EVALUATING SYSTEM ACCESSIBILITY USING AN EXPERIMENTAL PROTOCOL BASED ON USABILITY

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ABSTRACT

This article aims to a systematic approach to assess product accessibility and the adapted system of an experimental protocol originally designed to evaluate product's usability. The adapted protocol approach is focused on products and systems for visually impaired. The developed study with the proposed protocol investigates assistive technology adequacy to target users, regardless of their gender, age or previous experience in this technology usage. The tasks performed by 30 users community were categorized as activities of entertainment, learning and social inclusion. The data obtained from the experiment carried out with the protocol application enabled the test of a set of assumptions about the protocol usage.

KEYWORDS

Assistive Technology, Accessibility and Usability

1. INTRODUCTION

Accessibility has become a major concern of computer system developers. However, unlike its counterpart - Usability, it does not have an established protocol to evaluate quality in products and systems developed for users. For many interactive software systems, a large part of the interaction between user and technology depends on the use of visually presented material (ISO, 2008). Individuals, who are visually intact, typically use the keyboard, mouse, or other pointing devices to provide information and various screen types as output devices. On the other hand, blind or visually impaired users employ their auditory and tactile senses as visual sense. In this case, the typical non-visual forms of interface used in interactive software are auditory or tactile (Sodnik, Grega and Tomazic, 2011). Screen readers, software most commonly used by visually impaired users, are based on speech synthesizers that read the contents of computer screen using synthesized artificial speech (V. Raman and S. Yesilada, Y., 2003, Thiessen And Chen, 2008).To evaluate the usability of devices and accessibility systems, it is essential to follow an experimental protocol that provides a script with procedures and it is aided by documents that guide the evaluator during experiments planning and conduct. This research goal is to explain the factors that can lead a prediction on assistive technology impact on the target population.

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In particular, it examines how accessibility can affect the visually impaired users' behavior when using screen readers and Braille keyboards. To support this research, this work proposes an existing experimental protocol adaptation, originally designed to evaluate the interactive products and systems usability, adapting it to evaluate the usability level of accessibility resources available to the visually impaired, thus classifying the accessibility level from the utilitarian point of view. Help resources can consist of specific systems and components designed to increase accessibility levels, such as hardware, software, or input / output devices. The existing experimental protocol for usability evaluation was conceived, formalized and adopted over the years in research and products usability evaluation in the Laboratory of Human Machine Interfaces (LIHM) of the Federal University of Campina Grande (UFCG) (Aguiar and Vieira, 2009), (Lima, Vieira, Aguiar, 2010). The adapted protocol was validated in its suitability to evaluate screen readers accessibility level and Braille keyboard, when used by blind people and visually impaired.

2. BACKGROUND

To evaluate devices usability and accessibility features, an experimental protocol was adopted to provide a set of procedures and related documents to guide the evaluator during experiments planning and conduction. In the research literature, few studies have been found mentioning the adoption of a protocol during the devices usability evaluation and resources for accessibility.

The research, cited in (Hansen, Mislevy, et al., 2005), evaluated internet assistive technology, while (Sanchez and Hassler, 2017) cites an evaluation of speech synthesizers. However, these assessments were qualitative in nature, e.g. based on user opinion and focused exclusively on screen readers and speech synthesizers used to access Internet sites. The evaluation experiments cited did not mention the support of an experimental protocol and were limited to a small number of participants. Samples of users with fewer than 10 participants were not significant to support the reported inferences. In addition, the mechanisms used for data collection and analysis were only superficially addressed. In the researched literature, there were few reports of usability tests applied to evaluate the accessibility of devices for visually impaired users. Here follows a brief presentation of the relevant work found on this subject.

In the research described in (Hansen, Mislevy et al., 2005) a protocol for assessing accessibility features, more specifically the JAWS screen reader, is mentioned, based on observation of task performance followed by a user satisfaction survey. The tasks were designed to assess the user's skills in: reading comprehension, listening comprehension, grammatical structure, and writing and math skills using the tool.

The usability test was performed with fifteen participants: four blinds, two with low vision, three with learning disabilities, two were deaf, two deaf-blind and two without any type of disability. Despite its contribution, this protocol is focused on evaluating a screen reader when accessing the Internet and is not comprehensive enough to be used in the evaluation of other resource types. The need of specific participants during the tests (such as human assistants to act as interpreters) is not mentioned.

In reference (Sánchez and Hassler, 2017), a protocol is described to evaluate the usability of AUDIOMUD; A virtual reality software game for blind users. The game goal is to place the player in the human body in order to cure diseases, based on the listed symptoms, changing the conditions to which the body is subjected. The interaction with this virtual environment is based on a text reader (synthesizer) that guides the player along the navigation allowing interactions with other players, through a system of chat. In (Hansen, Mislevy, et al., 2005), the adopted protocol during the reported experiment is composed by the following steps: game introduction; Observing the user during the interaction, while recording the experiment in photo and video; Applying a questionnaire to raise the user satisfaction level and report the results.

It is important to note that in most of the publications cited, the experiments were designed to evaluate a specific device or help resource designed to improve the accessibility of web browsing activity.

Authors in (Hansen, Mislevy, et al., 2005) propose guidelines to ensure e-commerce sites security for the blind, while in (Borges, 2009) solutions are proposed to ensure accessibility in digital libraries.

From the review, it was clear that in rare cases where an experimental protocol is described, this is too shallow to answer the questions raised about the conditions under which the tests were performed. In addition, the sample size was too small to support the conclusions drawn. Hence the need to propose an experimental protocol to support the usability devices evaluation and systems designed to support the accessibility and accessibility level achieved.

3. MATERIALS AND METHODS

The experiment consisted in evaluating the usability of three accessibility aid features: a Braille keyboard and two voice synthesizers for blind users. The voice synthesizers used were DOSVOX and JAWS. DOSVOX software was developed for Portuguese language and it is available for free for blind people. The software tools evaluated were: text editor, screen reader and e-mail. JAWS is software marketed by Freedom Scientific and the features tested were the screen reader and the internet browser. The version chosen for tests was the most recent one at the time of the test preparation (version 4.1), with a platform developed for DOS environment instead of Windows. The JAWS version was 12.0, also the latest available below. JAWS and DOSVOX were chosen because of their popularity among users of the Institute for Blind People as well as the Braille keyboard.

An experimental usability protocol consists a set of interrelated steps, processes and activities to guide an evaluation team during the experiment phases: planning, conducting, collecting data, analyzing and reporting the results. These steps are presented in (Aguiar and Vieira, 2009). The adapted protocol supported the planning and evaluation phases of usability assessment experiences during which people with visual impairment participated in performing tasks to demonstrate the suitability of specific accessibility features. As the protocol proposed by (Aguiar and Vieira, 2009) has a comprehensive and modular structure, the adaptation implied to accommodate the usability assessment of the accessibility of systems and devices that resulted in small changes in their steps and processes, without changes in their structure. Its application is to verify that a visual support, under evaluation, conforms to an adequate technical standard of accessibility. The adequacy requirements are presented in (Lima, Vieira and Aguiar, 2010).

3.1 Inference of the User's help towards Performance and Motivation Levels

During the experiment, the choice of tasks aimed to investigate the hypothesis of how the aids could interfere in the users' performance and in their motivation level. Three types of activities were planned in the categories: learning, leisure and social inclusion.

Before starting activities, users were asked to express their preferences by choosing the keyboard type (Braille or conventional keyboard) and the desired media on which they wanted to read the script describing the tasks (Ledor, JAWS or DOSVOX system or printed Braille). Likewise, users had the option of answering the questions at the end of each task: writing in Braille, typing on the keyboard, or expressing orally when their voice would be recorded. The following is a description of tasks.

• Task 1 (task category: learning) - consisted of reading, with speech synthesizer support, and understanding a predefined text. Users had to choose between three texts, in different themes (1- World Cup, 2- Brazilian dance festival and 3 - explanations on how to apply for jobs in the public sector). After reading, users answered related questions.

• Task 2 (task category: fun, entertainment) - The user alone or, when needed, with the help of a team member expert, was asked to access a news site; Select and read news; And highlight (orally or in writing) the aspects considered most relevant and interesting.

• Task 3 (task category: social inclusion): The user alone or, when needed, with the help of a team member expert, was requested to access a specific financial website (Caixa Econômica Federal), which is the financial agent from the Brazilian government's program that offers loans to low-income families to buy houses and simulate the application for a loan, filling out the necessary forms.

3.2 User Group Recruitment

Recruitment of participants (users) was carried out through interviews based on the profile of the individuals and their availability and interest in participating in the research. Because of this research, thirty-two people were chosen and agreed to participate in the tests.

The number of participants was the direct result of their perception of relevance and potential impact to their community. Of the recruited group, 30 participants were identified as beginners or frequent users of JAWS and DOSVOX screen readers, who offer similar features. Each task was assigned an estimated period of time. The group of participants consisted of blind individuals, aged between 18 and 60, both genders, with blindness or acquired blindness, from a generalized context (teachers and school students for the blind).

This study focused on participant's computing skills and familiarity with screen readers. According to their abilities they were classified as beginners, intermediate and advanced. Beginners rarely used computers and had poor screen reader skills. Intermediate users were learning to use screen readers, and expert users were highly skilled in using screen readers and computers.

3.3 Group Performance: Testing Criteria

The groups were compared in performance using the ANOVA test, with classification criteria and the Tukey test, to evaluate the conditions of normality and homogeneity necessary for the tests validation. The system used for analysis was Minitab 15 (Minitab - 2012). The ANOVA and Tukey tests were chosen to compare the averages among the three groups of users, depending on the characteristics in the sampling universe (size and homogeneity) and the significance criterion for the two tests. In order to support this analysis, the following metrics were considered: total number of errors, time spent on the task, number of times the request was requested, number of errors due to interpretation of the text; Number of times participants reported difficulty understanding audio and related incorrect actions.

3.4 Group Performance Testing

The usability test followed the steps of the experimental protocol, with preparation of materials followed by a pilot test to validate the adequacy of resources and materials directed to the data collection and analysis of variables of interest. The experiments were carried out at the Laboratory of Human Machine Interfaces (LIHM) of the Federal University of Campina Grande (UFCG), and at the Instituto dos Cegos, Campina Grande. Users and usability specialists followed the procedures specified in the experimental protocol, duly adapted to the specific context of working with visually impaired people.

As specified in the protocol, participants were invited to sign an agreement stating the purpose of the experiment and the rules of participation, including their right to anonymity. You should highlight their right to stop participation at any time during the test. Conditions, accepted, participants were also asked to state otherwise if they agreed to the recording of video images. All participants agreed to video recording. At the beginning of the session, participants received the test script containing a description of each task to be performed. The script was available in Braille printed form and in electronic format, which could be read using a screen reader.

After introducing the participant to the test, they were asked to perform the tasks specified in the script. During the test, participants were filmed, and data were pooled for further analysis.

4. OBJECTIVES

The main objective of this research is to provide a procedure set, oriented by a protocol that can be clear and rigorous, allowing the replication of results regarding the accessibility claims of products and systems, thus validating their robustness.

During this research, the Braille keyboard was evaluated comparatively with the voice synthesizers, due to a generalized opinion that, despite the tactile feedback that facilitates the visual sensorial substitution, its adoption could be weakened by the increasing use of speech synthesizers. The goal during the experiment was comparing user preferences and effectiveness when performing tasks with both.

The performance evaluation was based on the following set of metrics: total time spent performing task; Completion of the task (completed successfully, completed only with help, completed, but failed, aborted); And the number of times the participant has asked for help. The main assumption was that the nature of the task could interfere with the participant's performance.

5. RESULTS

The percentage data presented in table 1 was obtained according to items 3.1 and 3.2, respectively, where the final states of Tasks 1, 2 and 3 are represented by the groups of participants classified as experienced, inexperienced and intermediate, according to with 3.3.

Table 1. Performance levels of participants versus nature of tasks

Participants	Task1: learning (A); Task 2: fun (B); Task3: social inclusion (C). Portion concluded (%)											
	Incomplete			With aid			Successfully			Failed		
	A	B	C	A	B	C	A	B	C	A	B	C
Experienced	0	0	0	0	0	0	13	19	40	19	29	60
Inexperienced	0	43	0	36	0	0	0	0	0	0	9	0
Intermediate	0	0	0	32	0	0	0	0	0	0	0	0

Task 1, most users requested help to run it, e.g. 36% of inexperienced users and 32% of intermediate users, while only the group of experienced users could perform the task, where 13% performed the failed task and 19% successful. In Task 2, it was observed that 43% of the intermediate users did not complete or abandon the task, while a small part of this group (9%) could complete the task, but with errors. Experienced users could complete the task (19% successful and 29% with errors).

And for Task 3, most experienced users completed the task with errors (60% of users), while the other 40% completed the task successfully.

The results reflect the participants' lack of knowledge about the tools, which were overcome, only for Task 1, and with the evaluation team help. On the other hand, the group of experienced users could complete Tasks 1, 2 and 3, although some of them with errors. There was also a strong influence of participants' experience in the outcome of tasks for those who could use JAWS and DOSVOX, regardless the nature of task. Parametric tests were applied to compare the results of the groups. The groups were compared in performance using the ANOVA test, with classification criteria and the Tukey test. The normality and homogeneity conditions required for the validation of the tests were accepted. The system used for analysis was Minitab 15 (Minitab - 2012). The ANOVA and Tukey tests were chosen to compare the averages among the three groups of users, depending on the characteristics in the sample universe (size and homogeneity), the criterion of significance for both tests were 0.5. To support this analysis, the following metrics were considered: total number of errors, time spent on the task, number of times the request was requested, number of errors due to interpretation of the text; Number of times participants reported difficulty understanding audio and related incorrect actions. The results of the statistical test are shown in Table 2.

Regarding the number of requests for assistance and incorrect actions, according to item 3.3, the p-value obtained and used was lower than the criterion of significance adopted for the ANOVA test adopted in 3.3, which allowed rejection of their respective null hypothesis. Thus, Tukey's test was applied, resulting in statistically significant differences between the means of two groups (experienced and intermediate) and (experienced and inexperienced) participants. Therefore, since the value zero does not belong to the confidence interval, it follows that the group of experienced users shows better performance.

About incorrect actions, there are differences between the average results for experienced and inexperienced groups of participants with inexperienced users exhibiting better performances (item 3.3). This result could be explained by considering inexperienced users submitted to a brief training (item 3.4) and being less experienced were more careful in performing their tasks, thus reducing the errors incidence.

Table 2. Results of the ANOVA and Tukey tests and their relevance for the adopted metrics

Metric	Groups	Mean	ANOVA (p-value)	TUKEY
Total Task Time	1	14.6	0.98	?
	2	14.5		
	3	14.2		
Total number of errors	1	2.4	0.9	
	2	3.8		
	3	4.9		
Number of Help Requests	1	0.01	0	Group3= Group2 (0,9 a 1,7)
	2	4.2		Group1 ≠ Group3 (3,1 a 5,8)
	3	4.6		Group1 ≠ Group2 (2,7 a 5,4)
Text interpretation error	1	2.9	0.08	
	2	2.4		
	3	2.9		
Difficulty to understand audio	1	0.2	0.05	
	2	0.9		
	3	0.9		
Number of Incorrect Actions	1	0.5	0.03	Group3= Group2 (0 a 0,8)
	2	0		Group1 = Group3 (0,5 a 0,3)
	3	0.4		Gruop1 ≠ Gruop2 (0,9 a 0,2)

Thus, with the presented inferences, the previous experience of participant with the resource did not interfere with the performance level of Task 1. The analysis of the usability results based on the nature of the task was performed only for the group of participants enabled in the Using the JAWS and DOSVOX systems, since this was the only group able to perform all tasks, considering the null hypothesis for the ANOVA test, referred to in 3.1.

According to 3.1, the hypothesis of the research, there are no significant differences between the means of the groups as to the total number of errors incurred in performing Tasks 1, 2 and 3. It also states that the number of errors is reduced when the Participant Is highly motivated to accomplish the task.

From the ANOVA test, the mean of the total number of errors decreased in the following order: the highest for Task 2 ($\mu T2 = 7.7$); Followed by Task 1 ($\mu T1 = 2,4$) and Task 3 ($\mu T3 = 1,2$). The value of the significance criterion ($p = 0.01$) was lower than the level of significance adopted for the hypothesis test, therefore, the null hypothesis was rejected. From the Tukey test, applied to the second hypothesis, it was verified that:

• The average of total number of errors incurred during Task 1 is equal to that of Task 3, since the confidence interval does not exclude zero (-3.9 to 6.3);

• The average of total number of errors incurred during Task 3 is different from Task 2, since the confidence interval excludes zero (1.3 to 11.6), meaning that the participants achieved a better performance during Task 3, With the mean error A 1.2;

• The mean of total number of errors identified during Task 1 is different from Task 2 because the confidence interval excludes zero (0.1 to 10.4), meaning that the participants achieved a better performance during Task 3, with an error rate equal to 1.2.

The usability of Braille keyboard was evaluated considering the difficulty of the user in locating characters during the evaluation test. As none of the participants had prior experience with the Braille keyboard, the predominant feature during the analysis was the participant's previous knowledge about Braille, rather than previous experiences with the keyboard itself. Among the 30 participants in the test, the clear majority (27) opted for Braille. By focusing on the sample of individuals who chose to use the Braille keyboard, 79% (19) had prior knowledge of the Braille method and 21% did not know.

Table 3. Participant knowledge about Braille versus ability to use the Braille keyboard during the test

Participants Groups		*Task 1 (%)*	*Task2 (%)*	*Task 3 (%)*
Had difficulties to use the keyboard	Knew Braille	22	0	11
	Did not know Braille	33	13	0
Did not have difficulties to use keyboard		45	87	89

Regarding Task 1, it can be inferred that the level of difficulty with keyboard use was higher among participants who did not know the Braille method (33%) when compared to those who knew it (22%), in contrast to Braille 45% Of users did not have difficulty using the keyboard. On the other hand, in Task 2, the difficulty in using the keyboard occurred only among participants who did not know the Braille method (13%). During this task, all participants reported some kind of difficulty in using the keyboard. Finally, few participants were able to perform Task 3, and considering that they had already gained more familiarity with the keyboard, the reported level of difficulty was low.

Given the experimental protocol modularity and scope for usability assessment, the changes needed to adapt it to accessibility assessment consisted of small adjustments in some steps, processes and activities; Mainly in the experiment planning stages to adapt the test environment to specific needs of the group of participants.

The adapted protocol, adopted in item 3.4, proved to be adequate for the purpose of supporting the usability evaluation of the accessibility resources, promoting an ethical treatment appropriate to the participants of the experiment. The results obtained (item 3.3), from usability point of view, indicate that there is no direct influence of previous experience with specific help resources, on the performance of the user, given the metrics: total task time; Total number of errors; Errors in text interpretation due to the difficulty in understanding the audio produced by the synthesizer. According to the results, it was verified that the inexperienced users, in some tasks, presented better performance, which can be explained by an introductory training session, more requests of help of evaluation team besides being less confident and therefore experienced participants. This result is evidenced by the fact that only the experienced participants completed Tasks 1 and 2; The latter being successfully completed only by this group. It is important to mention that, despite the experience of experienced participants with computer systems and accessibility aids, difficulties were observed in the group, which prevented them from performing tasks more efficiently.

On the other hand, inexperienced users could only use the accessibility aid products helping team, without which it would have been impracticable to participate in the experiment. Regarding the Braille keyboard usage, according to results, the difficulties observed in Tasks 1, 2 and 3 were higher among participants who did not know the Braille method. Given the last step of experiment, during participants were encouraged to discuss their experience, the participant's educational background impact on the expectations and opinions on the accessibility aids evaluated was highlighted. The steps to follow in this research are to refine the materials of the experiment and extend its application to an even larger sample that allows more inference between subgroups of participant profiles. The availability of the protocol should facilitate planning and usability testing, hopefully exposing the difficulties faced by the visually impaired community when using accessibility features, as well as their levels of acceptance regarding perception, understanding and ease of interaction. Although the focus of this research has not been evaluated by the JAWS and DOSVOX speech synthesizers, the protocol application results suggest that resource users may benefit from the redesign of some features related to the usability problems found.

6. CONCLUSION

Given the experimental protocol modularity and scope for usability evaluation, the necessary changes to adapt it to the accessibility evaluation consisted in minor adjustments in some steps, processes and activities; mainly in the planning steps of the experiment to adapt the testing environment for the specific needs of the group of participants.

The adapted protocol proved to be adequate for the purpose of supporting the assessment of the usability of accessibility features, promoting an ethical and adequate treatment to participants of the experiment. The results obtained, from the usability point of view, indicate that there is no direct influence of previous experience with specific aid resources, on the user’s performance, given the metrics: total task time; total number of errors; text interpretation errors due to the difficulty in understanding the audio produced by the synthesizer. According to the results, it was found that inexperienced users, in some tasks, displayed a better performance, which can be explained by an introductory training session, more numerous requests for help from the evaluation team besides being less confident and therefore more careful than the experienced participants. This result is evidenced by the fact that only the experienced participants completed Tasks 1 and 2; with the latter being completed successfully only by this group. It is important to mention that despite the

experience of the experienced participants with computer systems and accessibility aids, difficulties were observed in the group, which prevented them from performing the tasks more efficiently. On the other hand, inexperienced users were only able to use the accessibility aid products with the help of the team, without which would have been unviable the participation in experiment. Regarding the use of Braille keyboard, according to the results, the difficulties observed during Tasks 1, 2 and 3, were higher amidst participants who did not know the Braille method. Given the last step of the experiment, during which the participants were enticed to discuss their experience, it was highlighted the impact of the participant's educational background on the expectations and opinions on the evaluated accessibility aids.

The following steps in this research consist on refining the experiment materials and extending its application to an even bigger sample which allows for more inference between subgroups of participant's profiles. The availability of the protocol should facilitate the planning and performing of the usability tests, hopefully exposing the difficulties faced by the visually impaired community when using accessibility resources, as well as their acceptance levels regarding perception, comprehension and ease of interaction.

Even though the focus of this research was not evaluated the voice synthesizers JAWS and DOSVOX, the results from the protocol application suggest that the resources users can benefit from the redesign of some features related to the usability problems found.

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