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An exploratory study of library website accessibility for visually impaired users

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ABSTRACT

To extrapolate best practices for accessible library website design, the Web-browsing needs of users with visual impairments were investigated. Selected library websites were tested for usability and accessibility with six visually impaired persons who use screen readers. The results were analyzed in terms of accessible coding standards as well as high-level usability issues. The analysis results indicated that these library websites are not accessible for visually impaired screen reader users. The most common accessibility barriers encountered were issues of information architecture and usable Web design, rather than errors in coding. Suggestions to improve accessibility are proposed.

1. Introduction

Within the library and information science (LIS) field and profession, equal access has been emphasized as one of the foundational principles of intellectual freedom and participation for members of society (American Library Association, 2004; International Federation of Library Associations and Institutions, 2015). Now that digital formats are the de facto standard for information exchange, the equitable provision of online information services to all types of users is an increasingly critical part of this mission, with library websites serving as an important access point to online resources for those who are disadvantaged in terms of information accessibility. This study was carried out with people who have visual impairments as an exploratory inquiry into the access challenges of an information-disadvantaged population.[1] The goal of the study was to acknowledge (or better understand) the current status of library website accessibility for an underrepresented user group (in this case, persons with visual impairments) and to explore the implications of the study findings to LIS practice as a means of promoting equity of services. The specific focus was on meaningful accessibility, in other words the usability, of online library resources for users with screen readers in the context of navigating library websites to access information.

2. Problem statement

For libraries, promoting Web accessibility is critical to creating an inclusive environment because it addresses structural information disadvantages experienced by people with disabilities. People with disabilities are one of the largest diverse library user groups who experience information disadvantages, as 18.7% of Americans have at least one disability, and 12.6% have a severe disability that could affect their ability to access the Web (Interactive Accessibility, 2015). However, much of the existing diversity literature in LIS focuses on race and ethnicity (Gabriel, 2013; Jaeger, Subramaniam, Jones, & Bertot, 2011), and there is little attention to the information needs and behaviors of people with disabilities, particularly with regard to technology and library services.

According to Jaeger and colleagues (Jaeger et al., 2011; Lazar & Jaeger, 2011), the rapid growth of information technology has had a marginalizing effect on many groups, including those defined by age, socioeconomic status, literacy, language, culture, geography, and disability. For people with disabilities, a typical example of marginalization through technology is the barriers they experience when trying to access the Web. People with disabilities are one of the largest minority groups not typically considered as a regular user group by Web developers, which means that their needs are not adequately factored into the design of websites and other Internet-based information services. Unfortunately, as access to these services is increasingly required for full participation in society, the impact of the problem on people with disabilities is increasing proportionately.

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[1] This study grew out of an MLIS course, Web Accessibility and Usability, offered at St. Catherine University in the spring of 2013. The course was designed to teach the technical aspects of website usability and accessibility through student testing of websites. The accessibility testing assignment for the course developed into a funded research project when students sought the opportunity to test websites with users of assistive technologies. In April 2013, students in the class received a research grant to conduct accessibility testing of library websites with visually impaired users, resulting in an extended student-faculty research collaboration with additional data gathering and analysis by a subset of the students.

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Libraries do not appear to be an exception to the rule when it comes to Web accessibility. A number of studies reveal that typical library websites are not truly accessible for people with various disabilities (Lazar & Jaeger, 2011; Lewis, 2013; Southwell & Slater, 2012). As library resources continue to migrate online, it is critical that library professionals address this problem more assertively or risk an increasing lapse in their mission to provide a diverse public with broad access to information. To that end, the study described here investigated accessibility problems on three library websites, with a focus on the gap between traditional definitions of Web accessibility, i.e., compliance with various coding standards, and the notion of accessibility as meaningful access, which is defined here as usability for people with disabilities.

3. Literature review

3.1. Web accessibility legislation

Title II of the Americans with Disabilities Act (ADA), passed in 1990, provides general guidelines on the legal protection and equal rights of persons with disabilities and requires the equal treatment of persons with disabilities by public agencies, including public and academic libraries (Vandenbark, 2010). Section 508 of the Rehabilitation Act of 1973, as amended in 2001, more specifically requires that US federal agencies make their information and services, including online information, available to people with disabilities so that they have access to the same information as those without disabilities (Thatcher et al., 2006). In addition, Section 504 extends this provision to all entities funded by federal money, which includes a number of public libraries and their websites (Thatcher et al., 2006).

At present, there is no federal provision requiring accessibility for all websites. Providenti and Zai (2007) investigated whether the legal mandate for website accessibility could apply to academic libraries, and concluded that there is not a clear mandate, although the potential exists for indirect enforcement through Section 508. However, a recent decision by the Department of Justice may result in the introduction of new rules in Title III of the ADA that would extend the website accessibility requirements to all "websites of public accommodations," whether federally funded or not (Federal Register, 2014). These new rules, which are expected to be introduced in 2018 (Department of Justice, 2015), would mandate the accessibility of public accommodations websites such as e-commerce, tax preparation sites, schools, and public libraries (Vu & Launey, 2015).

3.2. Accessibility standards and guidelines

In general, accessible Web design seeks to meet the needs of people with disabilities coming from diverse backgrounds and possessing a wide range of abilities. The WAI (Web Accessibility Initiative) of the World Wide Web Consortium (W3C) is the leading organization establishing standards and requirements for accessible Web development, including the Web Content Accessibility Guidelines (WCAG). Using WCAG as a yardstick, Thatcher et al. (2006) and Horton and Quesenbery (2013) have pointed out many technical barriers to accessibility in current Web design, such as the lack of a basic text alternative (alt text) for images, the use of invalid or poorly structured HTML, which can lead to a cluttered experience for users or misrepresentation of content types by a screen reader, the improper use of color contrast, the inappropriate use of HTML headings, and the absence of skip links that allow blind users to bypass redundant navigation elements appearing on every page.

WCAG 2.0 represents an effort to make accessibility guidelines technology-independent, and in doing so, eliminates many of the specific directives found in version 1.0. The guidelines are broad in scope and can potentially result in a very comprehensive analysis of a site's accessibility; however, Vandenbark (2010) and Rømen and Svanæs (2012) assert that this lack of specificity results in ambiguity for developers using such guidelines as a baseline to create accessible websites.

3.3. Libraries, technology, and accessibility

Providing evidence of the accessibility challenges found on library websites, a study by Comeaux and Schmetzke (2013) found that between the years 1996 and 2006, academic library websites reduced accessibility coding errors from 5 per page to 1.7. However, since 2006, improvement has stagnated, with two out of five academic library websites still plagued by WCAG Priority 1 errors. A study by Oud (2012) confirms libraries' shortcomings in accessibility compliance. Her survey of 64 academic and public libraries in Ontario found that the average library website examined in the survey contained 14.75 accessibility problems per web page.

The impact of inaccessible library websites extends beyond legal compliance or access barriers. Through the use of qualitative interviews, Copeland (2011) found that libraries contribute to the social construction of disability by failing to create accessible websites. Learned attitudes, as well as a lack of research, resources, and training, are seen as barriers to accessible services in libraries. Though libraries have made many strides over the past several decades, accessibility, especially in regard to technology, is far from universal. Including patrons with disabilities in the definition of diversity is a necessary step toward minimizing marginalization. However, as Jaeger, Bertot, and Subramaniam (2013) note, the literature on accessibility in the LIS field is rarely presented in the context of diversity.

3.4. Library website use for people with visual impairments

Visually impaired patrons using assistive technologies encounter many challenges in accessing digital materials on library websites. Southwell and Slater (2012) examined the accessibility of U.S. academic library digital collections and found that only 42% were readable using a screen reader, while 58% were not. The primary reason these digital collections were not screen-readable was the lack of a transcript or otherwise digitally readable text associated with the digitized materials. Southwell and Slater argue that institutional policies and mandates are necessary to achieve consistent accessibility for digital library resources.

3.5. Accessibility testing with tools and users

The W3C (World Wide Web Consortium, 2011) defines Web accessibility evaluation tools as "software programs or online services that help determine if a website meets accessibility guidelines." These tools conveniently allow Web developers to evaluate the conformity of a website to accessibility guidelines with minimal effort; however, such tools cannot verify the accessibility of websites or guarantee their usability in terms of true functionality for disabled users (Section508.gov, n.d.).

In spite of this limitation, accessibility problems are often seen as distinct from usability, which leads to the assumption that a standards-compliant site will function well for people with disabilities simply because it is free from accessibility coding errors. But for meaningful access to occur, accessibility must extend beyond a mere provision of access through standards compliance. It must also ensure that users can achieve the specific goals of their information need and use (Lazar, Olalere, & Wentz, 2012; Walting & Crawford, 2010). In this study, accessibility is defined as the quality of access that allows people with disabilities to actually use the content that is presented in a way that satisfies their information needs.

Nielsen (2005) drew the connection between usability and accessibility by arguing that accessibility testing should involve real users in conjunction with accessibility evaluation tools. In a Web accessibility primer for librarians, Riley-Huff (2012) emphasizes the difficulty of

applying Web accessibility principles without firsthand experience with assistive technologies and points out that many disabled users are themselves novices with technology, and understanding the challenges they encounter as well as their techniques for browsing is critical to detecting problems. Kelly et al. (2009) go further and stress the importance of understanding user contexts in order to meet the needs of diverse technology users. They argue that prioritizing standards compliance over the context of use may in fact limit accessibility. A study by Rømen and Svanæs (2012) seems to confirm this view. Their research found that over half of the accessibility problems encountered by disabled Web users during a usability test were not addressed by either WCAG 1.0 or 2.0. Such research implies that automatic evaluation tools can only detect fewer than half of the barriers that real users with disabilities most likely face. In addition, Rømen and Svanæs found little to no correspondence between the priority levels of the WCAG criteria and the actual severity of problems faced by real Web users with disabilities; this implies that compliance with the highest-priority WCAG criteria does not guarantee that even the most severe accessibility problems will be eliminated.

Lazar et al. (2012) conducted a usability test with the aim of identifying the main accessibility and usability barriers for screen reader users on job application sites. They determined that job application websites are generally inaccessible and unusable, shown by the fact that only 28.1% of application attempts during the test were successfully submitted with no assistance. Some of the main accessibility barriers were badly worded link labels, bad or nonexistent form entry instructions, and an illogical tabbing order throughout the page (Lazar et al., 2012). The present study is similar to their study in that both involved usability testing for the sake of determining accessibility barriers on a specific type of website. However, the present study is unique in applying a usability testing model to the evaluation of library websites.

4. Research questions and study goal

The goal of this study was to gain insight into the Web-browsing needs of visually impaired and blind users in order to extrapolate best practices for accessible library website design. Screen reader users with visual impairments were interviewed and also usability testing methods were employed in observing users accessing library websites via screen readers. The barriers users encountered were then compared with those reported by an automated accessibility testing tool in order to determine whether the common practice of testing a site's accessibility only with automated tools is sufficient to detect major accessibility barriers.

4.1. Research questions

1. What specific accessibility barriers can be identified in the selected library websites by observing visually impaired participants attempting to access them via screen readers? What are some sources of barriers that result in inaccessible websites?
2. Are the barriers observed consistent with the results of technical (coding) accessibility audits produced by an automated testing tool? If they are not consistent, what are the discrepancies? Does an analysis of the discrepancies reveal additional, non-coding-related usability problems inherent in the Web design that may be preventing screen reader users' access to library websites?
3. What needs specific to screen reader users in accessing and using library websites can be observed in user testing? This question is intended to identify any accessibility problems with library-specific features that limit accessibility for visually impaired persons.

5. Method

This study borrowed techniques from usability testing to observe visually impaired individuals accessing websites with screen readers.[2] Usability testing is a widely accepted technique practiced in HCI to support effective user-centered website design and evaluation. Its purpose is to assess the usability of a product through observing it in use (Usability.gov, n.d.). While it is a useful tool for obtaining quick feedback on a product's design, it is important to note that the goal of usability testing in capturing users' reactions is merely to improve a product, and not to advance any scientific (or generalizable) discovery of underlying phenomena in the user population. With this limitation, the present study focused solely on capturing accessibility barriers in order to find their sources in Web design for the purpose of informing the development of possible solutions. The accessibility barriers were determined through usability testing. For the purpose of the comparative analysis discussed in RQ2, the websites were also tested for standards-compliant code using an automated testing tool called AChecker (2001).

5.1. Data gathering

Participants with visual impairments were recruited for the study by means of an email advertisement[3] that the authors sent out through Minnesota State Services for the Blind and Associated Colleges of the Twin Cities Disability Services. Six people responded and participated in the testing using their own laptops and screen readers, with each test lasting between 120 and 150 min. The participants ranged in age from 19 to 58 years old, and the group consisted of two women and four men. Participants had between 15 and 33 years of experience using screen readers for Web access. Four participants were current students (two at the undergraduate level and two graduate students), another was a full-time professional, and another was actively seeking employment. Five participants used the JAWS For Windows screen reader, and one person used VoiceOver for Macintosh.

Three library websites, two academic and one public, were tested. The public library serves a county with a population of about 350,000, and the academic libraries serve populations of about 5000 and 1000, respectively. Testing data were generated using interviews and a modified think-aloud protocol for usability testing, which were recorded via observation, note-taking and transcription.

The consent form[4] was read by one of the researchers at the beginning of the testing, and the participants signed with a pen. The test procedure consisted of a pre-interview, test session, and exit interview with each participant. The pre-interview consisted of general questions regarding the participants' Web use, as well as specific questions about any challenges they regularly experience as screen reader users. The testing portion consisted of an open-ended homepage exploration, followed by one to four task scenarios for each website, as time allowed. Each scenario was relatively simple, to allow for an exploration of issues and for redirection when accessibility barriers prevented task completion. The website tasks included catalog searches, making research appointments, and signing up for events. The testing instruction and task scenarios were scripted beforehand and read aloud to the participants, thus ensuring uniformity by guaranteeing that all participants heard the same wording throughout the test.

The traditional think-aloud protocol used to obtain participant feedback in usability testing had to be modified for this user group, who needed to focus on listening to the screen readers while attempting

[2] A screen reader is an assistive technology that allows low-vision or blind users to interact with computers using only a keyboard and listening device. Digital text-to-speech technology is used to read the entire text of the page, including certain hidden tags, in the order they appear in the underlying (unformatted) HTML code (Fig. 1). Using special keystrokes or key combinations, users are able to navigate the page in a variety of ways, including jumping from link to link, from heading to heading, or skipping between search fields or buttons on a page.

[3] Compensation was paid in the sum of $100 per participant for a two-hour session. For the tests that lasted an extra half-hour beyond what was advertised, the participants were paid $125, but most sessions lasted 2 h because the participants had prearranged transportation.

[4] The research, including the protocol for recruitment, consent, testing script, interview questions and other procedures, was approved by the IRB.

the task scenarios. Rather than directing study participants to narrate their thoughts in real time while browsing, they were encouraged to pause while talking about what they were doing if it was easier for them. After testing, an exit interview was conducted to gain insight into the participants' retrospective thoughts on what had happened, what their expectations had been, and what made the tasks difficult or easy. For each test, a team of two researchers made observations: one as note-taker and the other as facilitator.

For comparison purposes, a report was generated on the accessibility of the websites' homepages as defined by WCAG 2.0 standards using AChecker,[5] an automated testing tool that scans the HTML, CSS, and scripting of a webpage to check for accessibility standards conformance and returns a list of errors indicating the type and severity of the problems it finds. The purpose of the AChecker analysis was to determine how much overlap there was between the problems encountered by the human participants and those identified by the automatic tool. AChecker was chosen over other automated tools due to the researchers' familiarity and its performance capabilities; AChecker is free of charge, and it analyzes Web pages more quickly and with more comprehensible output than the other free tools that the researchers tested in their Web Accessibility course.

5.2. Data analysis

The data analysis consisted of three parts: 1) an analysis of the test results to determine the main barriers to access of the sites' content and their severity, and the sources of those barriers; 2) a comparison of the accessibility barriers identified during user testing with the results of an automated testing tool; and 3) an analysis of the participants' interview responses, to gain insight into their general information needs through their own accounts of their Internet use and access.

Barriers found in testing were analyzed by means of severity ratings (Table 1), which indicated the extent to which they prevented users from completing the task scenarios. The severity ratings were coded by consensus by the researchers using the testers' shared notes, in which each task was marked either “completed” or “not completed” along with a detailed description of the level of assistance required for task completion. Full descriptions of the severity ratings are given at the bottom of Table 1.

To compare the results of the usability test with those of the automated tool, the researchers cross-referenced any technical sources of usability problems that were found for each home page with corresponding standards-compliance issues identified by AChecker for the same page. The results of the comparison are listed in Table 2. Table 2 shows the number of known problems that AChecker listed for each site's homepage when set to the default settings (WCAG 2.0 at Level AA). AChecker also lists likely problems and potential problems, but those were not counted in this analysis because they are not definitive coding errors; rather, they are AChecker's suggestions of commonly problematic issues that ultimately require a human's discretion to determine whether they are real accessibility errors. For example, images are frequently flagged as potential problems because AChecker detects that they may be decorative images, in which case they would be required by WCAG 2.0 to have empty alt text. Such issues need to be examined on a case-by-case basis, and the potential problems list tends to contain many false positives. Consequently, this analysis counts only the objective known problems in order to avoid counting elements that are flagged as errors in spite of their conformance to technical standards.

6. Findings

About half of the tasks were completed successfully; of those, only half were completed without the researchers' intervention. No single participant was able to complete all of the tasks successfully. A task scenario that required finding a known item from a library catalog was completed by only one participant without intervention, taking 7 min. Another task that required finding a subject resource was completed only once without intervention, taking 5 min. A task that involved signing up for a workshop was completed by two participants in a relatively short amount of time without intervention, but was extremely difficult for all other participants. Of the rest of the tasks, about half were completed with some intervention, and the remaining tasks were impossible for participants to complete, even with intervention. The specific barriers are grouped according to the three major areas of data analysis: 1) the specific accessibility barriers found and their severity; 2) a comparison of the barriers found to the results of an automated testing tool; and 3) how the barriers relate to the general information-seeking and information needs of the participants, and whether or not these needs are being met by the tested websites.

6.1. Specific barriers found through user testing

6.1.1. Difficulty of using the catalog

All 6 participants encountered moderate to severe obstacles when it came to access and use of the library catalog. In fact, simply finding the catalog on a library website was surprisingly difficult for the test participants and resulted in non-completion of a number of tasks. This problem was primarily the result of the navigation issues discussed in the next section.

The participants who were able to locate a catalog generally found it difficult to use. Some of the catalog tasks required participants to filter search results by certain criteria, such as the desired format of the library materials. However, the checkboxes or other filtering options commonly found on online catalogs are not always well suited for screen reader use. In addition, it was observed that search options are often presented in a way that is not intuitive to screen reader users. For example, in one of the tested catalogs, the visual presentation of advanced filter options allowed a sighted user to easily perceive them all, but screen reader users could not because the search button was positioned above a number of search options. This resulted in the screen reader users missing them because they expected the search button to be placed at the end; thus, they did not scroll or tab beyond it to look for more options.

The formatting of the search results could also be problematic. In one of the catalogs, the titles on the results list were not formatted as headings or links, which would have allowed for much easier skimming because screen reader users can tab between them. This forced participants to listen to every word of the bibliographic entry for each result before moving to the next. Those users whose desired item came up higher on the list were able to complete the task, but not without frustration. Those whose search terms were broader were unable to complete the task, as it is not feasible to scan over 1000 results with no way of skipping quickly from item to item on the list.

6.1.2. Navigation problems

Navigation problems generally fell into two categories: difficulty navigating pages with large volumes of linearized text without the advantage of visual cues, and semantic and structural barriers such as misleading link labels and a lack of proper heading structure. It was also observed that the semantic and structural barriers compounded the linearization issue by making it difficult for screen reader users to group content in other non-visual ways.

6.1.2.1. Linearization issues. Linearization, the method used by text-to-speech technology, refers to the representation of website content in the exact sequence it appears in the source code (see Fig. 1 for a visual interpretation). Linearization often seemed to result in cognitive overload for the study participants; without the advantage of visual cues, they were required to “read” far more irrelevant text than a

[5] http://achecker.ca/checker/index.php.

Table 1
Accessibility barriers and their severity ratings.

Type of barrier	Severity rating (defined below[a])	Total number of occurrences ([b])	Number of sites (out of 3)	Number of users (out of 6)
Catalog				
Difficult to find catalog	Moderate	7	2	5
• Catalog search tool is not a link (not accessible from links list)				
• Confusion between Books page and catalog				
Difficult to search	Severe	3	1	3
• Cannot detect/use advanced search option(s)				
Difficult to browse search results	Severe	4	1	4
• E.g., lack of links/headings in catalog search results (cannot scan)				
Navigation				
Linearization	Slight	1	1	1
• Page organization and order of information presentation				
Headings	Moderate	8	2	3
• Lack of headings/poor page structure in calendar				
• Lack of hierarchical headings throughout site				
Link labels	Severe	12	2	4
• Poorly labeled link text/no description of link destination or out-of-context link labels				
Lack of labels on form fields (inefficient form entry)	Minimal	2	2	1
Dynamic elements				
Drop-down menu	Minimal	4	1	4
• Mouse-only drop-down menu				
• Drop-down menus not detectable				
Dynamic Tab panel	Severe	5	2	4
• Dynamic tab panel on which changes are not detectable				
Combo box	Severe	1	1	1
• Inaccessible combo box				
Misc				
Aurally meaningless presentation of graphic content	Slight	11	2	5
Function of event filters in calendar not clear	Severe	4	1	4
Site logo's alt text renders university's acronym, not full name	Moderate	5	1	5
Misspelled word which screen reader spells instead of speaking ("Advanced search")	Minimal	1	1	1
Overabundance of information and links	Minimal	3	2	2

[a] Severity ratings: Minimal - the barrier was mentioned as a potential problem; Slight - the barrier was easily overcome in a short amount of time; Moderate - the barrier presented a major slowdown, but participants worked around it and managed to complete the task on their own; Severe - participants could not finish the task on their own, resulting either in facilitator intervention or simply giving up on the task.
[b] Some of the participants encountered the same error multiple times on a site, so the total number of occurrences is not always equal to the number of users or sites.

sighted user typically would just to find the information they were looking for. In addition, the information often lacked any predictable flow since the sequence of HTML code rarely corresponds with its visual representation. The poorly sequenced catalog search interface mentioned above is one example of this problem.

6.1.2.2. Semantic issues. Poor link labeling, which includes non-intuitive anchor text, a lack of context in the surrounding text, and the omission of descriptive attributes in the HTML code, caused navigation problems across all of the sites tested. Without text describing whether a given link is useful (e.g. "read more" or "click here"), participants tabbing through links to find relevant content were consistently taken on extended detours, or "rabbit holes," as one participant put it. These detours were time-consuming and difficult to recover from, as was the case for two participants who tried to navigate within a site, but ended up on external sites without realizing the error for some time. Misleading text also caused detours; for example, one participant looking for ebooks followed the link "Find eBooks," but instead ended up listening to a LibGuide on available databases that might contain some ebooks. On another library site, participants consistently confused a menu item labeled "Books" (that linked to a page highlighting specific titles) for the catalog, causing long delays in their task progress because they did not have access to visual cues that indicated a false lead.

In some cases, the problem was more a lack of description in the sentences surrounding the anchor text, rather than the anchor text itself. The test participants repeatedly noted that links or headings relying on visual groupings for context, such as "Main Site | Kids | Teens" made no sense to them. In addition, participants had difficulty discerning the purpose of links labeled with isolated characters, such as a series of differently sized letters ("**A** A A"), which are supposed to indicate the option to resize text, or the numerical links at the bottom of an image carousel, which are meant to allow users to browse manually through the images.

6.1.2.3. Headings/hierarchical structure. A major barrier to navigation for some participants was the lack of hierarchical page structure on the tested sites. Two of the participants relied extensively on hierarchical heading lists to navigate the websites, much like navigating a book with a table of contents. However, when the test sites lacked a proper hierarchical heading structure, as was the case with one site in which all headings were set to level 2, navigation by headings was virtually impossible, thereby frustrating the participants who preferred heading navigation, and providing fewer options for the remaining users.

6.1.3. Dynamic design elements

The final major accessibility challenge for the participants was the lack of interoperability between dynamic Web elements, such as combo boxes, drop-down menus, and tab panels (switching between tabs while remaining on the same page) and screen reader applications.

Drop-down menus frequently created a challenge for participants. This was because screen readers often interpret the top level of a drop-down menu as a link, even if it does not actually link to a separate page. When a participant would select such an item from their list of links, it caused confusion since they were under the impression that they had gone to a new page, when in fact, they had not.

A similar problem occurred on sites containing scripting for a tab panel whose links dynamically changed the content within a single page rather than linking to a new page. All of the participants who

Table 2
Overlap between AChecker and participants' responses.

Detected by AChecker alone (homepage)	Detected by both AChecker and participants
Library Site 1 (13 errors found by AChecker)	
Some text not resizable (AA)	No labels on some form elements (A)
Language of page improperly specified (A)	Missing or invalid alternative text (A)
Code error: some "id" tags are not unique (A)	
Library Site 2 (24 errors found by AChecker)	
Lack of labels for some input elements (A)	Missing or invalid alternative text (A)
Insufficient color contrast (AA)	
Heading levels nested incorrectly (AA)	
Library Site 3 (13 errors found by AChecker)	
Lack of labels for some input elements (A)	Scripting contains events that require mouseover (A)
Heading levels nested incorrectly (AA)	

Note: Each barrier category is accompanied by its WCAG 2.0 priority level (A or AA).

encountered tab panels (four out of the six) became very confused after clicking on the links and not hearing the expected screen reader prompt announcing a URL change. These participants commented that they had no idea whether the links worked, and when they tried navigating the new page content, it seemed as though they were on the same page they had been previously. In these cases, the facilitators needed to explain that only a small portion of the page had changed.

Certain dynamic elements seemed to function well for the participants. Specifically, several commented favorably on combo boxes, which are similar to drop-down menus, but are accessed more easily by screen readers because they are identified as a distinct element rather than a link, and because their screen readers offered a shortcut key to jump quickly to the next combo box. There was only one case of a problematic combo box. Normal combo boxes allow keyboard users to arrow up or down through the list of options and then activate an "Enter" or "Go" button to select the desired option, but this particular combo box automatically selected the first option the participants landed on (the equivalent of clicking on the option with a mouse), linking them to a new page. In order to proceed further down the list, the participant had to hit the "Back" button from the new page and then arrow down again, which once more selected the next option automatically, making it impossible to effectively navigate the list of options.

6.2. Comparison to an automated testing tool

The results of the comparison with AChecker (Table 2) indicate that most of the barriers found by this tool did not cause noticeable problems for participants in their own use of the site. Conversely, most of the barriers identified from usability testing with the participants were not related to any of the items on AChecker's list of known errors. In fact, there seems to be little to no correspondence between AChecker's analysis of accessibility barriers and the participants' own experiences with the sites. Contrary to the expectation that the sites with the most coding errors would be the most inaccessible for participants, this was not the case. The two academic library sites had very few accessibility errors flagged by AChecker, but they had fairly low task completion rates. Such a small sample of websites cannot be treated as conclusive evidence, but this result agrees with the findings in the literature stating

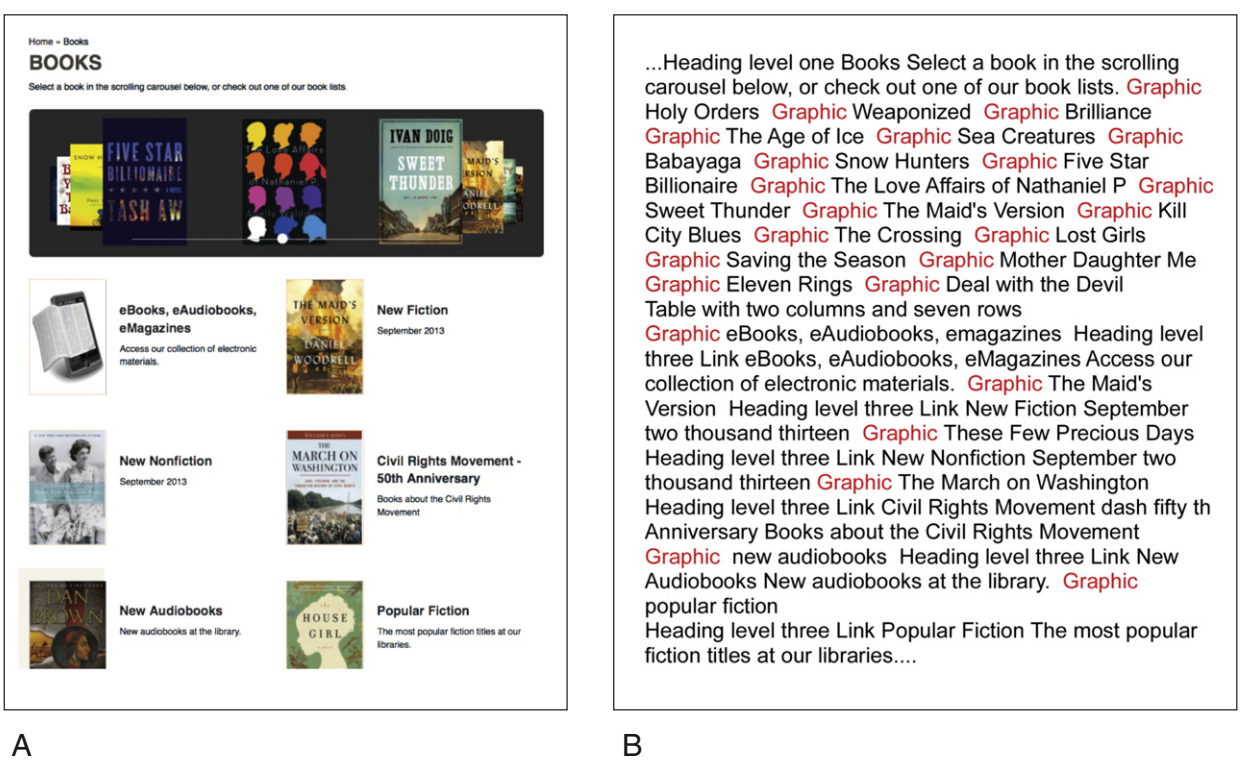

Fig. 1. Example of a library webpage as seen in a visual browser (a) and in its linearized form (b).

that focusing only on technical coding accessibility cannot guarantee true usability.

6.3. Information seeking and use

6.3.1. Strategies used for web browsing

Data from the test observations, feedback, and interviews suggested that screen reader users have multiple strategies for making sense of a new site. Three distinct approaches were noted: one relied on skipping through links lists (lists of links on a page that can be ordered sequentially or alphabetically) to navigate, another on headings lists, and yet another on scrolling through a page using the down arrow to listen to the first few words of each line (a form of aural text scanning). It was observed that the two users who were 50 years old or over and who had been using screen readers for more than 25 years tended to rely more heavily on headings for their initial navigation. These users focused more on familiarizing themselves with the general structure of the site, whereas the other four users, who were in their 30s or younger and who had been using screen readers for 12 years or less, were more likely to browse just the links for their initial navigation. It seems that the older users, who started using screen readers for text-only information before the emergence of the Web, preferred to use hierarchical headings. On the other hand, the younger users tended to rely more on links lists, perhaps because their first exposure to screen readers was within an environment of hyperlinks and non-textual content.

The browsing methods of all six test participants frequently involved some sort of word search, either in the links list or the full text of a page using the screen readers' word find feature, to look for an occurrence of some desired word that the user expected to find on the page. Word prediction, whether by links list searching or with word find, was a common navigation strategy throughout the testing procedure; all six of the visually impaired study participants used one or both of the word prediction strategies regularly while completing the tasks.

6.3.2. General web use vs. library websites

The interview data indicated that most study participants were not regular users of library websites, and they did not seem comfortable exploring them. Although all participants actively use the Internet for a variety of purposes, including email, social networking (via tools such as Facebook and Twitter), online shopping, finding audio reading materials, visiting sites on a favorite topic (such as music, fashion, books, or technology), or job searching, most do not rely much on library websites for their information needs. The participants who are current students demonstrated some familiarity with academic library websites, but none listed any libraries among the sites they use on a regular basis.

7. Discussion

In the discussion below, it is worth noting that one of the issues particular to the accessibility of library websites is that there are often two distinct sets of Web components: those created by the library, and those created by the vendor who provides the online catalog. While libraries can tweak the catalog web to some extent, they are largely at the mercy of what the vendor provides. Among the usability barriers found, many issues seemed to be related to those of vendor-supplied features and Web design where librarians have little control. This may imply that libraries should consider the accessibility of vendor-produced library systems and negotiate this with vendors.

7.1. Barriers for screen reader users on library websites

7.1.1. Web browsing strategies

The researchers observed two general patterns in the way study participants used their screen readers to browse. First, older participants used hierarchical headings more frequently when exploring a new page, whereas younger participants relied more heavily on links lists to obtain a broad overview. One possible explanation is that the older users started using screen readers in a predominantly textual environment before the emergence of the Web, while the younger users would have had their first exposure within an environment of hyperlinks and non-textual content. It is also possible that the older and more experienced screen reader users have, over time and through trial and error, developed more systematic strategies for approaching websites.

The second observation was that, regardless of age or preferred screen reader brand, all participants regularly sought specific information through the use of word prediction. Further research with a larger number of participants is needed to verify both of these findings. However, considering that many of the barriers uncovered in the study were caused by websites ill-suited for screen-reader-specific browsing strategies, it would seem that libraries need to better accommodate search and browse techniques that are unique to this user group in their websites if they are to be truly accessible.

7.1.2. Library website use

Pre- and post-test interviews revealed that the test participants were not frequent users of library websites, and while this does not mean there is a difference in their library use relative to the general population, it does suggest that there is room for improvement when it comes to outreach to this population. Groups who face disproportionate barriers to information also benefit disproportionately from library services and reaching them is crucial if libraries are to fulfill their mission to support equitable access to information.

7.1.3. Comparison to automated tools

The results of the comparison of the test results to those of an automated tool confirm the findings of Rømen and Svanæs (2012), who determined that the errors typically found by automated tools do not predict problems that are encountered most by disabled users. One possible explanation is that the test participants have developed strategies for dealing with typical coding errors. Another is that the barriers enumerated by AChecker and other automated tools highlight technical problems and not high-level usability issues. It is important to note that this finding, if correct, does not negate the importance of accessible coding: in this study, usability issues tended to prevent participants from using library sites as intended; thus, it is likely they did not even have a chance to encounter many of the technical errors listed by AChecker due to the interference of higher-level barriers.

7.2. Recommendations

7.2.1. Skimming catalog results

Based on the findings of this study, many of the tweaks that would make library catalogs more usable for screen reader users are quite simple. For example, placing a “skip to results” link at the top of the catalog search page, above the navigation menus and filtering options, would allow users to jump directly to the results with one keystroke, without excessive tabbing. Scanning the search results list could also be made more efficient by formatting the titles of items either as links or headings so that screen reader users can use a shortcut key to tab between them. Many library sites already have their catalog searches formatted this way, allowing screen reader users to skim through search results as efficiently as a sighted person by listening to titles only until they decide to dig deeper into a specific item.

7.2.2. Navigation barriers and link labeling

Though semantic issues can lead to navigation errors for all users, it was observed that the test participants expended a great deal of time and energy reorienting themselves because they could not access visual cues, and the resulting information overload seemed to be an indirect

cause of task failure. Therefore, semantic issues and cognitive fatigue resulting from the use of a text-centric technology to interpret a visually-oriented presentation appear to be high-level barriers that should be addressed at the Web design stage if a functionally accessible site is to be achieved.

Link text should be clear enough that the target page is evident even if the text is read apart from the context of the page; for example, "ask a librarian" is more obviously understood out of context than "click here." It is also important to avoid misleading link text, such as the "Books" link in the tested public library site, which might have been better named "New Arrivals," since the existing text implied to participants that it linked to an interface where they could search for books.

A hierarchical heading structure is another way to help screen reader users navigate the high volume of information in a library website. In a typical website, headings appear in larger or smaller font sizes to indicate to sighted readers whether they are main headings or subheadings. These headings can be an essential navigation aid for screen reader users, but only if the headings are coded in the underlying HTML according to their semantic level (e.g., <h1>, <h2>, etc.), not just styled with different font sizes in CSS.

7.2.3. Dynamic elements

For sighted users, dynamic features such as drop-down menus and tab panels streamline navigation by reducing the number of pages that must be visited. For screen reader users, however, navigating these features can be confusing. In order to make tab panels more accessible, WAI-ARIA (Accessible Rich Internet Applications) recommends using the roles "tabpanel," "tab," and "tablist" on the page's HTML (W3C, 2009). Compliance with WAI-ARIA Authoring Practices 1.0 ensures that the tab panel navigation will behave the way users expect.

Compliant code is also necessary when implementing combo boxes, which are perfectly accessible to screen reader users when coded properly. The combo box scripting itself should never take the user to a new page. A better practice, recommended by WebAIM (2013), is to have a separate "Submit" button so that users can arrow freely through the options and then hit "Submit" when they are ready.

7.3. Limitations of the study

The small number of participants included in the study limits the ability to generalize the findings on accessibility barriers to the larger population of screen reader users. Because the study was initially conducted as a class project, six was considered as a reasonable number of participants for exploring user situations and for testing website accessibility in a usability context. Although six can be an acceptable number of participants to identify design problems through usability testing, further research with more participants, is necessary to draw generalized conclusions of the specific Web access and usage patterns of users of various types of screen readers.

In addition, the findings are limited by the selection method and number of websites tested. The three library websites were selected randomly from within the researchers' own access and familiarity. Although the findings showed properties similar to the accessibility barriers found on non-library websites, the number was too small to generalize the current status of library Web accessibility.

The applicability of these findings for practicing librarians is admittedly limited as well, since in the majority of cases, library websites are partly or completely sourced by commercial vendors of catalog and database software. Because of this, the amount of control that librarians have over the website features discussed in this paper may vary a great deal. For example, both of the academic library sites tested in this study were designed and maintained entirely by the library's own staff except for the databases and the search result displays, while the public library site was a vendor-supplied integrated library system with little opportunity for customization other than moving elements around on the page.

8. Conclusion

The implications of the study findings should help to improve the accessibility of library websites. The library websites tested, which are not untypical of library websites generally, are not accessible to users with visual impairments. Many of the barriers detected through usability testing with this group are not merely the result of coding errors or non-conformance with technical accessibility standards; rather, they are high-level usability problems related to semantics and navigational design.

Library websites are important points of access to online library resources and services, and all users should be able to use these websites without encountering barriers related to accessibility and usability. The findings of this research, which studied just one disadvantaged group, suggest that libraries need to pay attention to these problems if they seek to provide a diverse public with broad access to information.

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