

An Exploration of the Application of Usability Evaluation Methods by Disabled Users

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Abstract— The involvement of system users during the system usability evaluation with the full awareness of their specific nature and characteristics is a key factor for achieving effective usability evaluation results. However, conducting usability evaluations for systems designed for disabled users is a challenging process that requires further considerations as compared to other ordinary usability evaluation procedures. This is due to the special needs and conditions of disabled users that must be considered while performing the usability evaluation. Therefore, it is essential to assess the effectiveness of different usability evaluation methods to help the evaluator selecting the most suitable ones for a particular system and a particular user group. The main contribution of this paper is to conduct an analysis of the effectiveness of applying several usability evaluation methods by disabled users. This analysis is based on the special characteristics of users with disabilities and on what adjustments should take place before the evaluation process begins. After conducting this exploratory analysis, we found that usability evaluation methods including inspection and testing methods can be applied to special needs users but many considerations should take place before selecting which methods are most effective. We believe that this work is particularly useful for the novice designers and usability engineers who have never conducted usability evaluations by disabled users before.

Keywords-UEM; Disabled users; Usability evaluation.

I. INTRODUCTION

There is a global agreement on that the usability is a key aspect of a software product's success. System usability can be viewed as the studies conducted that aim to answer the question of whether the system is good enough to satisfy the user's needs [2]. In order to properly acquire the desired level of usability in a software system, a disciplined approach should be followed. For that, usability engineering concept has emerged into software engineering to represent this disciplined approach [14]. Several usability engineering process models exist in literature that share an essential activity which is the usability evaluation [3]. Usability evaluation is an iterative process that encompasses a continuous measurement of the system's current usability level; this process continues to repeat until the desired usability level is reached.

In literature, several techniques, methods and guidelines exist that shape the usability evaluation activity. A usability evaluation method (UEM) is a process for producing a measurement of usability: in evaluation, there is an object being evaluated and a process through which one or more attributes are judged or given a value [18]. The standard output for all UEMs is a list of the potential usability problems [7]. These UEMs can be classified in several ways; a common way is to classify them into empirical user testing methods and usability inspection methods, according to the user involvement. While the user testing category covers methods that involve representative users as participants, the usability inspection category, on the other hand, includes methods that can be applied without user involvement [16]. User testing also includes developing realistic scenarios of the tasks that the users are required to perform [17]. Assessing the effectiveness of different UEMs is essential to help the evaluator selecting the most suitable UEMs for a particular system and a particular user group. This effectiveness is related to several factors such as the type of the systems, the nature and time of the usability study among the development lifecycle, the characteristics of test participants, funding and other facilities [2]. Several measures can be used for assessing UEMs effectiveness such as: the ratio and severity of usability problems detected, the ratio of task success and number of comments elicited [6].

The main contribution of this paper is to conduct an analysis study of the effectiveness of applying several usability evaluation methods by disabled users based on the special characteristics of such users and the adjustments that should take place before the evaluation process begins. However, the study was based on analyzing the literature and reviewing the fields that focus on the application of different UEMs with different disabilities. And the results that we obtained during this study were based on our findings and experience after analyzing these fields. The following UEMs will be analyzed in this paper in regard to their application by disabled users: Inspection methods, thinking aloud, attention analysis, field observation, coaching method, questionnaires and interviews. The rest of the paper is organized as follow: Section 2 presents the related works that studied the application of different UEMs by disabled users. Section 3 provides an exploratory review of applying different UEMs for users with specific disabilities along with the resultant considerations. Section 4 presents

summarization of the analysis results. In Section 5, we concluded the paper with a summary and the expected future work.

II. RELATED WORK

Most of the related work had discussed – as a part of a system development process- the results of conducting a specific UEM for evaluating the system’s usability by users with a specific type of disability. However, few works discussed the effectiveness of applying different UEMs by different disabled users and highlighted the challenges faced.

Regarding the challenges of the recruitment of special – non regular- test users, Brush et al. [4] discussed the problem of the availability of user representatives. They found it difficult to find sufficient professional users of testing the usability of an urban planning tool locally because users were geographically distributed. They conducted both local and synchronous remote usability testing and found the results comparable. The effectiveness of applying remote evaluation by disabled users was evaluated by Petrie et al. [9]. They presented two usability evaluation studies with disabled users. One was remotely conducted and in asynchronous way while the other was ordinary local evaluation. In the remote evaluation, there were two cases; summative evaluation and formative one. The resulting quantitative data of the local and remote cases were comparable. However, there was a difference in the data amount and richness in the favor of local evaluation.

Regarding usability evaluation by slow learning users, Abdollah et al. [1] developed a multimedia courseware learning tool for slow learners and performed a usability evaluation of the tool by the slow learners along with heuristic evaluation with teachers and one parent. Evaluation results showed that users with this disability were able to participate in the “efficiency” and “easy to learn” measurement testing while they were unable to participate in the “satisfaction” measurements testing considering their lack of respond abilities to written questionnaires. As for the deafness disability, Roberts and Fels [5] provided two studies that proved the viability of using the Think Aloud Protocol (TAP) method as a UEM in collecting gestures from deaf sign language users. Their study showed a similar success rate of using gestural TAP for deaf people and verbal TAP for hearing people. As for applying UEMs by blind users, Chandrashekar and Fels [8] assessed the applicability of conventional TAP method to blind users who uses a screen reader to access websites. They found that TAP cannot be used by such users in its popular form as a concurrent verbal protocol; it will instead require adjustment to be useful for blind users. However, the best approach for TAP adjustment wasn’t determined in the study.

Regarding the usability evaluation by users with cognitive disabilities, Lepistö and Ovaska [20] performed a think aloud usability test and found that it didn’t work well with this user group. They also conducted an informal walkthrough and found that this method showed effectively which parts of the application interest the participants most. Their study concluded that for evaluating usability by users with cognitive disabilities, several complementary methods might

be needed to collect data, and these methods should be adjusted to suit the characteristics of such participants. Another conclusion is that without the observational methods, many usability problems would have been missed. Authors also emphasized that evaluators should focus on gaining the participants’ trust before the evaluation sessions.

Rømen and Svanæs [19] have studied the usability evaluation by users with several disabilities (blind, weak-sighted, motor impaired and dyslexic) as a part of their validation of the usefulness of using Web Content Accessibility Guidelines (WCAG) as a heuristic for website accessibility. Several techniques were used for the testing process: a “think aloud” was conducted at first; then a short interview was conducted after completing the test tasks in order to uncover further problems. Evaluators also used a mobile usability lab which allowed the disabled users to be tested at their workplace and home using their own computer and technical aides. The study results showed that only 27% of the identified website accessibility problems could have been identified through the use of WCAG heuristics.

The works reviewed above have addressed the application of specific types of UEMs by disabled users as part of presenting the development process of a software system. However, this paper contributes to explore the effectiveness of applying number of UEMs (Inspection methods, thinking aloud, attention analysis, field observation, coaching method, questionnaires and interviews) for users with disabilities and to present the related conditions and considerations that would customize these UEMs to fit a specific disability. Furthermore, this contribution has been conducted by analyzing and reviewing the literature and the fields that focus on the application of different UEMs with different disabilities; and the obtained recommendations and considerations were based on our findings after analyzing these fields. We think that this work will help novice designers and usability engineers by giving them deeper insight on the areas that they should consider during the usability evaluation for systems designed for disabled users.

III. EXPLORATORY ANALYSIS OF APPLYING USABILITY EVALUATION METHODS BY USERS WITH DISABILITIES

Based on the nature of systems designed for users with disabilities and based on the disabled users’ characteristics, the most effective UEMs can be selected in order to discover all the possible usability issues that impact the system’s users [10]. In this study, we analyzed and discussed the application of different UEMs by users with different disabilities focusing on the users’ special characteristics. The analysis study was based on reviewing the literature and the fields and the obtained result was based on our findings and experience after performing this analysis study. However, the result was a set of recommendations and considerations that should take place before conducting usability evaluation by disabled users.

A. Inspection Methods and Disabled-Users

Before testing the system by real disabled users, inspection methods such as heuristic evaluation, cognitive

walkthrough and action analysis can be applied in order to find and resolve the general and common usability issues based on the expertise of usability and design. The system then becomes ready for testing by disabled users. Although there are many guidelines for designing accessible systems for users with different kinds of disabilities, usability engineers and the designers lack the experience with disabled people characteristics and their different assistive technologies. Therefore, many of the system's accessibility criteria are missed. In this case, the involvement of specialized therapists during the analysis becomes important in order to improve the effectiveness of the inspection methods in order to find more disability-specific usability issues. For example, in analyzing system designed specifically for users with physical impairment; the physical therapist can be participated in order to define the specific limitations that such users may face during the interaction with the system. And when we speak about system designed specifically for children with disability, like for example slow learning children, the involvement of persons like parents or teachers who are interacting with the child very closely and aware with most of the issues that this kind of children have, this can add more value to the inspection method and it will also help finding more usability issues. Generally we can say that relying only on these inspection methods can find some general usability problems, but in order to find more detailed problems and useful information on how to improve the usability, it is necessary to conduct the Usability Testing Methods by actual disabled users [9].

B. Test Methods and Disabled-Users

Usability Testing methods are conducted by real system users and their main objective is to identify problems that users face when dealing with the system. These tests provide precise identification and description of the usability issues that may lead to system re-designing [11]. In particular, for disabled users, many considerations should take place before conducting the test and some of these considerations are common for all type of disabilities; while others are specific for certain disability. Generally, for all kinds of disabilities, the testing environment (either room or laboratory) should be prepared and organized for the disabled user. For example, in case of physical impairment users, testing place should allow enough area for a wheelchair to get in, move around and face the computer. Furthermore, an important thing to consider before conducting tests by disabled users is the different profiles within this user group, i.e. disabled user may be employed or unemployed; educated or under-educated; technology 'power users' or computer illiterate. Information about these differences should be gathered in order to deepen the obtained results. Moreover, it is important to select what system interfaces to be tested by the disabled users. Therefore, different test tasks can be prioritized based on their importance in the system and also based on the amount of user interaction involved. This is because the areas of a system that have the most usability problems are the ones involving the most user interaction [17].

There are many usability testing techniques such as: Thinking aloud, Attention Analysis, Field Observation,

Questionnaires and others. Here, we will go through some of these techniques and analyze their effectiveness when being conducted by users of specific disabilities:

- Thinking aloud

The Thinking aloud method requires the user to verbalize all his/her cognitions when interacting with the system. It is considered one of the most effective techniques in identifying usability problems [11]. When conducting this method by disabled users, the evaluator has to consider the participants' disability before starting the test. For blind and visually impaired participants, they usually use a screen reader as their main assistive technology. However, the evaluator should focus on both the screen reader and the participant voice and expressions. And in this case, he/she has to position the audio recording equipment close enough to hear the screen reader. The evaluator can also use separate audio equipment for the participant's voice and for the screen reader, that way, when analyzing the data, the evaluator can combine between the two recordings [12]. Another case of disabled users are the deaf participants. In this case the evaluator has to record both the participant and the interpreter voice, depending on the situation. If the participant doesn't speak at all, the evaluator can record only the interpreter voice. If the participant speaks some, the evaluator probably want to record both of them. This technique will obviously put more stress on the participant because it is unnatural to his/her to express his thinking loudly and share it with others [11]. Therefore, we might say that think aloud method considered time-consuming and hard to apply for deaf participants since they have to share their thoughts with the interpreter who will give the answers to the evaluator. Also, Roberts and Fels [5] proved the viability of using this method in collecting gestural protocols from the sign language of deaf users and extract relevant usability issues and remarks.

- Attention Analysis

Attention Analysis method includes two categories: Attention-tracking and eye-tracking. In the attention tracking, the participant is asked to click on the areas in the system interface that he/she finds most noticeable. The eye-tracking method in the other hand requires special equipment in order to capture the users' eyes movement so the evaluator can analyze it and gain useful information on the noticeable interface elements. As we can see, this technique is inapplicable for blind participants. While for other disabilities it can be helpful in finding and analyzing which elements of the system are most distracting and how long users remain in certain sections of the system. Furthermore, this technique can be used for evaluating systems designed for aiding children with Autism syndrome by examine and identify the types of interface elements (i.e., animation) that attract and retain child's attention.

- **Field Observation**

This method involve an investigator who is observing the users as they work in their work environment, and taking notes on the activity that takes place there. Observation may be either direct where the investigator is actually present on the observation area or indirect where the task is recorded using a video recorder and later on the investigator can analyze it [15]. Allowing the observer to view what users actually do in their context, especially in case of disabled users, will add great value to the process of finding usability issues. Direct observation allows the investigator to focus attention on specific areas of interest and it will let him/her see how the disabled users use their assistive technologies, and which kind of daily practice they perform. And due to the nature of these users and their sensitivity to any new passive presence in their environment, the investigator should make sure that users are aware with the purpose of his/her presence and the main reasons of the observation. This is particularly important for mentally impaired and blind users who may be disturbed by a passive presence that they are not sure about.

- **Coaching Method**

In this technique the evaluator serves as the coach, where participants are allowed to ask any questions to an expert coach who will answer to the best of his/her ability. The purpose is to discover the information needs of users and find out the limitations in the system design to possibly redesign the interface to avoid the need for the questions [2]. This technique would help in case of blind participants who most of the times need guidance in order to make sure that they are in the right direction. Furthermore, it would help in case of children with learning difficulties since they need continuous help; and the coach can respond to their questions and give them the needed assistance.

- **Questionnaires**

Questionnaires are designed to help the evaluator in obtaining data about the users' subject judgment of the system and reflecting their level of satisfaction. It can be used to evaluate entire system or only partial aspects of the system. This technique is applicable for all kinds of disabilities, except disabled children and slow learners [1]. However, it can be performed in a much simpler form which is the "Interview" [13] in order to simplify the technique for disabled users. The issue with this technique is that it needs enough number of participants, not less than 30, in order to make sure that enough opinions have been collected [13]. However, establishing cooperative relationships with organizations of disabled people may help in recruiting the required number of user participants [9].

C. *Performing the Test Methods Locally or Remotely*

Finding and recruiting test users with special characteristics or specific demographics is a challenging

task [9]. For example: it is not easy to find blind or deaf person who can be participated and committed to the system usability evaluation. This is obviously due to the special issues these users might have such as: transportation issues and the need for continuous assistance. As a result, finding test participants with disabilities is a problematic. Since their involvement is a key factor in usability tests, conducting the usability test remotely in the disabled user's own environment would be a good practice. Disabled users usually use assistive software or hardware technologies such as: screen magnification programs for partially sighted people, single handed keyboards [9]. They also configure these technologies, in a way that fits their needs. Therefore, having remote evaluations which involve performing the test in the users' areas is valuable, especially that the evaluator will be able to closely see how an assistive technology is being used by the disabled user and how this technology affects the usability of the system under testing. As a result, more detailed usability problems can be discovered. As mentioned by Petrie et al. [9], there are number of "remote evaluation techniques" such as: portable evaluation, local evaluation at remote site, remote questionnaire/survey, video conferencing and others. Each one of these techniques can be selected according to the users and the evaluators' conditions. In contrast, going to each individual participants and perform the test in their environments is considered costly and time-consuming; especially when we are talking about large scale projects that need number of participants with different disabilities who may be located in different areas. Therefore, conducting the test locally in a usability laboratory by having the participants attend the test place is more effective and it can save time, cost and effort. As per what has been mentioned above, where to conduct the usability test either locally or remotely is an important dimension that should be considered to obtain effective usability evaluation by disabled users.

D. *Participants Independence*

One of the important issues that affect the effectiveness of the usability test results is the participants' independence and the amount of their contact with the evaluator during the test. In most of the cases, disabled users need some guidance during the test from the evaluators. Such communication should be very well planned and organized in a way that will not affect the accuracy and validity of the test results, since intensive communication can distract the participants' attention and prevent the evaluators from getting reliable results. Meanwhile, lack of help and guidance during the test could lead the disabled user to struggle in one task or become in the wrong direction. In case of deaf users who speech-reads, the evaluator should sit in a position in front of the test participant to allow him/her to read the evaluator's lip and face expressions during the communication, this could be distracted to the user if it is not kept to the minimum during the test. As for slow

learning children, communication has to be through the learning difficulties’ specialist who knows how to interact with children and provide the appropriate assistance.

E. Synchronous or Asynchronous Tests

Selecting among synchronous or asynchronous tests is about assessing the need to have the evaluator and the participant performing the usability test at the same time. In Asynchronous test, the evaluator can provide the participant the test details and manuals and leave him, and after finishing the test, the evaluator can collect the results data like video recording or screen recording tape. Synchronous tests in the other hand, implies having the evaluator participates with the user along the test time by observing him/her while performing the tasks. This way, the evaluator can explore more information like the non-verbal behavior of the participant can reveal more usability problems and their causes. In addition, one of the most important benefits of synchronous tests is that the evaluator will directly and carefully observe the disabled user and see how he/she

interact with the system using assistive technology. This will ensure a deep understanding of different usability issues that should be considered in system design [9][11].

IV. SUMMARIZATION OF THE ANALYSIS RESULTS

Generally, we can say that when evaluating the usability for systems designed for disabled users, combination between UEMs can be performed in order to find and discover most of the possible usability issues. Meanwhile, selecting the most effective UEMs should be done under many considerations like: the system goals, users’ disability type and the project’s time and cost constraints. Based on the previous section, results of analyzing the effectiveness of UEMs by disabled users are summarized in Table1. These results are depicted in the shape of considerations and recommendations along with the justifications behind the selection of these recommendations.

TABLE I. ANALYSIS RESULTS OF THE EFFECTIVENESS OF UEMs BY DISABLED USERS

Disability	Considerations/ Recommendations	Justification
Complete - Partial Deaf	Involve sign language interpreter in the test.	For effective communication with deaf users.
	Plan and manage the interaction during the test.	To avoid any distraction during the test for speech-reads users in order to get accurate reliable test results.
	Combination of test methods: thinking aloud and questionnaire is recommended to apply.	As per the review of previous works, these methods have shown effective results.
Complete -Partial visual impairment	Consider the screen reader assistive tool during the test.	Visually-impaired users rely heavily on the screen reader. therefore to get accurate results, these tools should be considered during the test.
	Provide required assistance when needed.	Based on the special nature and the difficulties faced by such users when using the different systems, immediate and direct assistance should be provided during the test.
	Omit the “task completion time” constraint.	Visually-impaired users spend more time on performing tasks than other disabilities. Therefore, the time constraint should be removed during the test. This ensures more flexibility that helps them complete the tasks.
	Use automatic validation tools.	These users use assistive technology heavily. Therefore, checking the compatibility of the developed system and the assistive technologies using these tools is important.
	Combination of inspection methods is recommended: heuristic evaluation and test methods (coaching method).	As per the review of previous works, these methods have shown effective results by visual impairment users.
Physical impairment	Perform synchronous remote test (in the user environment).	Due to the different obstacles these users may face to attend usability test lab, performing remote test allows more of them to participate in the test.
	Involve physical therapists for effective inspection method.	Such therapists can define the impacts on such disabled users and their limitations during system interaction.
	Combination of inspection methods is recommended: heuristic and test methods (field observation, questionnaire or interview).	As per the review of previous works, these methods have shown effective results by such users.
Children with disabilities: Slow learning, Autism	Involve parents and learning difficulties’ specialist for effective inspection methods.	Involving them can reveal more usability issues and assist in communication.
	Provide clear simple guidance and instruction.	Based their special nature and the difficulties they face when using computer applications, it is important to provide users with clear and simple guidance.
	Combination of inspection methods is recommend: heuristic evaluation and test methods (attention analysis, coaching method)	As per the review of previous works, these methods have shown effective results by such users.
Cognitive and Mental disabilities	Involve cognitive and mental health specialist for effective inspection methods.	Such involvement can reveal more usability issues and enhance the communication omng the test.
	Provide clear and simple guidance and instruction before the test.	Based on their special nature and the difficulties they face when using computer applications, it is important to provide users with clear and simple guidance.
	Combination of inspection methods is recommended to apply: informal walkthrough and test methods (field observation).	As per the review of previous works, these methods have shown effective results by such users
	The observer or test facilitator should build good relationship with the test participants and gain their trust before the test.	Due to the special nature of these users and their sensitivity, it is important to gain their trust to facilitate the communication during the test.

V. CONCLUSION AND FUTURE WORK

In this study, we analyzed and discussed the application of different UEMs by users with different disabilities focusing more on the users' special characteristics. The goal was to explore the effectiveness of applying number of UEMs with users with disabilities; and to present the related conditions and considerations that would customize these UEMs to fit a specific disability. However, the study was based on analyzing the literature and reviewing the fields that focus on the application of different UEMs with different disabilities. And the results that we obtained during this study were based on our findings and experience after analyzing these fields. We think that this work will help novice designers and usability engineers who have no prior experience with conducting usability evaluation with disabled users. However, this work will give them deeper insight on specific areas that they should consider during the evaluation. The future work will be conducting empirical evaluation with real disabled users in order to assess the effectiveness and accuracy of the obtained recommendations and results during this study.

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