WebinSitu: A Comparative Analysis of Blind and Sighted Browsing Behavior

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ABSTRACT

Web browsing is inefficient for blind web users because of persistent accessibility problems, but the extent of these problems and their practical effects from the perspective of the user has not been sufficiently examined. We conducted a study *in situ* to investigate the accessibility of the web as experienced by web users. This remote study used an advanced web proxy that leverages AJAX technology to record both the pages viewed and the actions taken by users on the web pages that they visited. Our study was conducted remotely over the period of one week, and our participants used the assistive technology and software to which they were already accustomed and had already configured according to preference. These advantages allowed us to aggregate observations of many users and to explore the practical effects on and coping strategies employed by our blind participants. Our study reflects web accessibility from the perspective of web users and describes quantitative differences in the browsing behavior of blind and sighted web users.

Categories and Subject Descriptors

K.4.2 [**Social Issues**]: Assistive technologies for persons with disabilities; H.5.2 [**Information Interfaces and Presentation**]: User Interfaces

General Terms

Human Factors, Experimentation

Keywords

web studies, web accessibility, blind users

1. INTRODUCTION

Browsing the web is inefficient for blind web users because of persistent accessibility problems. However, the extent of these problems and their practical effects on browsing experience are not yet adequately understood from the perspective of blind web users. For web access guidelines, standards, and future improvements to be truly relevant and useful, more information about real-life web interaction is needed. In this work, we seek to understand the accessibility of the web from the user perspective by measuring the accessibility of the pages that users visit and comparing the behavior observed in blind users to their sighted counterparts.

We used an advanced web proxy to enable our study and quantitatively measured both the presence and observed effectiveness of components thought to impact web accessibility. Most proxy systems can only record HTTP requests and cannot easily discern user actions performed on web pages [8, 20]. We used an enhanced version of UsaProxy [5] to record participants' browsing. UsaProxy can record actions that are impossible to record with a traditional proxy, such key presses, clicks on arbitrary page elements (including within-page anchor links), and the use of the "back" button to return to a page that was previously viewed. Recording user actions has traditionally required study participants to install specialized browser plugins [15, 9], but UsaProxy is able to record most user actions by using Javascript code that is injected into pages that are viewed. Because it uses Javascript to parse the viewed web pages, it can also record dynamic page changes, interaction with dynamic content and AJAX requests, which are an increasingly important accessibility concern. A proxy approach enables transparent setup by participants and allows them to use their own equipment with its existing configuration.

Prior work has sought a better understanding of the web user experience [20, 22]. The importance of measuring accessibility *in situ* from the user perspective is illustrated by the relative popularity of web sites visited by web users in our study, as shown in Figure 1. The distribution is Zipf-like [7], which results in three sites (google.com, myspace.com and msn.com) accounting for approximately 20% of the pages viewed by the participants in our study. The google.com domain alone accounted for almost twice as many page views as the 630 domains that were viewed five or less times during our study. The accessibility of popular sites more strongly affects users than do sites on the long tail of popularity. While our study is not a replacement for laboratory studies that use common tasks, it offers an important view of accessibility that better matches the experiences of real users.

Blind web users have proven adept at overcoming accessibility problems, and one of the goals of this study was to

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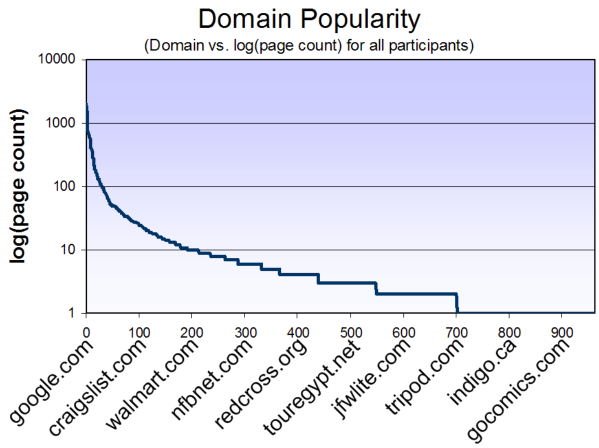

Figure 1: Log frequency of visits per domain name recorded for all participants ordered by popularity.

better understand the coping strategies employed by blind users as they browse the web. For instance, the lack of alternative text is an often-cited accessibility concern, but blind users can often obtain the same information contained within an image from surrounding context. Within-page anchors called "skip links" are designed to help blind users effectively navigate complex web pages by enabling them to jump to relevant content, but these links may be used infrequently because other screen reader functionality also enables users to move non-linearly through a page. If the context surrounding links on a page isn't clearly expressed to blind users, they may explore the page by clicking on links simply to see where they point and then return. WebinSitu explores whether blind web users avoid inaccessible content and also if they make use of coping strategies.

The direct effects of technology and developer practices for improving accessibility are difficult to measure in practice because users employ many different browsing and coping strategies that may vary based on the user's familiarity with the page be accessed. Related work has looked at task-based analysis of accessibility [24, 27, 10, 25], with a major focus on supporting effective accessibility evaluation (see Ivory for a survey of this work [21]). Realistic studies with blind web users are difficult to conduct in the lab due to difficulties in replicating the diversity of assistive technology and configurations normally used by participants. Previous work has advocated remote studies because they allow participants to use their existing assistive technology and software [24, 25, 16]. These studies noted that blind participants can be ineffective at providing feedback when a page is considerably inaccessible, indicating that simply asking blind users to list the problems they face may not be sufficient.

Overall, we found that blind web users browse the web quite similarly to sighted users and that most pages visited during our study were inaccessible to some degree. In our study these problems are placed in the context of their predicted effects because we implicitly weighted pages relative to their popularity. Perhaps most surprising, blind participants generally did not shy away from pages exhibiting accessibility problems anymore than did sighted users. Blind participants were, however, much less likely to visit pages containing content not well addressed by assistive technology. Blind users tended not to visit sites heavily dependent on Asychronous Javascript and XML (AJAX), but visited many pages that included Flash content. Blind users also interacted less with both dynamic content and inaccessible web images. Skip links, added to web pages to assist screen reader users, were only used occasionally by our participants. Our analysis highlighted several areas that may suggest the coping strategies used by blind web users when faced with inaccessible content.

The contributions of this paper are as follows: 1) We report on web accessibility as experienced by real web users. 2) We compare the browsing experience of sighted and blind web users on several quantitative dimensions. 3) We demonstrate the effectiveness of proxy-based recording for exploring the interaction of blind web users. 4) We formulate practical user observations that can influence the direction of future web accessibility research.

2. RECORDING DATA

We used a tracking proxy to record statistics about the web experience of our participants (see the diagram in Figure 2). The proxy is an extended implementation of UsaProxy, which allows both HTTP request data and user-level events to be recorded [5]. This method of data collection allows participants to be located remotely and use their own equipment. This is important for our study because of the diversity of assistive technology and configurations employed by blind users. Our proxy-based approach requires minimal configuration by the user and does not require the installation of new software. Connecting to the system involved configuring their browsers to communicate with the tracking proxy and entering their login and password. Names and passwords were not connected with individuals, but a record was kept indicating whether the participant primarily uses a screen reader or a visual browser to browse the web.

A browsing session begins with the participant initiating an HTTP request, which is first sent to the proxy and then passed directly to the web server. The web server sends a response back to the proxy, which logs statistics about the response header and web page contents. The proxy also injects JavaScript into HTML responses to record user-generated events and sends this modified response back to the user. After the response is received by the user and is loaded in their browser, the Javascript inserted into the page can record events such as key presses, mouse events, and focus events and sends data about each event, including the Document Object Model (DOM) elements associated with each event, back to the proxy for logging. For example, if a user clicks on a linked image, the click event and its associated image (dimension, source, alternative text, etc.), the link address and position in the DOM are sent to the proxy and recorded. The proxy also records whether content with which participants interact is dynamic (i.e. created after the page was loaded via Javascript) and whether the pages viewed issue AJAX requests.

All of the data pertaining to a participant's browsing experience is stored on a remote database. At any time during the study, participants may examine their generated web traces, comment on the web pages viewed, enter general comments about their browsing experience or delete portions of their recorded browsing history (See Figure 6). Our participants deleted only three browsing history entries.

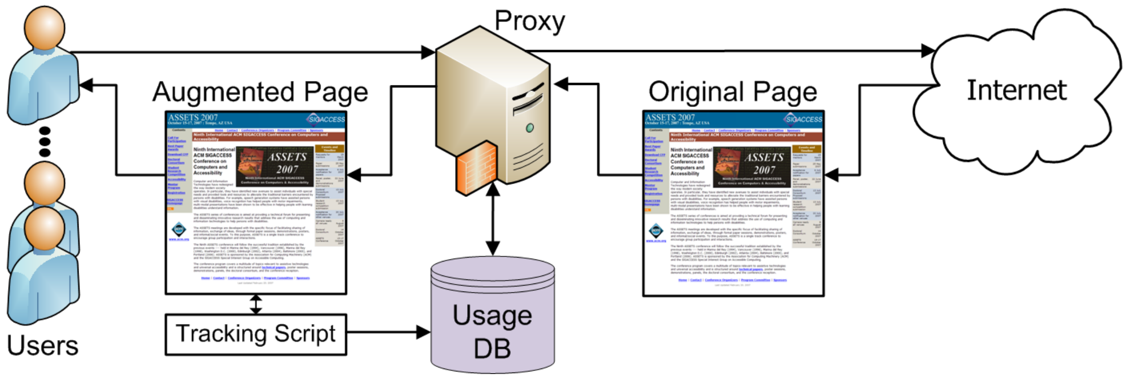

Figure 2: Diagram of the system used to record users browsing behavior.

3. STUDY DESIGN

In this study, we considered two categories of data related to web browsing that yield insight into accessibility problems faced by blind web users. Many definitions of blindness exist; we use the term *blind users* for those users that primarily use a screen reader to browse the web and *sighted users* for those who use a visual display. First, we recorded statistics relating to basic web accessibility of pages viewed in our study, such as alternative text for images, heading tags for added structure and label elements to associate form input with their labels. Second, we considered the browsing behavior of both blind and sighted users, including average time spent on pages and interaction with elements.

3.1 Accessibility of Content

Accessibility guidelines for web developers offer suggestions on how to create accessible web content. Most noted is the Web Content Acccessibility Guidelines (WCAG) [3] on which many other accessibility guidelines are based. Web developers often don't include the advice presented in these guidelines in their designs [10, 6]. Our study effectively weights pages based on the frequency with which they are viewed, allowing us to measure the accessibility of web content as perceived by web users. The individual metrics reported here suggest the accessibility of web pages that users view, but cannot capture the true usability of these pages. Because inaccessible pages can be inefficient or impractical to use, blind users may choose to visit sites that are more accessible according to ours metrics. In our analysis, we compared the browsing behavior of blind and sighted users according to the metrics below.

3.1.1 Descriptive Anchor Text and Skip Links

Navigating from link to link is common method of moving through web pages using a screen reader. Many screen readers provide users with a list of links accessed via a shortcut key. However, links can be difficult to interpret when separated from the surrounding context. For instance, the destination of a link labeled "Click Here" is impossible to determine without accompanying context. Prior work has shown that descriptive link text helps users efficiently navigate web pages [18] and related work has explored automatically supplying richer descriptions for links [17]. In our study we collected all links on the pages viewed by our participants as well as all links clicked on by our participants. We sampled 1000 links from each set and manually labeled whether or not each was descriptive.

Skip links are within-page links that enable users to skip ahead in content. They normally appear near the beginning of the HTML source of a page and are meant for blind web users. We identified skip links using two steps. First, we selected all within-page anchors whose anchor text or alternative text (in the case of images used as skip links) contained one of the following phrases (case insensitive): "skip," "jump to," "content," "navigation," "menu." These phrases may not appear in all skip links, but this works for our purposes of efficiently selecting a set of such links. To ensure that the chosen links were skip links, we manually verified each one chosen in the first step.

3.1.2 Structure, Semantics and Images

Browsing is made more efficient for blind web users when the structure of the page is encoded in its content and when the semantics of elements are not dependent on visual features. Heading tags (<h1>... <h6>) have been shown to provide useful structure that can aid navigation efficiency [27]. The <label>tag allows web developers to semantically associate input elements with the text that describes them. Often this association is expressed visually, which can make filling out forms difficult for blind web users. These are some of the easiest methods for encoding structure and semantics into HTML pages. Their use may foreshadow the likelihood that web developers will use more complex methods for assigning structure and semantics to web content, such as the WAI-Accessible Rich Internet Applications (WAI-ARIA) [4].

Investigating the accessibility of web images has often been used as an easy measure of web accessibility [6]. In this study, we analyzed the appropriateness of alternative text on images viewed by participants. We sampled both 1000 of the images contained on the pages viewed by our participants and 1000 images that were clicked on by our participants. We manually judged the appropriateness of the alternative text provided for these images.

3.1.3 Dynamic Content, AJAX and Flash

The web has evolved into a more dynamic medium than previous static web pages. This trend, popularly known as Web 2.0, uses Dynamic HTML (DHTML) and Javascript to arbitrarily modify web pages on the client-side after they have been loaded. All users may benefit from this technology, but it raises important accessibility concerns for blind users. Changes or updates to content that occur dynamically have long been recognized by standards such as the WCAG [3] as potential problems for screen reader users because dynamic changes often occur away from a user's focus. In our study, we recorded dynamic changes in viewed pages. A *dynamic change* is defined as any change to the DOM after the page has loaded. We took special interest when users directly interacted with dynamically changed content. Our system cannot detect when users read content that is dynamically introduced, but can detect when users perform an action that uses such an element. We also recorded how many of the pages viewed by our participants contained programmatic or AJAX web requests. While not necessarily an accessibility concern, these requests are indicative of the complex applications that often are accessibility concerns.

A growing number of web pages include Flash content. Recent improvements to this technology has enabled web developers to make much of this content accessible, but doing so requires them to consciously decide to implement accessibility features. Conveying this accessibility information to users requires users to browse with up-to-date versions of their web browsers, screen readers and Adobe Flash. We report on the percentage of web pages visited by blind and sighted web users that contain Flash content.

3.2 Browsing Behavior

Blind web users browse the web differently from their sighted counterparts in terms of the tools that they use and the way information is conveyed to them. We explored how these different access methods manifest in quantifiable differences according to several metrics. In particular, because blind web users have proven quite adept at overcoming accessibility problems, it is interesting to explore the practical effects of accessibility problems. For instance, an image that lacks alternative text does not conform to accessibility guidelines, but may still be accessible if it points to a web page with a meaningful filename. Similarly, skip links seem as though they would be of assistance to users, but users may choose not to follow them either because they are most often interested in content that would be skipped or because they prefer potentially longer reading times to potentially missing out on valuable information. Our study seeks to measure such factors. Beyond the simple presence of accessible and inaccessible components in web pages, we also wanted to collect information that helps suggest the effects of the accessibility of web page components.

3.2.1 Probing

A *probing* event occurs when a user leaves and then quickly returns to a page. Web users often exhibit probing behavior as a method of exploration when they are unsure which link to choose [18]. Probing is also often used as a metric of the quality of results returned when analyzing search engines [28]. If a returned link is probed, then the user likely did not find the contents relevant. Because exploring the context surrounding links is less efficient for screen reader users, they may choose to directly follow links to determine explicitly where they lead. If screen reader users probe more than their sighted counterparts then this would motivate the further development of techniques for associating contextual clues with links. In our study, we investigated the use of probing by our blind and sighted participants.

3.2.2 Timing

Underlying work in improving web accessibility is the goal of increasing efficiency for blind web users. In our study, we attempted to quantify the differences in time spent web browsing by blind and sighted web users. We first looked at average time per page to see if there is a measurable effect of blindness on per page browsing time. We then looked at specific tasks that were common across our users that we identified from our collected data. The first was entering a query on the Google search engine, looking through the returned results and then clicking on a result page. The second was using our web history page to find a particular page they themselves had visited during the web study, finding it on the results page and then entering feedback for the page. Even though both groups of users could accomplish these tasks (they were accessible to each group), this comparison provides a sense of the relative efficiency of performing typical tasks.

4. RESULTS

For our study, we recruited both blind and sighted web users. In the end, we had 10 blind participants (5 female) ranging in age from 18 to 63 years old and 10 sighted participants ranging in age from 19 to 61 (3 female). We began our recruiting of blind users by first contacting people who had previously expressed interest in volunteering for one of our user studies and then by advertising on an email list for blind web users. Our sighted participants were contacted from a large list of potential volunteers and chosen to be roughly similar to our blind participants according to age and occupation area. Participants were given $30 in exchange for completing the week-long study. Both our blind and sighted participants were diverse in their occupations, although fields related to engineering and science accounted for slightly more than half of participants in both groups. We placed no restriction on participation, but all of our participants resided in either the United States or Canada, with geographical diversity within this region.

Participant were sent instructions outlining how to configure their computers to access the web through our proxy. Only one participant had difficulty with this setup procedure and the issue was quickly resolved by speaking to the researchers on the phone. Each participant was told to browse the web as they normally would for 7 days. During this time, our participants visited 21,244 total pages (7,161 by blind participants), which represented approximately 325 combined hours of browsing (141 by blind participants). "Browsing" time here refers to total time spent on our system with no more than 1 hour of inactivity. The pages they viewed contained 337,036 images (109,264 by blind participants) and 926,901 links (285,207 by blind participants). Of our blind participants, 8 used the JAWS screen reader, 2 used Window-Eyes; 9 used Internet Explorer, 1 used Mozilla Firefox. All of our blind participants but one used the latest major version of their preferred screen reader. None reported using multiple screen readers, although we know of individuals who report switching between JAWS and Window-Eyes depending on the application or web page. All of our participants used Javascript-enabled web browsers, although we did not screen for this.

Our data was collected "in the wild," and, as is often required when working with real data, it was necessary to remove outliers that might have otherwise inappropriately skewed our data. For each metric in this section, we removed data that was more than 3 standard deviations (*SD*) from the mean. This resulted in an average of 1.04% of our data

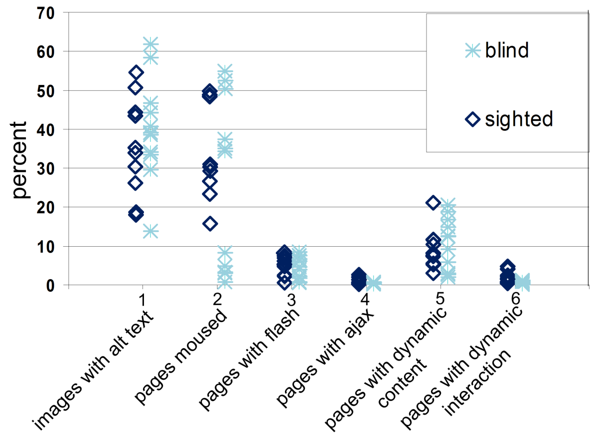

Figure 3: For the web pages visited by each participant, percentage of: (1) images with alt text, (2) pages that had one or more mouse movement, (3) pages with Flash, (4) pages with AJAX, (5) pages containing dynamic content, (6) pages where the participant interacted with dynamic content.

being eliminated for the applicable metrics. Our measures are averages over subjects.

The remainder of this section explores the results of our study for the two broad categories initially outlined in our Study Design (Section 3). A summary of many of the measurements reported in this section is presented in Figure 3 for both blind and sighted participants.

4.1 Accessibility of Content

4.1.1 *Descriptive Anchor Text and Skip Links*

Overall, 93.71% (*SD* 0.07) of the anchors on pages visited by blind users contained descriptive anchor text, compared with 92.84% (0.06) of anchors on pages visited by sighted users. The percentage of anchors that were clicked on by the two groups was slightly higher at 98.25% (0.03) and 95.99% (0.06), respectively, but this difference was not detectably significant. This shows that web developers do a good job of providing descriptive anchor text.

We identified 822 skip links viewed by our blind participants compared to 881 skip links viewed by our sighted participants, which was not a detectably significant difference. Blind participants clicked on 46 (5.60%) of the skip links presented to them, whereas sighted users clicked on only 6 (0.07%). Often these links are made to be invisible in visual web browsers. These results suggest that blind users may use other functionality provided by their screen readers to skip forward in content in lieu of skip links. We were unable to test this hypothesis due to difficulty in reliably determining when users used screen reader functionality to skip forward in content.

4.1.2 *Structure, Semantics and Images*

Overall, 53.08% of the web pages viewed by our participants contained at least one heading tag and there was no significant difference between pages visited by sighted and blind users. We found that on pages that contained input elements that required labels, only 41.73% contained at least one label element. Using manual evaluation, we found that 56.9% of all images on the pages visited by our participants were properly assigned alternative text and that 55.3% of the images clicked on by web users were properly assigned alternative text based on manual assessment of appropriateness. Blind participants were more likely to click on images that contained alternative text. 72.17% (19.61) of images clicked on by blind participants were assigned appropriate alternative text, compared to 34.03% (29.74) of the images clicked on by sighted participants, which represents a statistically significant effect of blindness on this measure ($F_{1,19} = 11.46, p < .01$).

4.1.3 *Dynamic Content, AJAX and Flash*

Many of the pages viewed by our participants contained dynamic content, AJAX and Flash content. Pages visited by sighted participants underwent an average of 21.65 (35.38) dynamic changes to their content as compared to an average of only 1.44 (1.81) changes per page visited by blind participants. This difference was marginally significant ($F_{1,19} = 3.59, p = .07$). Blind users interacted with only 0.04 (0.08) of page elements that were either dynamically introduced or dynamically altered, while sighted users interacted with 0.77 (0.89) of such elements per page. There was a significant effect of blindness on this measure ($F_{1,19} = 7.49, p < 0.01$). Our blind participants may not been aware that the content had been introduced or changed, or were unable to interact with it. Pages visited by blind and sighted users issued an average of 0.02 (0.02) and 0.15 (0.20) AJAX requests, respectively. This result is statistically significant ($F_{1,19} = 4.59, p < 0.05$) and suggests that blind users tend to avoid web pages that contain AJAX content. Of the dynamic content categories, Flash was the only one for which we were unable to detect a significant difference in the likelihood of blind versus sighted participants visiting those types of pages. On average 17.03% (*SD* 0.24) and 16.00% (11.38) of the web pages viewed by blind and sighted participants, respectively, contained some Flash content. There was not a detectably significant difference on this measure ($F_{1,19} = 0.90, n.s.$). We also calculated these four metrics for domains visited (groups of web pages) and reached analogous conclusions.

4.2 Browsing Behavior

As an input device, blind users used the mouse (or simulated it using the keyboard) a surprising amount. On average, blind participants used or simulated the mouse on 25.85% (*SD* 22.01) of the pages that they viewed and sighted participants used the mouse on 35.07% (12.56) of the pages they viewed. This difference was not detectably significant ($F_{1,19} = 1.35 n.s.$). Blind and sighted participants, however, on average performed 0.43 (0.33) and 8.92 (4.21) discrete mouse movements per page. This was a statistically significant difference ($F_{1,19} = 44.57, p < .0001$).

Our users arrived at 24.21% of the pages that they viewed by following a link. The HearSay browser leverages the context surrounding links that are followed to begin reading at relevant content on the resulting page [23] and could likely apply in these cases.

4.2.1 *Probing*

Our blind participants exhibited more probing than their sighted counterparts as shown in Figure 4. On average, blind participants executed 0.34 (*SD* 0.18) probes per page while

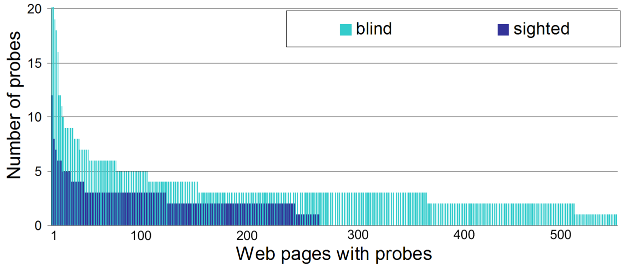

Figure 4: Number of probes for each page that had at least one probe. Blind participants performed more probes from more pages.

sighted participants had only 0.12 (0.12), a significant difference ($F_{1,19} = 10.40, p < 0.01$) and may be indicative of the greater difficulty of blind web users due to limited context. (See Figure 4 to better visualize participant probing behavior for individual pages).

4.2.2 *Timing*

In examining the time spent per task, we found that our data was skewed toward shorter time periods, which is typical when time is used as a performance measure. Because this data does not meet the normality assumption of ANOVA, we applied the commonly used log transformation to all time data [1]. Although this complicates the interpretation of results, it was necessary to perform parametric statistical analysis [14]. All statistical significance reported here is in reference to the transformed data; however, results are reported in the original, untransformed scale.

We found that blind participants spent more time on average on each page visited than sighted participants. For a summary of the results, see Figure 5. These results seemed particularly strong for short tasks, where sighted users were able to complete the tasks much faster than blind users. Blindness had a significant effect on the log of time spent on each page for all but the longest time period. Table 1 shows that the average time spent by blind and sighted participants approach one another as task length increases.

We also identified four tasks conducted by both blind and sighted participants, which enabled us to compare the time required for users to complete these tasks.

Google This task consisted of two subtasks: 1) querying from the Google homepage, and 2) choosing a result. On the first subtask, blind and sighted users spent a mean of 74.66 (*SD* 31.57) and 34.54 (105.5) seconds, respectively. Blindness had a significant effect of blindness on the log of time spent on issuing queries ($F_{1,17} = 7.47, p < .01$). On the second subtask, the time between page load to clicking on a search result for blind and sighted users was 155.06 (46.14) and 34.81 (222.24) seconds. This represents a significant effect of blindness on the log of time spent on searching Google's results. ($F_{1,19} = 28.3, p < .0001$).

Providing Feedback Another common task performed by most of our participants was to provide qualitative comments on some of the web pages that they visited as part of the study (See Figure 6). This task also consisted of two subtasks: 1) querying for web pages from the user's web history, and 2) commenting on one of the pages returned. On average, blind and sighted users took 30.36 and 18.41 seconds to complete the first subtask (*SD* 20.59,

Range	Blind	Sighted	$Sig.F_{1,19}$
0 - 1.0	0.38 (0.26)	0.23 (0.23)	$32.55, p < .0001$
0 - 2.5	0.76 (0.65)	0.38 (0.49)	$31.83, p < .0001$
0 - 5.0	1.04 (1.05)	0.51 (0.80)	$10.69, p < .01$
0 - 10.0	1.25 (1.54)	0.77 (1.52)	$6.90, p < .05$
0 - 20.0	1.50 (2.35)	1.11 (2.51)	$5.01, p < .05$
0 -	5.08 (16.68)	11.30 (74.36)	$0.01, p < .91$

Table 1: Average time (minutes) and standard deviation per page for increasing time ranges.

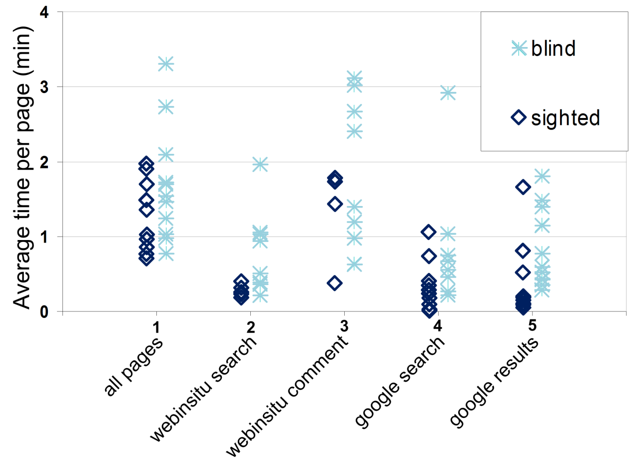

Figure 5: For each participant, average time spend on: (1) all pages visited, (2) WebinSitu search page, (3) WebinSitu results page, (4) Google home page, (5) Google results pages.

19.84). This represents a marginally significant effect of blindness on the log of time spent querying personal web history ($F_{1,14} = 4.2529, p = .06$). On average, blind and sighted participants spent 104.60 (30.98) and 68.74 (78.74) seconds, respectively, to leave a comment. This represented a significant effect of blindness on the log of time spent commenting on personal web history ($F_{1,11} = 5.23, p < .05$).

5. DISCUSSION

Our study provided an interesting look into the web accessibility experienced by web users. Overall, the presence of traditional accessibility problems measured in our study did not seem to deter blind web users from visiting most pages, but problems with dynamic content characteristic of Web 2.0 did. Our blind participants were less likely than sighted participants to visit pages that contained either dynamic content or which issued AJAX requests. Much of this content is known to be, for the most part, inaccessible to blind web users.

Our blind participants did not detectably avoid Flash content. Upon manual review of 2000 examples of Flash content, we found that 44.1% of the Flash objects shown to our participants were advertisements. The inaccessibility of these Flash objects is unlikely to deter blind users from visiting the pages which contain them. Only 5.6% of the Flash objects viewed by our participants (both blind and sighted) presented the main content of the page. The remainder of Flash objects contained content relevant to the main content of the page but supplement to it. Blind users may miss

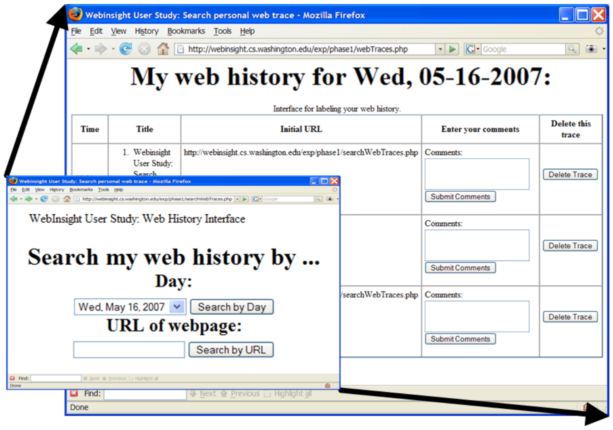

Figure 6: Web history search interface and results.

out on some information contained in such Flash objects but might still find value in other information on the page that is accessible. Flash was also often used to play sound, which does not require a visual interface. Finally, recent strides in Flash accessibility are making it easier to design accessible Flash objects that can be used by blind users.

We also observed that blind web users were less likely to interact with content that is inaccessible. Participants were less likely to interact with content that was dynamically introduced. We also found that blind users are more likely to click on images assigned appropriate alternative text. This should be a warning to web developers that not only are their pages more difficult to navigate by blind users when they fail to assign appropriate alternative text, but they may be driving away potential visitors.

Our blind participants employed numerous coping strategies. For example, blind participants used the mouse courser when page elements were otherwise inaccessible. One participate explained that he is often required to search for items that are inaccessible using keyboard commands. Blind participants also exhibited more probing than their sighted counterparts, suggesting that web pages still have far to go to make their content efficiently navigable using a screen reader. Technology that obviates the need for these coping strategies would be quite useful.

Overall, our observations underscore the importance of enabling accessible dynamic content. While our blind participants employed (inefficient) coping strategies to access web content that might be considered inaccessible, they generally avoided dynamic content altogether.

6. RELATED WORK

The Disability Rights Commission in the United Kingdom sought to formally investigate the accessibility problems faced by users with different disabilities [10]. In this extensive study, the results of focus groups, automated accessibility testing, user testing of 100 websites, and a controlled study of 6 web pages were combined. This work identified the effects of a number of different accessibility problems. Coyne and Nielsen conducted extensive observation of blind web users by going to the homes and workplaces of a number of blind individuals [11]. Each session comprised manually observing users completing four specified tasks, which did not allow them to record low-level events associated with each browsing session or for extended periods. Since both studied were conducted, new web technologies have become increasingly important, such as scripting and dynamic content in the form of dynamic content, AJAX, Adobe Flash and Rich Internet Application (RIA). WebinSitu adds to both studies by enabling the observation of participants over a longer period of time. We measure the practical and observable effects of accessibility features on web users, which is difficult to determine in a controlled lab study.

Watanabe used lab-based studies to find that the proper use of HTML heading elements to structure web content can dramatically improve the observed completion time of both sighted and blind web users [27]. In contrast to this study, which used screen recordings and key loggers, our study used remote observation of browsing events to record statistics about browsing behavior. Our study finds analogous results for other annotations that are assumed useful for accessibility, such as images with proper alternative text.

Another approach that has been explored is to consider the accessibility of the web divorced from user behavior. Some studies have used manual evaluation of pages [26] and others conducted automatically via a web crawl [6, 12]. Other studies have used automated evaluation [13]. Not considering which pages users will likely visit or the coping strategies they might employ makes the practical effects of the results obtained difficult to interpret.

Proxy-based approaches to recording user actions on the web have been explored before. The Medusa Proxy measures user-perceived web performance [22] and WebQuilt displays a visualization of web experiences based on recorded HTTP request [19]. Traditional proxy systems are limited to recording information contained in HTTP requests and so others have created browser plugins that can record richer information about user experiences [9]. The UsaProxy system by Atterer *et al.* on which WebinSitu is based is not the only example of using Javascript to record web user actions. Google Analytics allows web developers to include a Javascript file in their web pages that allows for tracking and analyzing the actions of visitors to their web pages [2].

The benefits and trade-offs involved in conducting remote studies with blind participants have been explored previously [25, 24]. Gonzalez *et al.* introduced a proxy-based system that injected Java applets into web pages that could be used for remote testing with disabled web users [16].

WebinSitu enables wide deployment to blind and sighted participants who are likely using a diversity of browsers and assistive technology. Developing plugins for each desired browser and deploying them would be a large undertaking. Our users initially expressed concern over installing new software onto their machines and wanted to make sure they knew when it was and was not collecting data. Specifying a proxy server is easy in popular web browsers (Internet Explorer, Firefox, Safari, Opera, etc.) and allows users to maintain transparent control.

7. CONCLUSION

We presented a study *in situ* of blind and sighted web users performing real-life web browsing tasks using their own equipment over the period of one week. Our analysis indicates that blind web users employ coping strategies to overcome many accessibility problems and are undeterred from visiting pages containing them, although they took more time to access all pages than their sighted counterparts. Blind users avoided pages containing severe accessibility problems, such as those related to dynamic content. In all cases our blind participants were less likely than our sighted participants to interact with page elements that exhibited accessibility problems. Our user-centered approach afforded a unique look web accessibility and the problems that most need addressing. As we move forward with this work, we will continue to design studies investigating accessibility from the perspective of users who are often adept at overcoming accessibility problems.

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