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INVESTIGATION OF METHODS FOR THE DESIGN OF ASSISTIVE DEVICE: UCD AND MEDICAL TOOLS

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Abstract: This paper reports the results of a study about design methods for assistive device. Publications dedicated only to this question are rare. That is why fifteen case-studies presenting the design of assistive device have been analyzed: this paper extracts the underlying design methods and whenever possible their benefits and weaknesses. Unfortunately, information about the choice of design methods and their impact is often lacking in the literature. A table summarizes and classifies the design methods identified in the case-studies. Results show that User-Centered Design (UCD) tools are widely used for designing assistive device. Many authors stated or expected the UCD approach to be helpful in this field. Rarely designers use additional tools from other fields such as anthropometric values from ergonomics, joint range measure / psycho-motor tests from medicine and ABAB design from psychology, although they seem totally relevant.

Key words: Design method Assistive Device
Disability User-centred design

1- Introduction

The objective of this paper is to investigate methodologies regarding the design of assistive device (a product ‘applied to or directly manipulated by a person; eg, wheelchairs’ [F3] with aim to “increase, maintain or improve functional capabilities of individuals with disabilities” [P3]).

Choosing the right design method for designing for disabled people is a question that was first raised to us during the AE2M project (Ergonomical Adaptation of the Musical Material) [T1], [T2]. This project aims to provide disabled children with special equipment enabling them to play music on their own. The design of these adapted systems appeared to be difficult. It’s known that “Although many aids for the disabled appear to be quite simple, their design is subject to many difficulties” [O1]. One of these difficulties is the impossibility for the designers to rely on their own experience as users since their abilities are very different from the disabled users [O1].

The AE2M project led us to the following question: Which design methods should be used for the design of an assistive device?

Unfortunately, this has been rarely discussed in the literature [A2], [B4], [N1] and [O1]. But numerous articles present the design of assistive device in practice [B4], [C1], [D1], [H1], [W1], [W2]... The fifteen most explicit articles regarding the design approach were selected for this study. In this paper, these case-studies were analyzed to identify the underlying design methods used. No restriction about the type of disability (physical or cognitive impairments...) or the type of application (seating, mobility, aids for daily living...) has been applied during the case-study selection. For more details about the application and the target users of the products in each case-study, see column “Application” of **Table 1** in Appendix.

This analysis led us to create a classification of the design methods as presented in **Table 1**. Two main categories for design tools have been created. Next section focuses on what we identified as “User-Centred Design” tools. Then, section 3 identifies tools coming from the ergonomical, medical and psychological fields. Last, a conclusion envisages some perspectives in terms of suitable design methods for assistive devices.

2- User-Centred Design tools

User-centred Design (UCD) is a design approach which emphasizes the adaptation of the product to the user through user involvement in all the design process (it has been described by a norm [I1]). Most selected case-studies follow more or less a UCD approach (such as the involvement of users in some design stages) even if another design approach is claimed. Actually, UCD is rarely explicitly mentioned in the case-studies (see column “Design approach” in **Table 1**). It would be hard to define to what extent case-studies follow

a UCD approach, so it was decided to identify the underlying UCD tools in the case-studies.

First, it is necessary to explain what UCD tools are. They are design tools to support UCD (such as “User interview” or “Usability evaluation”). Designers have to pick up the most appropriate tools for their project like in a tool box. In the literature, they are called UCD **methods** [A1], [V1], UCD **techniques** [A1], or UCD **methodology** [R1]. We prefer calling them UCD **tools** since they are modular parts of one unique design method. The use of each of these UCD tools is studied below.

2.1 – Frequency of the use of UCD tools

The eighteen selected case-studies were browsed and then categorised, according to Vredenburg UCD tools classification [V1]. Results are shown in **Table 1**.

Table 1 shows that UCD tools are widely used for the design of assistive device especially “Usability evaluation” and “Survey”. The most common tools seem to be the most intuitive (“Usability evaluation” and “Survey”). Some UCD tools may have been used by designers who did not know the UCD approach at all. In that case, designers did not **choose** the most appropriate UCD tools since they did not know all the UCD tools available. So results are hard to interpret. **Table 1** shows that “Informal expert review” is not very common. In fact, experts were often involved in the design process but not for reviewing the concepts, prototypes or final products. In three cases, experts helped to understand the user needs [B4], [H1], [P1]. Surprisingly “Field studies” is rarely used whereas it is known that the environment is essential in the assistive device field: “a solution that work in one context may not transfer to another context for the same person” [C2].

2.2 – Benefits and weaknesses of the UCD tools

It’s now known that placing the user at the centre of the design process and involving him from the early stages of the design process is essential [A1]. Is it also true for the design of assistive device ?

Many authors expected or stated that the involvement of user would be very helpful for designing product dedicated to disabled users [A2], [C2], [N1], [O1], [W1]. Unfortunately, the impact of the UCD tools is rarely discussed in the selected case studies. It is partly due to the fact that “many case studies are developed to illustrate the successful use of a design method” [F2]. Moreover, it can be difficult to establish benefits of any design methods and UCD tools in particular. According to Vredenburg [V1], measurement of UCD design effectiveness and common evaluation criteria are lacking. Vredenburg reported also that the quality of the results is not the only factor to be considered when choosing a UCD tool. The ease of use is a very important factor: “The UCD professionals were more mindful of the factors directly associated with the process (Speed, participant cooperation, user involvement...) followed by outcome (Validity, Quality of results, understanding context, credibility of results) and Input/Resources (Low cost, Availability of expertise, Availability of information)” [V1].

It’s known that implementation of UCD tools is particularly challenging in the field of assistive device [B4], [N1]:

- Users can be hard to find [M1],
- User tests with disabled cost more time and money [G1]
- Various communication issues can occur [S3], [N1]
- User tests can cause user’s fatigue [P2]
- User tests can affect user’s self esteem [P2]

Ways to solve these issues are emerging such as:

- Educating designers “on how to operate when the user base may contain older or disabled people” [N1]
- Involving people who know disabled users such as experts, therapists, and parents (in case of disabled children)

In this section, the use of UCD tools for designing assistive device has been studied. Results showed that even if involving disabled participants can be tricky, UCD is widely used for designing for disabled people (all case-studies selected used at least one UCD tool during the design process). Results show also that UCD is **expected** to be helpful but evidence for this is somehow lacking in the literature. In the following section, the use of complementary design tools will be studied.

3- Measures and tests from ergonomics, medicine and psychology

3.1 – Tool from ergonomics: anthropometrics values

Hobson explored the use of anthropometric values for the design of a seating assistive device [H2]. This author stated that existing able-bodied anthropometric sources were not sufficient for the design of a seat for cerebral palsy people. In fact, for any application, measurement techniques used for the non-disabled population is not appropriate for the disabled population [B2]. So measurement techniques dedicated to the disabled population are needed [B3].

3.2 – Tool from medicine: joint range & muscle force measures

Among the selected case-studies, two mentioned joint range and muscle force measures [W1], [W2].

It’s difficult to evaluate the impact of these measures: it’s only one step in the design process, and only two applications were available. In the case [W2], the relevant joint range & muscle force of the user were measured. Then, a motion analysis of the tasks was also performed. So, uncomfortable movements / tasks were precisely identified. Based on this, the following steps consist in replacing the uncomfortable movements / tasks in maintaining the operation in the user range. What needed to be improved and the user’s abilities was precisely identified, so the use of joint range and muscle force measures seem here a powerful tool. Joint’s range of motion and muscle force measures come from the rehabilitation medicine: it is very useful clinically and therapeutically but not necessarily for the design for all

applications [B2]. Also the data collection in this field is intense and time-consuming [B2].

3.3 – Tool from medicine: psycho-motor tests

Among the selected case-studies, only one mentioned explicitly the use of standard psycho-motor tests [C1].

The impact of the use of psycho-motor tests is difficult to evaluate: it's only one step in the design process, and only one application was available. In the case identified [C1], relevant tests were selected. Then, potential old users were recruited and tested. The results were then compared with the normal values. This comparison led to the identification of the specific difficulties of the old people (whenever old users scored statistically significantly lower). Based on this, four design principles were established and guided the following steps of the redesign. What needed to be improved was successfully identified. So the use of psycho-motor tests seems here an effective tool. It should be noticed that implementing these standard tests is not easy, since their range of validity is very narrow (type of illness, range of ages, language of the test) [F1].

3.4 – Tool from psychology: ABAB design

In psychology, **ABAB design** is the “fast alternations of two different treatments or conditions, each associated with a distinct and discriminative stimulus” [B1].

It has been used to check that disabled users can learn to use a specific assistive device [L2], [L3], [L4], [L5], [L6], [L7], [L8], [S2]:

- First, the researcher chooses a specific user's gesture to activate a stimulus.
- In phase A: the frequency of the activation gesture is measured, but the stimulus is not activated by the gesture.
- In phase B: the frequency of the activation gesture is measured, and the stimulus is activated by the gesture.

The potential increase of frequency of the responding in phase B proves that the user has learnt to use the interface. This description matches the typical ABAB design, but it should be noted that many other variants exist, they are called **multiprobe design** [L9], [S1].

The main benefit of this method is enabling to work with people with severe/profound impairments. It's known that “any person with a minimum developmental functioning of two or three months should be able to learn a simple contingency” [L1], [S4]. The main weakness of this method is the difficulty to interpret the results. If no significant difference in the responding occurs, the potential reasons are various:

- User lacks motivation, [D2], [I2], [L1]
- User is not able to learn to use the interface [L1]
- In phase A, the stimulus is not available but the user makes the activation gesture to check if the stimulus is available again [S1]

It should be noticed that all publications mentioning the **ABAB designs** come from the psychological field. These articles were written from a psychologist's point of view, but they were

considered as design case-studies in this paper, because they were of great interest. No similar case-study from the design field was found in the literature.

This study shows that relevant tools for measuring disabled users' abilities already exist outside the design domain such as:

- Joint range and muscle force measures
- Psycho-motor tests
- and “ABAB study”

Reusing these tools seem of great interest for designing for disabled users. Surprisingly, these tools are rarely used by designers.

4- Conclusion

This paper aims to identify design methods suitable for the design of assistive device. Design methods and their impacts have been extracted from fifteen case-studies presenting the design of assistive device. This study yields interesting findings.

- First, UCD tools are widely used; although their implementation can be more difficult with disabled users. Many authors expected these UCD tools to be helpful but their effectiveness in practice is somehow difficult to establish.
- Rarely, designers re-use complementary tools from ergonomics (anthropometrics values), rehabilitation medicine (joint range & muscle force measures and psycho-motor tests), and psychology (**ABAB design**). Knowledge about the effectiveness of these complementary tools is only partial since information about this is often lacking in the literature. We know that these tools come from fields specialized in measuring people's abilities (ergonomics), disabled people's physical abilities (rehabilitation medicine) and developmental abilities (psychology), so they seem promising for a better understanding of users' abilities in the field of assistive device.

In order to draw guidelines, more case-studies should be studied and existing design methods should be fully evaluated regarding their use with disabled participants. Currently, the literature focuses on the **applicability** of the design methods but knowing their **efficiency** seems crucial to us and remains not explored enough. How to evaluate the efficiency of design methods regarding their use with specific participants is an open question. Allsop [A3] introduced a **cost and value** analysis of child participation in healthcare technology design which seems of great interest.

In connection with the A2EM project [T1], [T2], we intend to improve the way we design assistive device for enabling disabled children to practice musical instruments. We aim to achieve a better understanding of the users' abilities by combining the UCD approach and medical approach of measuring people's abilities in a real multidisciplinary

approach. As explained in this paper, UCD tools have to be adapted to disabled users. And ways to take into account more medical data during the design process have to be explored. So, new methods and tools have to be developed.

5- Appendix

Publication	Design approach	Application	UCD tools						Tools from ergonomics, rehabilitation medicine, and psychology				
			Informal expert review	Usability evaluation: Prototypes or final product testing by user	Survey: Written question prepared by the designer and answered by users	User interview: Discussion between designer and a user	Focus group: "Include a wide range of stakeholders to discuss issues and requirements" [A1]	Field studies (or On-site observation [A1]): "Collecting information concerning the environment in which the artefact will be used" [A1]	Anthropometrics values	Joint range & muscle force measures	Psychomotor tests	From rehabilitation medicine	ABAB design
[B4]	Iterative process	Wheelchair-mountable manipulator Wheelchair for users of various impairments and ages ¹		X									
[C1]	Participative design	ATM for all including old people		X	X						X		
[D1]	Emotion driven design	Wheelchair for children ¹			X	X							
[H1]	Iterative process	Toy to Stimulate the Language Development of Toddlers with Multiple Disabilities	X	X									
[L2], [L3], [L4], [L5], [L6], [L7], [L8].	-	Microswitches to control environmental stimuli (songs, television, recordings of people talking...)		X ²									X
[P1]	-	Low-cost wheelchair for Indians	X	X	X	X	X	X					
[S2]	-	Commercial mouse to control carton videos and music		X ²									X
[W1]	UCD & AD-SWOT	Bathing assistive device for hemiplegic people		X		X				X			
[W2]	USERfit & AD-SWOT & AD-TOWS	Hair washing assistive device for users with shoulder mobility restriction	X	X				X		X			

Table 1: Fifteen design case-studies of assistive device and their design methods

¹ Some projects were not finished, that's why there was no opportunity to perform an "Usability Evaluation".

² ABAB design can be here considered as a particular way to perform an "Usability Evaluation". It should be kept in mind that these publications are outside the design field.

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