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Published online: 03 Jul 2020.

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A review: accessible technology through participatory design

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ABSTRACT

Purpose: The literature review presents a conceptual participatory design through accessibility technology solutions, considering the design experience to be an essential factor in communication processes. Technologies must assess a wide range of disabilities based on characterisations that helps daily activities. This work includes collaboration concepts to assist in the development of accessible technology. Collaborative design requires the fostering of communication between actors involved in the design process.
Methods: This work implemented with a protocol of guidelines developed by a group of experts in disability research. The relevant literature is included and assessed based on three categories: accessibility, assistive technologies, and participatory design.
Results: A knowledge gap can be identified: the development of assistive technology processes should enhance the voice of participants and consider their ideas, desires and needs.
Conclusions: Multidisciplinary communication is necessary to identify problems and propose solutions, and it is essential that people with disabilities collaborate with experts from a range of disciplines to identify problem-solving patterns.

➤ IMPLICATIONS FOR REHABILITATION

- A participatory design can develop a holistic understanding of the participant's motivation and rehabilitation needs. This has provided a grounded basis to offer information about the assistive technology design.
- A participatory work provides information about the technology design which may finally result in a better understanding of rehabilitation, other types of home-based healthcare or the gamification for rehabilitation.
- The rehabilitation professionals can explore requirements of a customised technology for users, which allows to transfer knowledge about disabilities and skills in rehabilitation to people with disabilities, their families and communities.
- The notion of a research problem in rehabilitation can be re-evaluated through a participatory design process that attempts to capture the subjective experiences of persons with disability.

Introduction

In the world today, positions regarding disability are presented in a range of distinct scenarios. From a social perspective, it becomes evident that communities, minority groups, politicians, academics, and researchers, among others, seek to identify problematic issues in an attempt to improve the quality of life of people with disabilities in the context of real life practices.

Accessible design depends on resources that can help identify the kind of user, for example, through listening directly to the participant. People with disabilities who undergo the classification of ability loss are defined as able-bodied, moderate or severe in different situations [1], allowing objectives to be set according to their disability level and the provision of suitable assistive technology. Likewise, accessible design requires an understanding of the context of, and variation in, population ability and how these interact with products.

Similarly, a real-world situation provides scenarios to identify problems that arise during different daily activities. These situations can evaluate and promote the goals and needs of different people, and also include ideas and thoughts from individuals. Additionally, people can assume the role of expert users and become expert users in their own life experiences [2].

The development of technologies has established a methodology for new platforms to communicate, plan, model, build and deploy [3], but technological changes need continuous innovation based on the most recent advances. The participatory design methodology establishes communication as a dialogue among all participants, involving all users in the problem-solving process.

Methodologies based on participatory design consider the degree of user participation, such as the co-design method which involves the full participation of the person-user in all design processes [4]. Likewise, the person-user with special needs can take on the role of expert based on their life experience of their respective disability [2]. The primary purpose of participatory design is to provide efficient solutions through supporting the ideas of and taking inspiration from the design group that includes the person-user. Likewise, participation based on dialogue allows the people-users to engage in collective ideation

and construction processes. This literature review explores these themes to help improve understanding of a broad range of disabilities from a technological perspective, and with participatory-processes. The article contains results from case studies that explore solutions and applications aimed at developing products or services for people with disabilities. Additionally, a conceptual literature review references holistic experience in participatory design. The databases and criteria are selected and used to determine how participatory design and accessible design combine concepts and methods; these criteria could offer clarity to the assistive technology of products or services, regarding the workflow stages from accessible patterns.

Methods and materials

This process involves a systematic review of conceptual literature references, including scientific papers, to determine relevant case studies in the field today. To this end, a protocol was established, following the guidelines developed by a group of experts in disability research [5].

Literature review strategies

The conceptual reference review strategies used in this article include peer-reviewed scientific papers to determine case studies. Keywords were identified by experts in disability studies, as well as in design and assistive technology.

These keywords included accessibility, assistive technologies, participatory design; the process was completed in November 2018. The digital databases selected were JSTOR, ScienceDirect, Web of Science, Springer, IEEE Xplore and ProQuest.

Based on literature review protocol, the first stage was to select databases to search for literature from which the title and abstract were scanned. The criteria search filters were defined based on the highest to lowest number of citations, and a timeframe of five years of publication. However, that was dependent on the search parameters of the database. From the total results found, the first 100 paper results were taken into account to avoid information saturation. Next, abstracts were reviewed in order to find relevant papers to download and classified by the inductive thematic codes that emerged.

The thematic codes that emerges were plotted on a chart to cross-reference documents, thus identifying relevant papers through a deductive process. For this process, the -qiqqa- software [6] was used to implement a content analysis of the literature selected.

The following sections explore theoretical considerations and case studies and notes on how to understand participatory design and accessible design from a technological approach to identified correlations are also included.

Experience design for memorable experiences

Experience design is approached from two fields: marketing and user interfaces. According to Pine and Gilmore [7], the term "experience", as applied in marketing, relates to the economic development process for the commercialisation of products and services. Later, these same authors defined the so-called "experience economy", which distinguishes intangible services and tangible goods from memorable experiences. However, that proposal has a weakness in decision-making strategies concerning new markets in relation to the quality of products or services [8].

As a result, Pine and Gilmore showed an analysis of new markets with a strategic approach for the commercialisation of products that works by identifying categories based on people's experiences. The data collection instrument was a paper logbook, in which people had to record their past and present experiences, focussing on their current quality of life.

The second approach comes from the concepts and standpoints in the field of interface design and emotional design [9]. Moreover, user experience studies have used concepts from computer science in fields such as usability and human-computer interaction. This perspective considers the senses, hearing, touch, taste, smell and sight, or as Desmet and Hekkert [10] called it, the aesthetic experience, regarding the product's ability to seduce one or more of the senses.

Different clues are used, for example objects or human presence, to increase the remembrance of an experience [11,12]. Therefore, these clues act as triggers for the memorable experience to prompt the use of a product or service. Correspondingly, a "sweet spot" is an expression equivalent to the significance [13–15]. Different methods assess the expressive characteristics of the user as emotional, behavioural components based on the product experience. The emotional design method considers factors from the discipline of psychology, where emotions describe changes in the person-user [16].

Some workflows undertake stages to consider the cultural identity of people in the development of products or services. In this way, the proposal by Press and Cooper [13] establishes four cyclic phases. The first phase -life context-, identifies cultural dimensions oriented to social life such as values, beliefs and shared meanings expressed through material objects, services and activities [11,13]. The second phase -engagement-, considers the perception of the situation and must hold interest the ideation process that contributes to maintaining the people's attention. In the third phase -experience-, the product or service designed becomes part of the welfare of people, with a degree of satisfaction based on real experience. The last phase -resolution-, involves reflection on experience satisfaction, assessed from the expectations for the product or service.

The fields of user interface and marketing relate to high-quality experiences for the person-user. Research process must perceive a situational context from which features associated with products or services to be designed emerge. Additionally, the main issue to improve user experience is communication with the person-user throughout the design process.

On the other hand, some senses may be absent due to natural or accidental causes. Thus, the experience would be fragmented and intensify the senses individually [11,16,17], and these can determine the level of experience in categories such as physical, social and self-presence interactions with the activities performance [12]. Likewise, interactions based on technology use different means of perception, such as a virtual presence, to stimulate sensations from virtualised systems.

Distinct methods of participatory design

Active participants have a voice in the design process. As such, they contribute to the design process. The degree of participation relies heavily on the research method proposed. Similarly, user-centered design is another methodology that needs identification parameters to enable the researcher to interpret the data. Also, an iterative and generative user intervention [18] allows the conceptualisation and development of a product or service. Some participatory design methods include a facilitator role in order to

maintain the communication between the design group participants [19]. The researcher and the user become central components in the process through toolkits that allow participants to express their ideas and thoughts [4,18].

Different design methodologies, such as user-centered design, consider a person as an informant-user to test prototypes for listening to or observing a product or service experience. On the other hand, participatory design allows an understanding of holistic features about the interests, needs and preferences of the person-user [18]. Data collected becomes the input of the design process, such as parameters to co-design the product or service prototype. The ideation process establishes an active intervention from the design ideas group, looking to empower the person-user based on their expectations and needs, and on expert points of that consider key concepts or past experiences [4,20,21].

Therefore, participatory design involves users participating in a co-design method, with dialogue being the primary tool throughout the design phases. Understanding the person-user and building empathy between participants is crucial during the entire design process. Furthermore, both the expert and the person-user are regarded as equal partners in group design, and whose shared experiences in the design process imply an interdependence of collective work.

By focussing on people with disabilities, co-design may be used to facilitate the ideation, adaptation and assessment of a technological product or service intended to improve people's accessibility within their real context situation. This process may be useful as an answer to complex problems, and it is crucial to keep in mind that it is not a linear process. Several iterations must be considered during the design process as multiple variables of problems emerge. Reflection during the process requires commitment from the complete design group.

Furthermore, design groups formed by multidisciplinary participants have registered positive results [22]. To solve multidisciplinary product problems, they must be deconstructed into more straightforward and flexible sub-problems. Thus, distinct viewpoints can merge towards the most effective solution. For instance, research has evaluated the difficulty of opening screw top jars with reduced mobility hands; that process is assisted by prototypes to facilitate efficient completion of the task [23,24].

From the aforementioned perspective, the co-design method seeks to integrate the user's voice into the design process. The person-user role enables dialogue, which helps participants express their opinions and ideas about their experience, as in the cases of initiated design [25] or diffuse design [26]. On the other hand, participation may be passive, whereby individuals are not directly involved in the process of designing the activity, instead serving as observers and listeners. In contrast, active participation involves the participant's unique ideas based on their own life experience [15]. Moreover, the facilitator role must promote collaboration among the different participants [27], so that involvement in this process can change from passive to active.

Experience as a holistic unit

A holistic perspective must interpret people with special needs by understanding the phenomena within the context of their individual lives. Patterns based on goals and connected product-related experiences can be defined through a three-level hierarchy: the Why? focuses on goals to be established; the What? address the concrete outcome a person-user wants to achieve; and the How? provides the opportunity and motivation to accomplish these goals [28]. These three levels focus on a cultural component of the people. New experiences are necessary to seek alternatives in aspects such as labour, sports, housework, and everyday tasks. However, it is complex to think about expectations and wishes for improving well-being because each person thinks and judges subjectively.

Therefore, experience patterns are divided into three phases, anticipation, event, and cooling, which could determine the representation of experience. A storytelling activity can be interpreted as a self-report because experience patterns include units of analysis such as competence, stimulation, motivation, autonomy, popularity, meaning, safety, and physical effort [28,29]. Likewise, Bacha [30] argues that practicing reflexive narratives has shown how story-based experiences could be used as data to establish categorisations. The author finds multiple holistic characteristics that emerge from the autobiographical story [31].

Emotional design can perceive positive or negative states that are collected during an activity, and interpret the flow of user experience [32]. The flow of experience components allows the collection of self-reported data in order to recognise emotions. Intrinsic and extrinsic motivations allow for associations, objects and environment based on past and present memorable experiences [11,17].

This paper has introduced experience concepts with multiple threads in the design processes. In this regard, the foundation begins with positive experiences that intervene as a symbolic presence and as experience clues [7,17]. Likewise, the experience presented as a motivational and emotional unit can be collected in different activities. The concept of experience design determines personas as user archetypes that could represent behaviour patterns which relate person-user characteristics in a real context activity. Regarding this, some experiences are ongoing, and some are indefinite. However, experience design sets boundaries [14] in order to establish a new experience.

In summary, lifestyle must be understood through people's daily activities in order to propose a problem-solving product or service. The visceral experience of its users must be considered to identify the most effective solutions. Methodology design must consider the voice of the people based on their capabilities and life experiences. These concepts are also associated with maintaining the people's interest and with handling products or services focussed on a holistic unit in the design process.

Accessible technology design

The design practices oriented to solve problems for people with disabilities as a consequence of the war in 1950, began around the discussion of what was accessibility and how it should be treated. The accessible design concept emerged on the base of paradigms of disability, with several reflections aimed at assuring people with disabilities the same opportunities to contribute to society. Regarding the development of assistive technologies, it was essential to improve the well-being and quality of life of individuals. Therefore, it was vital to establish parameters for design approaches and standards regarding communities with disabilities [33,34].

One initiative called "barriers-free" disrupts physical obstacles that obstruct the free movement of wheelchairs [33]. Consequently, standards and laws for building accessible environments were implemented. Subsequently, in 1961, the American National Institute of Standards (ANSI) published the first version of ANSI A117.1 - Accessible and usable buildings and facilities [34].

Design manifested possibilities for accessibility approaches to be part of society-oriented construction processes for products and services. Story [35] mentions three approaches to accessible design: Universal Design (UD) integrates accessibility guidelines and principles from the beginning of the design process in order to develop suitable objects and spaces for any person.

UD contains others two approaches that are intersected, adaptive design which presents the possibility of a redesign for any person, and transgenerational design which focuses on the changing anatomical or functional structure of people as a consequence of age. Likewise, accessible design, also called inclusive design in terminology used principally in the United Kingdom, as described in the British Standard on Managing Inclusive Design, emerged from the normalisation of the idea that the design of products and spaces should be as inclusive as possible [34,36].

An aspect of comparison between UD and assistive technologies is based on the principle of flexible use of UD. This purpose attempts to maximise usability based on the design for all [34]. On the contrary, assistive technologies designed for a specific audience, and these do not consider the design of objects and environments to be used equitably and with accessibility to all people. Specially, this applies in cases of high levels of disability, where the people with this condition need assistance from a device or another person. However, a participatory design can bring these two approaches into one framework called *design for everyone* [37]. From a holistic unit, the author implements the do-it-yourself (DIY) methodology to develop assistive technologies focussed on designs of low cost for the development of technology.

Technology has an essential role in supporting people with disabilities and facilitating difficult or impossible activities. Furthermore, assistive technologies may be designed and developed with low-level technology (mechanics) or high-level technology (electromechanics or computer-based) for products and services that increase sensory, low ability and functional losses [38,39].

In this sense, these technologies extend the capabilities of people with disabilities. In this regard, Jones and Pal [40] present ethnographic information in the context of the civil war in Sierra Leone. Social model approaches infer negative attitudes, stigmatisation, and obstacles towards labour, educational and political participation. The authors describe a social action solution focussed on the population of a responsible society facilitating the participation of people with disabilities. Technology-amplified capabilities emerge from low-cost devices used by people with disabilities in communication processes, allowing them to reduce inequality and overcome the social dampeners that hinder their participation in society [41,42].

A social theories perspective based on empowerment through technological tools and on computer ethics, Johnstone [43] presents characteristics of technology as seen from the field of ethics. This outlines two roles, firstly design ethics, which consists of enhancing the ability to change the actions of people and should be objective regarding how people will use the design solutions, and secondly, the adaptation of technology to facilitate actions in their real context.

Another role, focussed on ethics, considers how to use technology to prevent abandonment. The expansion of people's capacities to use a resource represents a new alternative to dignify the person and take into account their human rights. The human capabilities approach developed by Amartya Sen and Martha Nussbaum describes the capabilities and functionings focussed on well-being, quality of life and human freedoms [44–46].

On the other hand, Vanderheiden [47] proposes three approaches to accessibility. Firstly, people changing their physical appearance as a result of medical intervention, surgical or therapy; Secondly, a type of rehabilitation engineering known as assistive technologies [37] that identifies tools to facilitate daily activities. And thirdly, changes in the environment intended to increase use by all people, as an approach of non-discrimination towards people with disabilities, such as, for example, the UD concept. Additionally, this approach addresses the problem of changing the way the world is designed or will be designed in the future.

Accessible technology has been designed in a way that can be reached by multiple users with similar needs. It is a technology with built-in customisation features, so that the user can personalise their experience to meet their needs.

Design for accessibility considers transforming scenarios for people with disabilities, thus addressing the problem of changing the way the world is or will be designed. Jones and Pal [40] describe the relationship between technology and people with disabilities, demonstrating how technology expands people's capabilities. Data collection is implemented through semi-structured interviews and, as a result, can infers the importance of assistive technologies as an amplifier of low abilities and diverse capacities, facilitating bodily or cognitive functioning. In this way, Nasr [23], using qualitative methods and a user-centered design methodology, presents results regarding rehabilitation technology processes with people who have suffered a stroke and live at home. In this case, the design of technology is limited to a specific audience.

Participatory design processes like the co-design method may enhance assistive technologies from a holistic unit of people with disabilities. Besides, assistive technologies extend the capabilities of people in order to facilitate the implementation of their usual activities [38,40,47].

Co-design refers to the full involvement of users in the different stages of the process, such as ideation, design and evaluation. The central aspect consists of combining the life experience of the person-user with the professional experience of experts to propose efficient solutions. This participation must actively consider the ideas and voice of the person-user, and all participants must be considered equal partners in the full design process by sharing their experience in the tacit design [48].

The co-design process can involve people with disabilities responding to complex problems with an iterative design process. Therefore, it cannot be rushed because there are multiple variables in the real-world problems being addressed, and this process requires a commitment to building change.

Accessible design through participatory design seeks an efficient solution based on the identification of the problem and the problem-solving process. For example, generative prototypes may provide ideas and abstract concepts for a concrete prototype that can achieve a product or service result. These prototypes can be physical objects and digital devices [49,50]. Similarly, the ATOLL tool shows a possible solution from a three-dimensional environment as a prospective tool for promoting dialogue to understand the advantages and disadvantages of possible product use [51].

In summary, participatory design processes can enhance the development of accessible technologies through a recognition of the holistic unit of people with disabilities in a real context situation. Therefore, technologies facilitate or extend the capabilities and functionings of people with disabilities in order to enhance the performance of their daily activities.

Participatory design for assistive technologies

Different researchers implement a participatory design methodology to develop assistive technologies based on case studies of people with disabilities. Experience participation processes have positive results when people's voices are taken into account by the design process at any level of participatory involvement [45,52]. Likewise, researchers integrate other disciplines such as health, technology, and design. However, some participants in the design group had a negative attitude and remarked on a lack of reflection during the process [53].

A case study with people over 60 years of age identified problems in computer internet browsing. The work also proposed tangible solutions to facilitate actions like sending emails and exchanging text messages. As a result, it developed a device called Infobricks, assistive tools for internet browsing that allow older people to adapt to their needs [52].

The use of technology as an amplifier of capabilities must consider the values of privacy, autonomy. and security, which are relevant in the design of technologies known as "value sensitive design" [45]. For instance, the design of tricycles for people with disabilities in Ghana presented a contribution to the expansion of capacity in people with reduced mobility. The principal objective was based on needs for both transportation into the city and for labour activities. A design group developed an appropriate tricycle solution that can be adapted with a portable icebox for ice cream to be stored and sold. This allows the people with disabilities to increase their income, opportunities, and self-esteem, while also contributing to improving mobility and other capabilities. The problem-solution fulfils specific needs. However, this solution can be extended to anyone with the same needs.

Assistive technology has been specifically designed to help individuals with disabilities to perform a task. However, this technology can never guarantee access to all people, as the cost requirements depends on the level of technology implemented. However, assistive technology must be designed with accessibility for people.

In summary, people-users must be involved during design and assessment processes. For this reason, the participatory design methodology establishes a general process that includes the identification of problem patterns and their possible solutions through assistive technologies. Additionally, technology can be a tool to create opportunities for improving quality of life. Finally, these considerations may reduce the abandonment of technology, and moreover, stimulate the use and empowerment of technology for people with disabilities [38,54,55].

A multidisciplinary approach for technological adaptation

Advances in technological systems and techniques change exponentially and continually, meaning constant processes of transformation. In terms of computer systems, hardware and software are components that can be upgraded and used as tools. Computer systems are useful for designing ways of interaction, communication and usability, and the best designs must consider diverse disciplines such as engineering and design in a collaborative way [56]. Multiple points of view allow the perception of many variables in the same problematic situation through the observations of participants. Besides, exogenous social factors like family members and caretakers are not considered in the adaptation of technologies.

Collaborative work seeks a robust solution, but when the design group is made up of multidisciplinary participants the communication process can be difficult to manage. Several toolkits of a participatory design methodology may facilitate this communication. Additionally, experience design combines aspects to develop technologies that involve the person-user as a social actor. In fact, praxeology contributes to the actions of people within a real context [21,57] thus allowing participation and collaborative teamwork.

On the other hand, the experience of a person-user may not be listened to in a multidisciplinary design group because of the expert ideas from different knowledge domains. The design process must prompt the voice of person-user and implement strategies to interpret and recognise the participation process in the design technology. This article describes an approximation of possible ways to promote engagement and decision-making within a participatory design process.

The social construction of reality relates a socio-cultural form of knowing, doing and feeling and, in this way, design is oriented towards making sense [57–59]. It promotes decision-making and meaningful aspects of life experience. Similarly, signification is a useful concept to facilitate the relationship between people and technology. For instance, research has used the concept "enchantment" to refer to facilitating relationships between people and technology [60]. For this reason, an emotional component can be perceived by technological devices in order to infer the emotional state of users.

The participatory design methodology allows an exchange role between the user and a diffuse designer during the design process. Each role establishes a different point of view that can be observed and assessed during an activity. Likewise, empathy between the members of the design group and the person-user must be attuned. Context information can gather naturally and induce people to identify ideas from their motivations and goals [61]. Thus, it should foster spaces for participation based on empathy. These characteristics can reinforce the concepts of accessible design in the adaptability of existing products or the creation of new products.

Conclusions

This literature review presented a conceptual exploration of participatory design and the development of accessible design processes. This allows to infer a relationship between the participation in a design process and the experience of situations from which it is possible to develop assistive technologies for products or services.

An assistive and accessible technology must have features that complement each other, since the technological approach should be considered as a tool that facilitates the daily activities of people with disabilities. Besides, the forms of access must be guaranteed considering the complexity of the technological development. Consequently, designs must be thoughtful as to the adaptation and solution of a product for people.

A conceptual perspective showed how experience design approach establishes communication alternatives for people with disabilities. Likewise, experience design of technologies observes aspects in the identification and characterisation of the person-user in order to facilitate the activities. Some activities can be difficult or impossible to do.

The development of assistive technologies has applied methodologies as participatory design through co-design, that includes the participation of people with disabilities as experts due to their life experience. The experience design process proposes alternatives in order to build a sensitive value in the product being designed. Also, people have a relationship to the development

process. For this reason, a technological response can absorb ideas from people-users in order to help manifest their own creative experience.

The highlighted aspects of participatory design describe an active participation of the person-user that generates a sensitive value in the product. People with disabilities have capabilities to explore their situational context in their daily activities. The role of design based on disability studies involves people, either individually or collectively, in design processes that promote participatory design as useful to developing accessible technology. Likewise, a user-centered design approach may improve the workflow with a holistic vision of the real world.

Participatory design methodology is evolving and expanding new methods, domains and technologies. Likewise, other methodologies such as human-computer interaction or user-centered design are reconsidering a holistic unit into the design process. Participatory design reflects a concern around a well-defined group of users, relabelled as -person-user- or -people-users- in this work.

This work shows a significant potential to address the relationship between aspects of participatory design throughout an entire design process involving a person-user as diffuse designers. This could help researchers to clearly define the nature of participation compared with other design disciplines. Also, during the design process it emerge a mutual learning between people-users, designers and researchers.

Finally, a knowledge gap was identified, based on a multidisciplinary design group without a dialogue workflow for making sense of things during the design process. Experts dominate work with people with disabilities as users, and do not consider their voices from the beginning of the design processes.

This article presents an opportunity to incorporate participatory design experiences, such as the use of tools and techniques for ideation, conceptualisation, and prototyping, into technological solutions for people with disabilities. Similarly, the foundations of experience design based on accessible technology provide a prospective vision about usable technology to avoid its early abandonment. and allow alternative tools in the development of assistive technologies through the experiences, ideas, and motivations of people with disabilities.

Acknowledgements

Disclosure statement

Funding

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