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Evaluation of Web Accessibility and Usability from Blind User's Perspective: The Context of Online Assessment

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ABSTRACT

The central premise of our research is that the Web lacks accessibility and usability, creating problems for blind users in Web interactions. We want to understand the nature of accessibility and usability problems blind users face in a Web-based task. Extant literature recognizes this problem exists, but does not explain its nature. This understanding is needed to determine accessibility and usability requirements of the Web for blind users. Our research takes a task-oriented approach to develop this understanding in the context of online assessment. Employing verbal protocol analysis, we capture evidence of problems 6 blind participants observe and experience in completing the task. Analysis reveals two aspects of Web design that present accessibility and usability problems for blind users. Findings will help future research develop blind user profile for Web applications. Our study demonstrates an effective method for qualitative evaluation of Web accessibility and usability for the blind.

Keywords

Accessibility, usability, evaluation, Web interaction, blind user, verbal protocol analysis.

INTRODUCTION

For the 37 million blind people around the world, Web interaction is a challenge (Brophy and Craven, 2007; Lazar, et al. 2007). This is primarily because current Web technology lacks accessibility and usability (Leuthold, et al. 2008; Kelly, 2008). Accessibility allows users access system functionality (Goodhue, 1986). Usability is the degree to which a system conforms to users' cognitive perception about accomplishing a task (Goodwin, 1987). Although lack of accessibility and usability is undesirable for all, it creates more problems for the blind in Web-based tasks (Correani, et al. 2004). Blind users face difficulty performing many Web-based tasks that have become a part of our daily routine.

Literature informs us that the accessibility and usability problems of blind Web users have multiple aspects, but does not clearly explain the nature of this problem. Web interaction for blind users is made possible through mediation by screen-readers to read on-screen text in a sequential manner (Leuthold, et al. 2008). This interaction style is associated with constraints like cognitive overload (Theofanos & Redish, 2003), inefficiency (Lazar, et al. 2007), and inability to recognize images (Harper, et al. 2006). Often, ignorance of developers and designers about non-visual Web interaction impedes design of accessible and usable Web sites (Lazar, et al. 2004). Although design Guidelines exist to help developers and designers in this regard, conformity does not guarantee effective accessibility for the blind (Clark, 2006). Research that examines blind user's' online experience is very scant and does not clearly explain where and why such users have difficulty during Web interaction (Leuthold, et al. 2008). This understanding is necessary to determine Web accessibility and usability requirements for the blind. Our research attempts to develop this understanding. We examine the question: *What is the nature of accessibility and usability problems blind users face in performing a Web-based task?*

We take a task-oriented approach to examine the nature of problems that blind users face in completing Web-based tasks. This task-orientation provides a complete understanding of the problem (Goodwin, 1987). We choose online assessment as the context of our investigation. We employ verbal protocol analysis (Ericsson & Simon, 1980) to examine blind users' web interaction. Six blind participants were asked to perform online assessment on the Blackboard course management system while verbalizing their thoughts and actions. Audio transcripts of verbalizations provide a rich set of qualitative evidence. Analysis reveals two aspects of Web design that presents accessibility and usability problems for the blind. We discuss the nature and characteristics of these problems and suggest possible remedies.

Our study makes two important contributions to HCI research. First, it informs what blind users observe and experience while interacting with online assessment environments. This represents the first step in creating a user profile of this group of Web users about whom our knowledge is scant. This understanding is important to determine accessibility and usability requirements of the Web for the blind. Our study also contributes with a very effective and feasible technique for subjective evaluation of Web accessibility and usability for the blind. It demonstrates how to trace accessibility and usability problems of a system from blind user's perspective, and characterize these with the help of extant design principles. Our findings have implications for accessibility and usability in the design of systems used for online assessment and interactive forms. We recognize that the scope of this study is limited due to small sample size and focus on online assessment only. In future, we plan a full-scale study with a larger number of participants, and include other common Web-based tasks. The research design of that study will also include objective evaluation of Web sites using an accessibility checker.

In the next section, we summarize extant knowledge on the problems blind users face on the Web and identify the knowledge gap. We then discuss principles on good accessible and usable Web design. We provide a detailed description of our research design to evaluate Web accessibility and usability and discuss the findings of our qualitative analysis. We conclude the paper with a summary of our findings and possible solutions to the problems discovered.

BLIND USERS' EXPERIENCE WITH THE WEB

Blind individuals comprise a significant user group with distinct Web interaction requirements. For blind users, Web interaction is a sequential listening activity. This interaction is mediated by a screen-reader that interprets on-screen text and presents this aurally (Di Blas, et al. 2004) by reading pages serially from top left to bottom right (Leuthold, et al. 2008). All inputs are made exclusively through keyboard (Harper, et al. 2006). This interaction style has its distinct accessibility and usability needs (Bornemann-Jeske, 1996).

Web technology lacks accessibility and usability for the blind (Theofanos & Redish, 2003; Correani et al., 2004; Leuthold, et al. 2008; Kelly, 2008). Research shows that 80% of Web sites do not meet basic accessibility requirements (Loiacono and McCoy, 2004). Web sites that comply with such requirements still present access barriers for the blind (Correani et al., 2004). Objective evaluation reveals Web accessibility and usability has declined recently (Leuthold, et al. 2008). A lack of Web accessibility and usability creates more problems for blind users in completing online tasks (Correani, et al. 2004).

Most researchers believe that blind users' accessibility and usability problems stem from the graphical user interface (GUI) (Franklin and Roberts, 2003; Yu et al. 2006; Harper, et al. 2006; Mahmud, 2007). The contention is that screen readers do not recognize graphics, and therefore fail to convey graphical information to the user (Leuthold, 2008). These studies ignore a blind user's experience of the problem. This knowledge is needed for understanding the nature of the problem. Research that examines blind users' online experience informs that non-visual Web interaction suffers from following constraints:

1. Serial nature of interaction means at any moment, users perceive a snippet of the content, losing all contextual information (Lazar, et al. 2007).
2. Inability to quickly scan page means users have problem locating goal-relevant information (Di Blas, et al, 2004).
3. Complex page layout makes screen-reader's feedback ambiguous (Lazar, et al. 2007). This, along with screen-reader mispronunciations, make comprehension difficult for the blind (Theofanos & Redish, 2003).
4. Innumerable screen-reader commands are difficult to remember or use during Web interaction (Theofanos & Redish, 2003).
5. As a listening activity, Web interaction is a cognitively burdensome task (Millar, 1994; Thinus-Blanc & Gaunet, 1997).
6. These represent only glimpses of the problem. These do not tell us where and why such users face problem during Web interaction. This kind of knowledge is needed to understand the nature of the problem (Foley, Wallace, & Chan, 1984).

WEB ACCESSIBILITY AND USABILITY EVALUATION CRITERIA

In this section, our goal is to develop a set of evaluation criteria that helps us characterize a problem. The Web Content Accessibility Guidelines provide four principles of Web accessibility. In section 3.1, we discuss how we intend to use WCAG's principles to characterize a blind user's accessibility problems during Web interaction. Scholars in HCI have proposed several principles for evaluating system usability. In section 3.2, we identify usability criteria to characterize a blind user's problems during Web interaction.

Web accessibility criteria

The Web Content Accessibility Guidelines (WCAG), developed by the World Wide Web Consortium (W3C) is the de facto standards on Web accessibility. Although not universally applicable like ISO standards, WCAG is recognized as the primary design principles on Web accessibility (Kelly, et al. 2005). WCAG comprise a hierarchy of 4 guidelines and 18 checkpoints. Table 1 summarizes the main ideas of these guidelines and corresponding checkpoints (http://www.w3.org/TR/WCAG20).

Table 1. WCAG guidelines and checkpoints.

Guideline	Checkpoints
Perceivable	1. All non-text content that can be expressed in words should have a text equivalent of the function or information that the non-text content was intended to convey. 2. Synchronized media equivalents must be provided for time-dependent presentations. 3. Information/substance and structure must be separable from presentation. 4. All characters and words in the content can be unambiguously decoded. 5. Structure must be made perceivable to more people through presentation(s), positioning, and labels. 6. Foreground content must be easily differentiable from background for both auditory and visual default presentations.
Operable	1. All functionality must be operable at a minimum through a keyboard or a keyboard interface. 2. Users can control any time limits on their reading, interaction, or responses unless control is not possible due to nature of real time events or competition. 3. User can avoid experiencing screen flicker. 4. Structure and/or alternate navigation mechanisms must be added to facilitate orientation and movement in content. 5. Methods must be provided to minimize error and provide graceful recovery.

Understandable	1. Language of content must be programmatically determined. 2. Definition of abbreviations and acronyms must be unambiguously determined. 3. Content must be written to be no more complex than is necessary and/or supplement with simpler forms of the content. 4. Layout and behavior of content must be consistent or predictable, but not identical.
Robust	1. Technologies must be used according to specification. 2. Technologies that are relied upon by the content must be declared and widely available. 3. Technologies used for presentation and user interface must support accessibility, or provide alternate versions of content that support accessibility.

We believe though WCAG is necessary, it is not sufficient for evaluating Web accessibility for the blind. WCAG's vast literature does not refer to any empirical research as the basis of its recommendations (Leuthold, et al. 2008). These have evolved from ideas and discussions among representatives from software industry and disability support organizations (Kelly, et al. 2005). This raises question on WCAG's normative character demonstrating a positive impact on blind users' online experience. Experts also suspect if **WCAG recommendations accurately represent accessibility and usability needs of blind users** (**Clark, 2006; Kelly, et al. 2005;** Leuthold, et al. 2008; Di Blas, et al. 2004). Accordingly, we believe WCAG represents a good starting point in achieving Web accessibility for the blind.

In this research, we use the four guidelines – perceivability, operability, understandability, and robustness as accessibility criteria to evaluate online assessment environments. We conceptualize the four criteria in the context of a blind user's Web interaction as follows:

1. Perceivable: It is possible for the blind user to perceive all Web content.
2. Operable. It is possible for a blind user to operate all interface Elements
3. Understandable: It is possible for a blind user to understand all content and controls
4. Robust: It is possible for the screen reader to interoperate with every aspect of the Web

Web Usability criteria

Usability is a qualitative attribute for assessing how easy it is to use a system (Dumas & Redish, 1999). Although there are several guidelines to evaluate usability of a system, we adopt an integrated set of usability criteria for evaluation of online assessment environment. This is a synthesis of design principles put forth by three renowned usability experts. The design principles include Jacob Nielsen's Web usability criteria, Donald Norman's principles of good design (Norman, 1988), and Shneiderman and Plaisant's golden rules of interface design (Shneiderman & Plaisant, 2004). The ten criteria adapted for our study are:

A. Web Usability Criteria (Nielsen, 1993)

1. *Learnability*. If first-time users can become productive quickly in terms of finding information and using functionality on the Web site.
2. *Efficiency*. If Users can accomplish online tasks quickly, without much cognitive effort, after learning the Web site.
3. *Errors*. If users are prone to commiting errors , and if they recover from it quickly.
4. *Satisfaction*. If users are satisfied with how the website works.
5. *Memorability*. If returning users have to relearn how to use the Web site.

B. Principles of Good Design (Norman, 1988)

6. *Visibility.* If users can tell what is going on with the system, and alternatives for action by observing it.
7. *Good mappings.* If users can determine the relationships between actions and results, between the controls and their effects, and between the system state and what is visible.
8. *Feedback.* If users receive full and continuous feedback about the results of actions.

C. Golden Rules of Interface Design (Shneiderman & Plaisant, 2004).

9. *Consistency*. If the sequence of action is consistent in similar situations; if labeling, order and effects of user interface elements are consistent.
10. *Working memory load*. If displays are kept simple, multiple page displays are consolidated, and window-motion frequency are reduced.

METHODOLOGY AND RESEARCH DESIGN

Participants for this study include six blind individuals, with an average age of 23 years, registered with an institution of special education for the blind. These institutions allowed us to use their computer labs for the study. Each participant had at least 5 years experience using the Web with Jaws screen-reader. None of these participants had ever used a learning management system, or other online assessment tools.

We employed verbal protocol analysis (VPA), in which participants think aloud while performing a task (Ericsson & Simon, 1980). Audio-recordings of participants' verbalizations comprise contextually-rich qualitative evidence of their experience with a system. A space of possible encodings representing task-relevant information is defined a priori (Todd & Benbasat, 1987). Audio-recordings are transcribed, and broken down into single units of thoughts – segments. Each segment is encoded by identifying the category that expresses the same information (Ericson & Simon, 1984).

We developed a coding scheme derived from the Seven-Stages of Action Model (Norman, 1988). It comprised seven categories - goal identification; intention formation; plan of action; execution ; perception of system state; interpretation; and goal accomplishment (Norman, 1988). We introduced two sub-categories in interpretation – consonance and dissonance (Festenger, 1957) and two sub-categories in goal accomplishment – failure and success. Segments labeled as dissonance and failures represent problems faced by participants during the task. Our coding scheme is data-driven; it evolved from analysis of evidence from our pilot study with two blind participants.

We designed a representative assessment task using the Test Manager functionality of the Blackboard LMS. We placed a link to the assessment on the "Assignments" page. This link takes a user to a second page with direction to begin the assessment by clicking Okay. The subsequent three pages present a question each in three different formats. These include multiple-choice, multiple-answer, and short-answer questions – three most commonly used formats. Participants began by reading a set of instruction about logging on to Blackboard, and completing the assessment while concurrently verbalizing. Audio-recordings of these verbalizations, along with screen-reader's speech output helped us capture participants' thoughts and actions. We transcribed the audio-recordings into a rich set of qualitative evidence. We decomposed participant's verbalizations into single units of thoughts or segments. We then categorized each segment according to our coding scheme.

We examined coded verbalizations, along with screen-reader's speech output, to understand where and why our participants faced accessibility and usability problems during the task. Our primary focus was on examining segments suggestive of dissonance or failure. Segments in other categories provided contextual information, and helped us gain a holistic understanding of a problem.

FINDINGS AND DISCUSSION

Our analysis reveals two aspects of Web design that create accessibility and usability problems for blind users in online assessments. Table 2 summarizes our findings. Subsequent subsections discuss these problems in detail.

Table 2. Summary of findings [(u) =Web Usability principle; (a) Web accessibility principle]

Problem from User's Perspective	Concerned Aspect of System Design	Design Principle Violated	Possible Remedies
I. Uncertainty about arriving on a new page	Inconsistent feedback associated with activation of links	Satisfaction (u) Feedback (u)	Provide feedback consistent with blind user's mental model of visiting a link
II. Susceptibility of skipping a question	Positioning of cursor focus on the navigation bar	Error Avoidance (u) Visibility (u)	Position the cursor focus on the question text on moving to a new page

I. Uncertainty about arriving on a new page.

Participants were unsure about arrival on a new page after activating a link. This represents a gulf of evaluation resulting from participants' inability to perceive or interpret system response through screen-reader. Tables 3 present evidence of this problem.

Table 3. Gulf of evaluation

Participant	Activity	Verbalizations
S2	Entering into the assessment page	Once again, I entered into the same problem. It didn't tell me I have entered into a new page. It didn't say page has how many links. It just said frame. I don't know what that means. But I clicked on a link.
	Beginning the assessment	Once again, I have no indication whatsoever from the speech program that I am starting the page, updating the page. So frustrating. But it is somewhat frustrating. When you do click on a link, it is not saying you have arrived on a new page. It just doesn't say anything at all.
	Moving to a new question	Jaws is not saying anything. It didn't actually tell me if I was in a different page
S4	Entering into assessment page	What the heck! It's the contact, it's saying something about contact. (Refering to "Content Frame" announced by screen reader after moving to a new page) I don't know what it's like

This problem violates two usability principles - feedback and satisfaction. Verbal protocols in Table 3 reveal that system feedback following link activation is inconsistent with participants' expectations. It is incomplete, ambiguous, and frustrating, creating uncertainty among participants. This uncertainty is undesirable in any situation, but more so in a time-bound activity like assessment. Users spend extra time and cognitive effort, and have less cognitive resources for decision making (Sweller, 1988).

Our analysis reveals important clues to blind users' mental model. These users recognize arrival on a new page based on two types of screen-reader feedback:

a. Percentage of page downloaded
b. Summary of page elements (e.g. number of links, frames, headings)

Feedback in unconventional forms (e.g. "Content Frame Updated" as in Blackboard) confuses blind user. A solution would be to program the Web application to provide feedback following link activation consistent with blind user's mental model.

II. Susceptibility of skipping a question.

Participants were vulnerable to skipping assessment questions presented by Blackboard without realizing it. Committing such an error is something blind users cannot afford. Error avoidance principle (Nielsen, 1993) recommends that Web design reduces user's susceptibility to committing error, and facilitate quick recovery. Table 4 presents evidence that demonstrates how participants were oblivious to committing the error. If this is the case, all possibilities of recovery are lost.

Table 4 includes evidence of error committed by S1, who had no idea that he was moving to another question without answering the current one. It is noteworthy that this finding was based on analysis of screen-reader's speech in the absence of S1's verbalization. Evidence of this problem comprise screen-reader's announcement (prefixed J), screen-reader typing echo (prefixed J*), and participant's verbalizations (prefixed S1). Table 4 also presents evidence of S4's vulnerability to the error, which was avoided after she was prompted to verify her location.

Table 4. Evidence about susceptibility of skipping question 2

Participant	Verbalizations
S1	J. 1: Microsoft Internet Explorer Dialogue: Confirm question submission. Okay button. To activate, press space bar. J*. 1: Space. J. 2: two percent...one hundred percent. Frame 4. Course Content Frame. Updated. Go to first question button. Go to previous question. Question 2 of 3. Go to last question. Blank.

	Graphic links to assessment questions and answers. Same page link read question. Same page link. Course content frame) S1. 29: Oh, sorry...just going up and down. J. 3: Go to next question button. J*. 2: Enter. J. 4: Microsoft Internet explorer dialogue. Question may be incomplete: 2. Continue? Okay button. To activate, press space bar. J*. 3: Space. J. 5: Microsoft Internet explorer dialogue. Confirm question submission. Okay button. To activate press spacebar. J*. 4: Space.
S4	99: I'm going to the next question. 100: So Enter on Go to Next Question. 101: One. (Responding to "Which question are you on now?") 102: Sso, I'm gonna go to question 2. Researcher: How do you know that you are at question 1? 103: Cuz it says go to question two. 104: Go to the next question... Researcher: Where does it say that 105: There we go! (Hearing "Question two of three) 106: Right there 107: Alright. (Hearing "Go to next question button") Researcher: So what are you going to do? 108: Go to question two Researcher: How are you going to do it? 109: By "go to next question." Researcher: Which question are we on? 110: Question one. 111: Maybe go on that one Researcher: What did it just say? 112: Question two of three Researcher: What does that mean? 113: I'm on question two Researcher: So why did you go to next question? 114: Oh! 115: Well, I thought I was still on question one

This problem results due to default cursor focus. When a new question page loads, the system brings the cursor focus to the navigation bar that has "Go to Next Question" button (refer to J. 2 in Table 4). Incidently, the user arrives here by activating the "Go to Next Question" button in the corresponding section of the previous page. The user is likely to confuse that the previous attempt to activate the button failed, and makes another attempt to do so. This way, she unintentionally skips the question (refer to J. 3 and J* 2 in Table 4). As evidence reveals, messages like "Question 2 of 3" and "This question may be incomplete" are ignored by participants (refer to J. 2 and J. 4 in Table 4) . These messages are announced without the context, and therefore do not grab participants' attention. This problem represents violation of accessibility requirement for providing context and orientation information.

This problem can be remedied if the application is programmed so that cursor focus moves to the question text when a new question page loads. This makes the new question "visible" to the user. Visibility means a user can perceive a change in state by just observing it (Norman, 1988). Visibility for a blind user represents perceiving data objects and available commands aurally through screen-reader (Yoshikawa, 2003). Enhanced visibility can reduce blind users' susceptibility of skipping questions.

CONCLUSION

The purpose of our study is to develop an understanding about the nature of accessibility and usability problems blind users face during Web interaction. These users interact with Web sites and Web applications to perform a task for achieving some goal. Accordingly, we adopt a task-oriented approach to discover where and why these users face difficulty completing an online task. The context of our investigation was online assessment – a common task in today's academic environment.

We employ verbal protocol analysis to collect evidence of problems 6 blind participants observed and experienced completing a representative assessment over the Blackboard. Our analysis reveals two aspects of Web design that presents accessibility and usability problems for the blind in an online assessment. These problems represent violation of good design principles in multiple ways. The two problems include:

Blind users have difficulty ascertaining their arrival on a new page of an LMS. This is because they receive a feedback about link activation that is inconsistent with their mental model. This accounts for violation of two usability principles – consistent feedback and satisfaction of use. A possible remedy is to program the LMS such that the feedback associated with link activation is complete and consistent with blind user's mental model.

Blind users are susceptible to skipping an assessment question without realizing. This error is induced by positioning of cursor focus on the navigation bar on moving to a new question page. This accounts for violation of two usability principles - error avoidance and visibility. This also accounts for violation of an accessibility criteria that requires providing context and orientation information. A possible remedy could be to position the cursor focus at the question text on moving to the new question page.

The solutions we suggest may be evaluated in future research through an experiment. These findings have implications for design of Web systems used not just for assessments, but also for similar purposes including interactive forms and questionnaires.

Our study makes two important contributions to HCI research. First, it informs what blind users observe and experience while interacting with online assessment environments. This represents the first step in creating a user profile for this group of Web users, about whom we hardly know anything. This kind of understanding is fundamental to determine accessibility and usability requirements of the Web for the blind. A second contribution of our study is a very effective and feasible technique for subjective evaluation of Web accessibility and usability for the blind. It demonstrates how to trace accessibility and usability problems from blind user's perspective, and characterize these with the help of extant design principles.

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