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User-centred design with visually impaired pupils: A case study of a game editor for orientation and mobility training

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ABSTRACT

Digital technology facilitates the lives of visually impaired people. To design accessible technology accepted by the target group, comprehensive methods of user-centred design are needed. In this paper, we present a case study with visually impaired pupils aiming for gaining bottom-up insights to support the ideation and design of a game editor to support orientation and mobility training. We involved relevant stakeholders (pupils, teachers, mobility trainers) using multiple methods, including (contextual) interview, focus group, (ideation) workshop, Gamestorming, digital survey, behavioural observation, self-experience, and early stage prototype testing. With our approach, we were able to gain a rich understanding of the needs of visually impaired pupils. The objective of this paper is to serve as reference for researchers cooperating with visually impaired pupils by providing (1) design implications for a game editor, and (2) a comprehensive reflection on approaches and issues of user-centred design methods with visually impaired pupils.

1. Introduction

Advances in digital technology are a blessing for the 285 million visually impaired (VI) people in the world [1]. In contrast to analogue data, digital information can be processed easily by assistive technologies, such as screen readers, Braille displays, and text-to-speech engines. With such constant advances in technology, VI people have better access to information and services than ever before, providing greater independence. This advantage especially applies to the "digital natives" of today, who grow up surrounded by digital technology.

However, the majority of researchers, designers, and developers have normal vision and therefore usually a limited understanding of the needs of VI children. Designs can easily fail when the needs and preferences of VI children are not taken into account. Thus, it is important to involve them in all phases of the design process of technology. Although the importance of a user-centred design (UCD) process is widely agreed on, the question how to implement such a process is still under debate [2]. Choosing the appropriate approach is challenging, not only because of the special needs of VI children, but also because of the large heterogeneity of visual impairment in the target group. Therefore, there is a need for scientific discourse about ***what needs to be considered during the process of designing with and for VI children***.

The research presented in this paper was part of a two-year project conducted in cooperation with a school for VI pupils. The project aimed at making orientation and mobility (O&M) training for VI children more fun, by applying an educational game approach that supports O&M training. In contrast to existing work (e.g. [3]), we do not focus on creating one game, but let pupils design their own game levels by providing a game editor. This aim raises open research questions on ***how to design an accessible O&M training game editor***.

We position our work as a case study for the participatory creation of a game editor for VI children. The main contribution of this paper is to serve as reference for other projects that aim at cooperating with VI children, especially in the context of games for O&M training. Additionally, we provide (1) ***design implications for the creation of an O&M training game editor*** (Section 4) and (2) a comprehensive ***reflection on approaches and issues when applying UCD methods with VI pupils*** (Section 5), contributing to a definition of best practices.

2. Related work

As we intended to let pupils design their own games, research about ***participatory design with VI children*** was of special

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relevance. For this purpose, the inclusionary model for involving impaired children in the design process [4,5] defines different levels of involvement (user, tester, informant, design partner) as well as severity of disability. The "Children in the Center" framework [6] suggests the need for participation of children, families, and researchers. Participatory design methods for user involvement mainly exist for VI adults, for example using scenarios stimulating the dialogue between designers and blind users [7]. Another approach suggests workshops with both blind and sighted people together [8]. Thereby, sighted participants were blindfolded to experience and subsequently discuss problems blind participants have to face.

Methods suitable for involving children (not VI children in particular) in different phases of the participatory game design process, are described in the "Child Centred Game Development" [9]. Approaches for participatory design with VI children can be found for example in the context of sound toys [10] or Wii games [11]. Methods especially relevant in the ideation phase of a project are playful brainstorming methods like Gamestorming [12]. However, choosing the most appropriate method is not the only critical factor in the participatory process. In order to successfully conduct workshops with children and identify and avoid problematic workshop situations, researchers, who are not trained in working with children, can build on previous work [13] on group dynamics that influence the participatory design process with children. Further methods used in technology design for children can be found in a review by Jensen and Skov [14].

Considering ***accessible game design***, most commercial games are still inaccessible to VI people (cf. [15]) However, there are various games specifically designed for VI children, like music games ("Rock Vibe", Allman et al. [16]), sports games ("Vi Bowling", Morelli et al. [17]), and adventure games [18]. Regarding the accessible design of a game for VI children, the balance between challenge and accessibility needs to be countervailed to avoid frustration and the exposition of vulnerabilities [19]. Therefore, we aimed at developing a fair game that does not provide advantages for children with low vision compared to blind children. Another important aspect in the co-design process is the involvement of VI people in all project phases. Often, the development process of games for blind people is done by sighted participants [20]. In our work the game development is done with a game editor operated by VI pupils with a computer.

In the present paper, there is a focus on ***games that improve O&M skills*** of VI people. Research in this area found that wayfinding skills and mental maps could be improved by full body interaction in a virtual world ("MovaWii"; Sanchez et al. [21]), by navigating through a maze within a haptic and audio game ("Audio Haptic Maze"; Sánchez and Espinoza [22]), and by interacting with an audio-based virtual reality environment simulation [23]. In a study including a haptic device for O&M training [24], participants were able to transfer skills acquired in the virtual world into the real world. The authors also proposed a model to develop video games for wayfinding [3], that includes end users mostly in the analysis and evaluation phase. In our study, end users also participated strongly in the design phase, as the functionalities of the editor are crucial for the later design of user-generated games. While positive effects of playing O&M training games have already been shown (e.g. [23,24]), we expected that actively designing games would have even stronger effects.

In contrast to previous work in the area of digital game-based O&M training, we aimed at providing a game editor that allows VI children to create their own game levels. By advancing methods for participatory design and ideation, we involved VI pupils strongly in the comprehensive UCD process.

3. User-centred design approach

We followed a comprehensive UCD approach as defined by ISO 9241-210 [27]. The UCD process ensures a strong integration of later users throughout all phases of the project. An overview of user involvement and methods used is depicted in Fig. 1. The focus of the present paper is on an in-depth requirements analysis in the areas of O&M training and accessible video game play as well as on first iterations in design, implementation, and evaluation of the developed game editor.

In most stages of our UCD process, children were involved as "design partners" [4]. We did not include VI children with intellectual disabilities in the design process, as most of our methods require a certain level of cognitive ability. We selected UCD methods potentially suitable for VI pupils and adapted specific elements (e.g. verbalization of ongoing processes in the moderation of workshops, letting pupils note down text on their PCs with assistive technology instead of posters or sticky notes). Although we did not include pupils with impairments other than visual in the game design process, the game play itself can be made accessible to children with various other impairments as well. This can be achieved by creating simpler games for cognitive impaired children or include only locations accessible for wheelchair users.

The pupils repeatedly involved in the process consisted mainly of a group of 25 teenagers and young adults (mean age: 18.52, SD: 2.37) from several classes of a school for VI pupils in Vienna, Austria, with business and polytechnical focus. The pupils' visual abilities varied from low vision (17 pupils with different levels of visual acuity and sizes of visual field) to blindness (8 pupils, 6 congenitally blind, 2 later blind). All eight blind participants and four participants with low vision used a screen reader and a Braille display. Eleven participants with low vision used screen magnifiers and two participants with low vision did not use any assistive technology for interacting with computers.

The pupils with low vision did not use assistive technology for navigation. All blind pupils used a long cane and the flash sonar technique, although in school some navigated shorter distances without a cane or with the help of colleagues. No participant owned or used a guide dog. We adapted the "Children in the Center" framework [6] by including teachers and mobility trainers of the school instead of the pupils' families, as they were stronger involved in the O&M training. For all participating pupils under the age of 18, their legal guardians had to sign an informed consent. Pupils over 18 years signed the informed consent themselves. Blind pupils over 18 years were assisted by having the informed consent read to them.

3.1. Requirements analysis or "Getting to know the VI pupils"

The aim of the comprehensive requirements analysis was threefold: (I) to develop suitable participatory design methods (e.g. playful brainstorming methods), (II) to gain a deep understanding of the procedure of O&M training for VI people, and (III) to analyse the pupils' behaviour and needs regarding video games. To accomplish these aims, we involved key stakeholders by using multiple methods briefly described in Table 1.

Regarding the development of suitable participatory design methods, we investigated the viability of Gamestorming methods [12]. We analysed three idea generation methods potentially accessible for VI pupils: (1) ***Anti-Problem***: a problem is attempted to be solved by working on a solution for the exact opposite problem; (2) ***Mission Impossible***: an irresolvable problem is defined to trigger unusual solutions and create something new; and (3) ***Object Brainstorm***: tangible objects (see Fig. 2) inspire a creative idea generation for a specific problem. We investigated two idea evaluation methods: (4) ***Card Sort***: a number of cards is sorted according