A User Centered Design Roadmap for Researchers and Designers Working with Visually Impaired and Blind Children

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***Abstract*— Today, user-centered design has become an essential and successful practice to design interactive systems. With the growing acknowledgment of the importance of universal usability and the need for influencing designs, User-Centered Design (UCD) ought to be structured to adapt its methodologies to the needs and requirements of people with disabilities. This paper is preliminary research that identifies the most relevant UCD methods, needs and best practices for working with Visually Impaired and Blind (VIB) children. We start by reviewing UCD methods and identify those that are most suitable for VIB children. We then propose a UCD process for VIB children and discuss how they apply with respect to needs, requirements and abilities of VIB children.**

Keywords- User centered design; Visually impaired and blind child ; Participatory design; E-learning system

I. INTRODUCTION

User-Centered Design (UCD) is a collection of processes and techniques that emphasize putting users at the center of product design and development. It considers user's requirements, needs, objectives and feedback. The Usability Professionals Association (UPA) [1] formally defines UCD as an approach to design that grounds the process in information about the people who use the product.

According to Carr et al. [2], in User-Design users are engaged in the actual creation of their own systems in negotiation with leaders and designers; meanwhile in User-Centered Design overall control remains in the hands of designers and approval power remains with leadership. We believe that by involving users at each phase of the development process, the end product will respond to their characteristics and, therefore, provide end-users with a positive experience and better usability.

In comparison to their counterparts, children with visual disabilities have entirely different ways to structure, order, and perceive the world, assuming a singular mental model quite distinct from sighted children. Children with non-visual mental models have to cope with devices designed for children with visual mental models. Even though interactive systems designed for sighted children go through a rigorous UCD process, it does not mean that they meet the needs of non-sighted children. This is a major issue affecting both usability and accessibility. Lots of UCD research exists for VIB adults, such as those surveyed by Sahib et al. [3], however there is very little addressing VIB children [4]-[7].

This research proposes revising the UCD process to be adapted to VIB children by identifying their needs and requirements, and then highlighting appropriate methods and best practices that cater to them. The paper is organized as follows: Section II gives a review of UCD and research with children and VIB children. Section III highlights the requirements and needs of VIB children and the UCD methods most appropriate for them. Section IV proposes a refined UCD process for VIB children. And finally, in Section V, we conclude with the summary and potential future research.

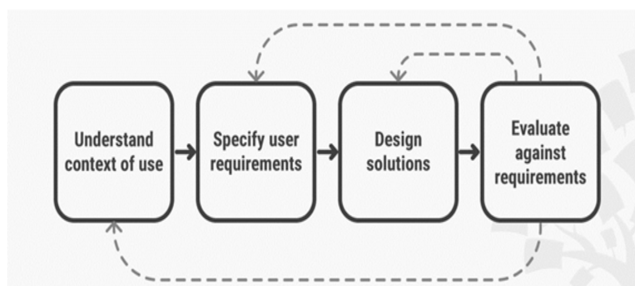

Figure 1. The Iterative Process UCD (ISO 9241-210) [47].

II. RELATED WORK

In this section we summarize methods found in literature used to implement UCD in general, with children and those used more specifically with VIB children.

A. *User Centered Design*

UCD is design that is based around real user requirements, and typically involves task analysis, prototype development with users, evaluation, and iterative design [8]. Devi et al. [9] defined UCD as a framework in which usability goals, user characteristics, environment, tasks and workflow of a product, service or process are given extensive attention at each stage of a design process.

According to ISO 9241-210, the UCD approach shown in Figure 1 takes into account the user's abilities, limitations and context in which the user operates to ensure the design of usable and accessible products [8][10]. As illustrated in Figure 1, each iteration of the UCD process involves four distinct phases. The complete process includes multiple iterations of these four phases, until evaluation results are satisfactory, and all requirements have been met:

1. Understanding the context of use: gathering requirements.
2. Requirements specification - specifying the user and organizational requirements
3. Design - Producing designs, prototypes and solutions
4. Evaluation - Carrying out user-based assessment of the site and test need satisfaction against user specific contexts.

To implement User-Centered Design a myriad of methods have been adopted. Some methods are investigative in nature (e.g., surveys and interviews) while others are generative (e.g., brainstorming) [8][10]-[12]. A summarized list of UCD methods and the UCD stage they are appropriate for are shown in the first and second columns of Table 1.

The context in which UCD methods are applied can differ depending on the target audience and system being developed. To identify several areas of interface improvement for the user interface of a Hazard Service system, Argyle et al. [13], conducted usability testing on experienced forecasting professionals via web-based tasks and a questionnaire. Meanwhile, in an attempt to maximize patient engagement Wachtler et al. [14] employed focus groups and semi-structured interviews in the design of a clinical depression prediction tool that will be incorporated into routine clinical practice. To design a preference-based family planning decision system Stevens et al. [15] used focus groups, qualitative surveys and evaluation measures. Couture et al. [16] adopted scenarios and usability testing in designing a safety-reporting tool for hospitalized patients and their family members. To enhance IoT wearable systems, Bernal et al. [17] identified contextual needs and iterative interviews to reach safer environments in energy companies. With futuristic goals in mind, Eggen et al. [18], used similar UCD methods to achieve seamless integration of user experiences in smart homes. In the following sections we explain why UCD method choices differ when the target audience is younger in age.

B. *User-centered Design with Children*

Since 2002 there has been more interest in involving children in the design process to which some have expressed as a complex process [19]-[21]. Nesset et al. [22] argue that there are more advantages than disadvantages of including children in the design process. But the issues is not *including* them, it is more to do with engaging them in the process according to Rogers et al. [23]. This engagement can take on multiple forms, each with various dimensions: user, tester, informant or design partner [24]. Schepers et al. [25] for instance, look at the role of children in participatory design as a co-designer and not just a participant. While Sims [26] looks at how children can be an advantage when incorporated in the design process of healthcare technologies.

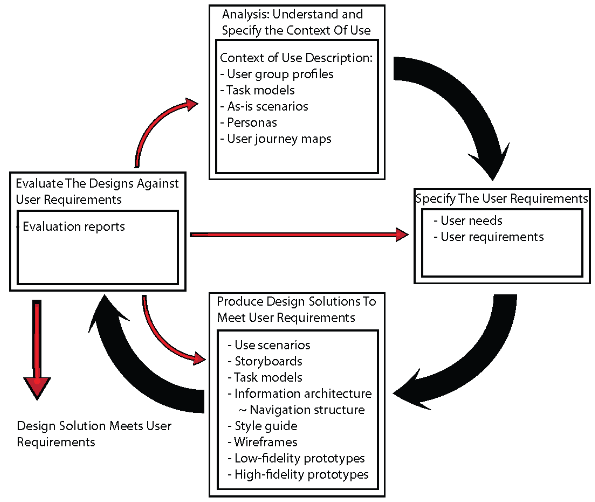

Figure 2. User Centered Design process according to ISO 9241-210.

In education through gaming, Gelderblom [27][28] finds that in spite of involving younger children in the design of a web based educational game using well-tested techniques; participatory design successfully meets the requirements. Despite not having fully developed language skills, the participation of children in UCD has been successful, encourages creativity and offers many opportunities.

C. *User-centered Design for VIB children*

It can be problematic for designers to exclusively depend on their expertise to correctly imagine the needs of a normal end user. Designers depend on UCD methods to better understand the end users' needs. Moreover, it is more challenging for the designers to make sure that they effectively understand the difficulties and obstacles VIB end user faces while interacting with interfaces. In order to create usable and accessible products for visually impaired children (VIB), it is essential to include them in all stages of the development process. Mattheiss et al. [5]-[7] highlight the problem of having many existing participatory design attempts for visually impaired adults as opposed to very few involving children. Bateman et al. [29] successfully incorporated UCD to VIB students in the design of an electrostatic haptic touchscreen, resulting in a noticeably high percentage of accuracy

The inclusionary model for involving impaired children in the design process defines different levels of involvement (user, tester, informant, design partner) as well as severity of disability [30]. The Children in the Center framework by Kärnä et al. [31] suggests the need for participation of children, families, and researchers. Some participatory design methods suggest workshops comprising of both blind and sighted people together, were sighted participants are blindfolded to experience and subsequently discuss problems blind participants have to face [4]. Mattheiss et al. [7] discussed lessons learned regarding approaches and issues with multiple UCD methods used with VIB children.

III. VIB CHILDREN'S REQUIREMENTS AND NEEDS

In a dialogue system there is almost no difference in using interfaces between sighted and VIB user. However, in case of graphical user interfaces special needs and requirements of VIB child should be considered. In this section special requirements and needs of the tools and user interface features used by VIB children are presented. Later a recommended, semantically, and blind-friendly adaptive user centered design is proposed.

A. VIB Requirements and Needs

1. Information access is sequential [32]. At any given point, VIB users perceive only a snippet of the content and often lose contextual information.
2. No rendition of graphics [33]. VIB users cannot perceive or interpret information communicated through images, color, and layout.
3. Quick information scan is not possible [34]. VIB users cannot locate goal-relevant information efficiently and easily by scanning information.
4. Keyboard-based [35]. VIB users cannot use functionality that requires mouse input.
5. Complex layouts create problems. When Web pages have a complex layout, screen readers feedback becomes ambiguous [32]. Screen-readers also mispronounce many words according to Theofanos and Redish [36] which creates comprehension problems for the VIB user.
6. Requires learning complex interface. VIB interaction requires memorizing hundreds of key commands [36]. The wide range of screen-reader functionality makes it more difficult for VIB users to remember and use appropriate functions for effective Web interaction.
7. Higher cognitive load. Cognitive resources must be split, trying to understand the browser, the screen reader, and content [36]. This leads to greater cognitive burden for VIB users on the Web [37][38].

VIB individuals are particularly dependent on their hearing and tactile senses. Adapting a graphical user interface for blind people involves some specific usability requirements:

1. The task has to be adequate given the capabilities of blind users (task adequacy),
2. The user interface has to provide a balance between the 2D access of sighted people and the 1D access of blind people (dimensional trade-off),
3. The user interface has to provide specific access to all the relevant user interface objects (behavior equivalence), for blind people
4. The user interface has to avoid losing relevant semantic information (semantic loss avoidance), &
5. The interface has to deal with a wide variation in the functionality and programming of the assistive technologies for blind people (device-independency).

B. Recommended UCD methods for VIB

The UCD framework for VIB should be dependent upon feedback gathered in the form of interviews with assistive device experts, as well as preliminary tests with visual impaired users. There is a need to select suitable UCD methods for VIB students and adapt them according to the situation (e.g., verbalization of ongoing processes in the moderation of workshops, allowing students to note down text on their devices, with assistive technology instead of posters or sticky notes). Table 1 illustrates the UCD methods, which phase they can be used, whether or not they can be used with the VIB, whether they are suitable for children and whether they are recommended for the proposed UCD for VIB children.

TABLE 1. RECOMMEBDED UCD METHODS FOR VIB CHILDREN

UCD Method	***UCD Phase***	***Suitable for VIB***	***Suitable for child***	***Recommended***
User survey questionnaire	Understanding the context of use	Y	Y	Y
Interviews	Understanding the context of use	Y	Y	Y
Contextual inquiry/interview	Understanding the context of use	Y	Y	Y
User observation/field study	Understanding the context of use	Y	Y	Y
Analyze context of use	Requirements specification	Y	Y	Y
Focus group (requirements)	Understanding the context of use/ Requirement specification	Y	M	M
Brainstorming	Requirements specification	Y	Y	Y
Evaluate existing system	Requirements gathering & specification	Y	Y	Y
Card sorting	Requirements specification	N	Y	N
Affinity diagramming	Requirements specification	N	Y	N
Scenarios of use	Requirements specification	M	M	M

Use cases	Requirements specification	N	N	N
Task analysis (analytical)	Requirements specification	N	N	N
Set usability goals	Requirements specification	Y	M	M
Storyboarding	Requirements specification	N	Y	N
Low fidelity prototype	Requirements specification	N	Y	N
High fidelity prototype	Design	Y	Y	Y
Wizard of Oz	Design	N	N	N
Conceptual models	Design	N	N	N
Participatory design	Design	Y	Y	Y
Heuristic Evaluation (HE)	Design/ Evaluation	N	N	N
Design walkthrough	Evaluation	Y	Y	Y
Usability Testing	Evaluation	Y	Y	Y

To understand why some of the UCD methods listed are recommended in VIB child research we offer the following descriptions:

1. **Participatory design with VIB children** can be challenging, as designers have to ensure their methods of communicating design ideas and feedback with users are appropriate and effective [39].
2. **Low and high fidelity prototyping** is a common way of brainstorming design ideas with users, but for VIB children visual prototyping techniques are not appropriate. Therefore, alternatives have been proposed: Brewster et al. [40] describe haptic paper prototypes that use cardboard mockups, and Miao et al. [41] describe a tactile paper prototyping approach using Braille and tactile graphic mockups.
3. **User survey questionnaires** are classic investigation tools [42]. Implementation can be based on individual comprehension level and tailored to needs using either braille-based or Web-based surveys. With the increasing uses of technology, meeting accessibility standards of web-based versions should be considered to ensure text is focused, presented correctly, and is well organized.
4. **Interviews & contextual inquiry/interviews** are powerful design and requirement gathering tools. They can be administered structured or semi-structured and adjusted to suit the VIB child's cognitive level and education. Investigations into user's environments might help elicit specific data that may otherwise not be considered [43].
5. **User observation/field study** witnessing users in specific contexts and/or environments is as powerful as contextual inquiries. By observing VIB children in action researchers can immediately identify problems with completion of specific tasks, identify frustrations while using tools and recognize things that work more efficiently. Pointers drawn from observations regardless of their numbers are key to successful design.
6. **Brainstorming.** Although tricky to implement effectively with VIB children, brainstorming sessions can result in a myriad of preferences, needs and direction for further product and application designs [44]. Sharing visuals, conveying hand gestures, and information gaps between participants are some of the concepts to keep in mind before running such sessions.
7. **Design walkthroughs** Creativity is key when attempting to run design walkthroughs with VIB children. Abate et al. [45] recommended using suitable tools to convey design and incorporating storytelling or game play into the process to keep children aware and engaged.
8. **Usability testing and evaluation** is one of the best tools to recognize problems and points of frustration for users [46]. Being in a room with a VIB child and using a master apprentice model for example, can help researchers identify needs versus extras and ease of use issues. In addition, usability testing offers the option of comparing two designs in one session, which can help reduce the number of sessions needed. However, recruitment of participants willing to sit in hour-long sessions is difficult for these evaluations.

IV. UCD PROCESS FOR VIB CHILDREN

The User-Centered Design process is made up of a set of iterative activities that result in a final design that meets all the user requirements, as shown in Figure 2. The process includes collecting feedback from the initial stages to the very end, beginning with analysis, specifying the user requirements, producing design solutions and evaluation in addition to iterative cycles of all phases until the design is complete.

However, as shown previously, when designing for VIB children it is important to modify the UCD process to cater for their needs and requirements. The proposed UCD VIB child-friendly process, shown in Figure 3, has been refined to include recommended methods from Section III.

To understand context of use during the analysis phase of working with VIB children, we recommend adopting a user survey questionnaire, contextual inquiry/interviews, or user observations and field studies.

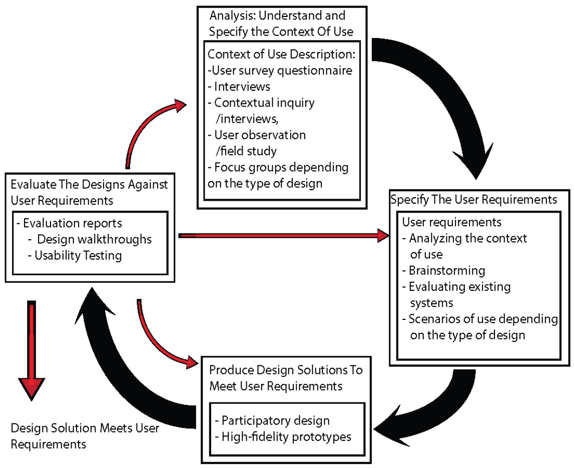

Figure 3. User centered Design adapted to a VIB Child user.

VIB children are more likely to convey opinion and ideas through speech rather than on paper, and through semi-structured interviews instead of structured ones. As for specifying user requirements, methods like analyzing the context of use, and depending on the type of design, brainstorming and scenarios of use have a higher chance of acquiring needs as opposed to other methods. Again, here we notice verbal methods are more effective in acquiring needs and requirements.

Iterative design process phase with VIB children will benefit from methods, such as participatory design and high-fidelity prototypes and heuristic evaluations only if applied by experts. Participatory design methods are popular when designing with children. The need to engage a VIB child in the design process and communicate the design ideas to them has to be in a form accessible to them. This can be achieved successfully using scenarios and dialogue interactions [3].

Once complete, the evaluation phase for VIB children includes usability testing and design walkthrough methods. Watching and listening to VIB children using design evaluation methods can be very rewarding if done correctly and with clearly set goals.

V. CONCLUSION AND FUTURE WORK

User involvement in the design process for VIB children is crucial for effective interactive interfaces. The proposed UCD process recognizes VIB child specific needs, requirements, abilities, and accordingly recommends the most suitable UCD methods. The ultimate goal is always to deliver successful systems that are easy to use and satisfy user needs and help motivate VIB child live more independently in their everyday lives. The process also ensures that the design and development teams remain focused upon the key users they are designing for, the VIB child. For future work we will conduct experiments to determine the feasibility and validity of the recommended VIB-UCD methods.

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