 Results

Figure 5 shows a comparison of the estimated and actual grasping positions. The figure shows that the maximum error of 71.6 mm was at P1.

If the difference between the estimated value and the actual value was ≤80 [mm], which is the average width of an adult male hand [5], we considered the estimated value acceptable. Thus, the maximum error at P1 was within the acceptable range.

We think that the measurement error stems from individual difference in wooden materials and fixation between handrails and the walls.

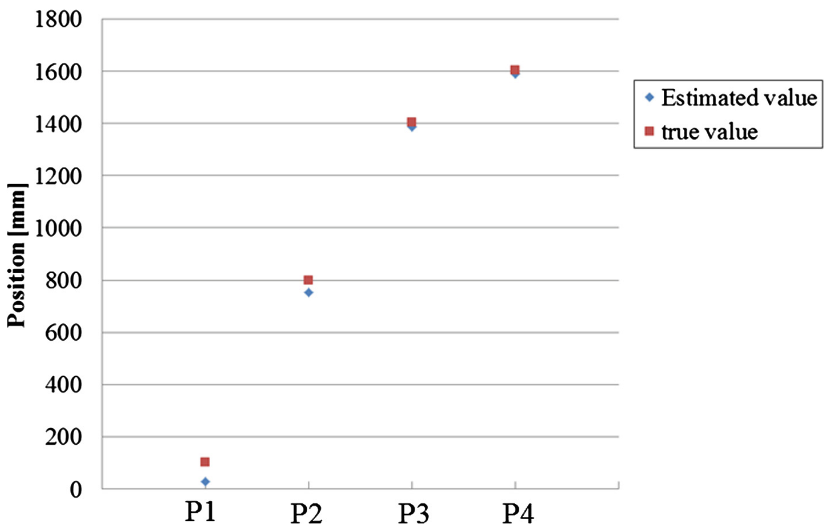

Fig. 5 Estimated and actual positions of the load applied to the handrail

3.3 Field Test in Actual Home

We tested long-term monitoring using the developed handrail sensor installed in the home of an 88-year-old woman. Figure 6 shows the experimental device installed along a hallway in her home.

Figure 7 shows images of the woman using the handrail. We successfully recorded 480 h of consecutive data.

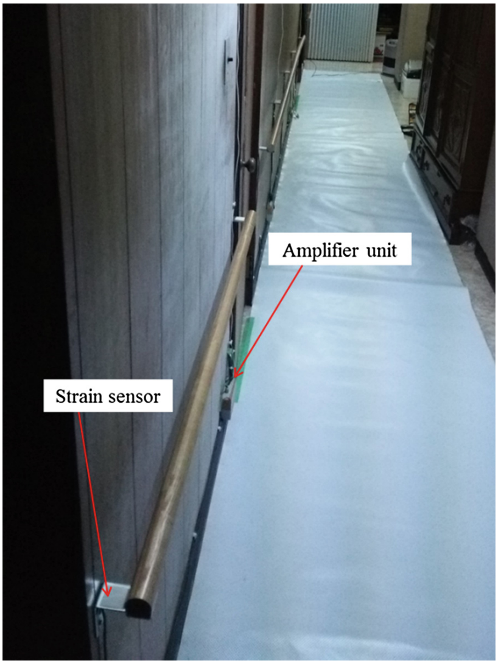

Fig. 6 Experimental handrail sensor installed in an actual home

Fig. 7 Images showing an 88-year-old woman using the handrail sensor installed in her home

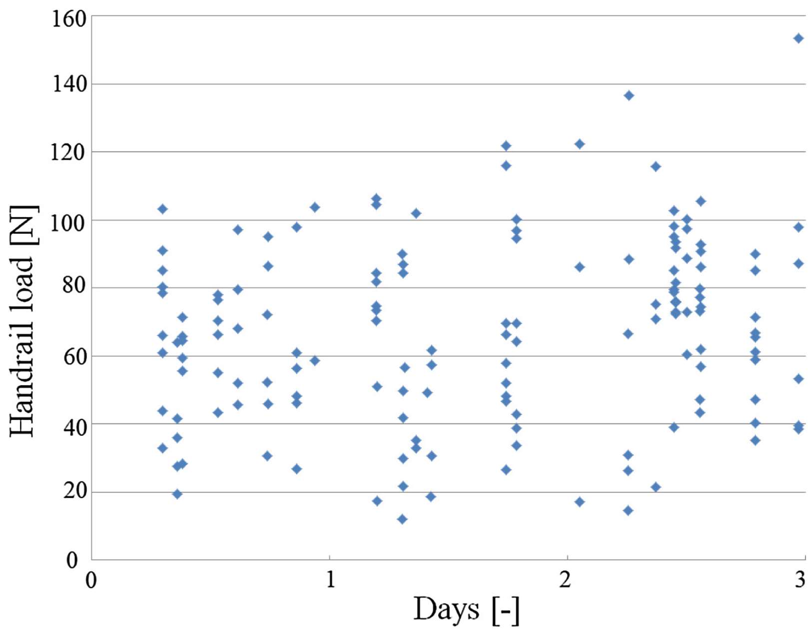

Fig. 8 Load on the handrail during the field test in actual home

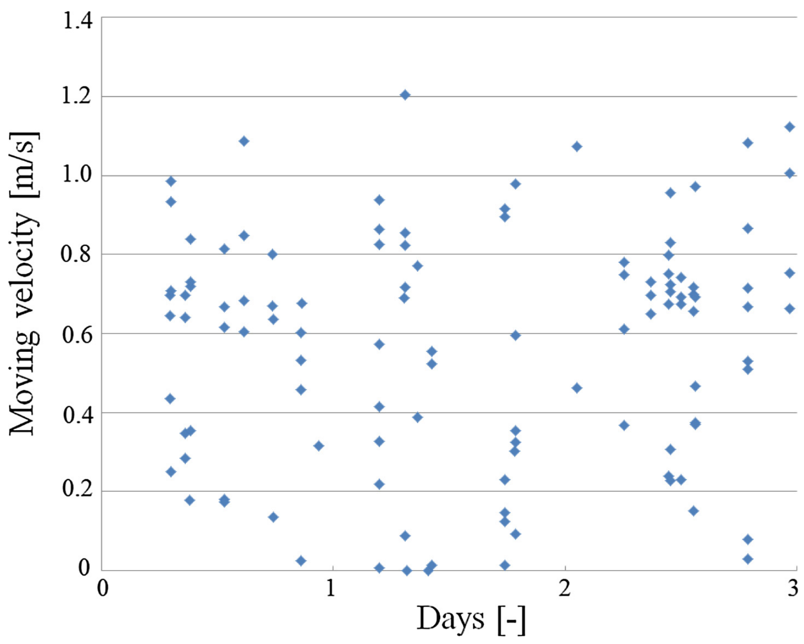

Fig. 9 Movement velocity determined during the field test of the handrail sensor in actual home

Figure 8 shows the distribution of the handrail load over 3 days, and Fig. 9 shows the distribution of the movement velocity over 3 days. The results indicate that the sensor is capable of monitoring the handrail load and walking speed of an elderly person in an actual daily living environment.

The average walking speeds for each of the 3 days are 0.57, 0.48, and 0.63 m/s. The average handrail loads for each of the 3 days are 62.0, 62.1, and 73.7 N. Thus the system can detect slight difference in the walking speed and the handrail load.

4 Conclusions

A handrail sensor was developed as a new IoT-type sensing system for monitoring the mobility of elderly people. The developed sensor can noninvasively monitor the degree of dependence on the handrail, the position of an applied load, and the walking speed of the user. A successful field test of the handrail sensor was conducted in the home of an 88-year-old woman, providing 480 h of consecutive data. Future work will include conducting interventions based on long-term data obtained using the handrail sensor, and evaluating the effect of these interventions.

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