The Dissertation Committee for Jennifer Elizabeth Jobst Certifies that this is the approved version of the following dissertation:

An Exploratory Study of Screen-reader Users Navigating the Web

Committee:

Don Turnbull, Supervisor

Mary Lynn Rice-Lively

E. Glynn Harmon

Randolph Bias

Vicki Almstrum

An Exploratory Study of Screen-reader Users Navigating the Web

by

Jennifer Elizabeth Jobst, B.S.; M.S.

Dissertation

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

The University of Texas at Austin

May 2009

Dedication

This dissertation is dedicated to John Slatin, accessibility guru extraordinaire, and Casey, the orange poof. I wish you were both here for this.

Acknowledgements

I would like to acknowledge my family for their constant and mostly undying support. I would especially like to acknowledge my husband Sean, for cooking dinner while I worked, and the cats, who could always be counted to sit on whatever paper I needed most. Special thanks go to Dr. Don Turnbull, Dr. Kay Lewis, and Dr. Vicki Almstrum – without you, I would not have finished.

An Exploratory Study of Screen-reader Users
Navigating the Web

Publication No.______________

Jennifer Elizabeth Jobst, Ph.D.
The University of Texas at Austin, 2009

Supervisor: Don Turnbull

Researchers have learned much about how sighted individuals seek information on Web sites - for example, users follow “information scent” as they move from page to page, and individual differences may impact successful information seeking on the Web. While it is possible that individuals with disabilities, especially those with severe visual impairments, perform information-seeking activities in a similar manner, little is known about how individuals who use screen readers to navigate actually seek information on the Web. In this study, we used both qualitative and quantitative measures to investigate the Web navigation techniques of four screen-reader users and how a user’s experience affects these navigation techniques and his or her ability to successfully complete an information-finding task. We compared metrics for between-page and within-page navigation to studies of sighted users. We also considered how a Web site’s compliance with Section 508 guidelines affects the overall information-finding experience of a visually-impaired individual.

We discovered that among the four individuals in this study, user experience was not necessarily indicative of a successful information-finding experience. As individuals, the participants' navigation techniques varied widely; as a group, they generally searched more frequently and used the back button less frequently than has been reported for sighted individuals. Screen-reader users in this study followed a more flimsy, linear navigation style and generally used scrolling actions rather than searching actions. When using a Web site that has a Section 508 compliant home page, we found that the screen-reader users in this study completed information-finding tasks significantly more quickly, used significantly fewer actions, and reported a more satisfying information-finding experience. They were also more successful at finding the information goal and encountered fewer impasses. Using both quantitative and qualitative measures was critical in this study. The quantitative metrics allowed us to compare values and the qualitative data provided additional insight into individual differences as well as allowing a deeper understanding of the quantitative data.

The information from this study contributes to the growing body of research knowledge about screen-reader users. It also contributes a new understanding of screen-reader users that can be used by the worldwide community of Web developers, designers, and users.

Table of Contents

List of Tables

List of Figures

1. Introduction

Early studies of information-seeking behavior focused on finding information in a library setting. More recently, research has moved toward studying information seeking in electronic environments. The popularity of the Web has led researchers to investigate information seeking and browsing in this medium. Researchers have learned much about how individuals scan Web sites. For example, users follow “information scent” (P. Pirolli & Card, 1999) as they move from page to page, and individual differences may impact successful information seeking on the Web (Dillon & Jobst, 2005). However, the focus of the majority of this research has been sighted users. While it is possible that individuals with disabilities, especially those with severe visual impairments, perform information-seeking activities in a similar manner, very little is known about how blind individuals who use screen readers (such as JAWS and Window-Eyes) to navigate seek information on the Web. The few studies available (for example, Coyne & Nielsen, 2001; Craven & Brophy, 2003; Gerber, 2002) indicate that individuals who use screen readers to seek information on the Web generally take more time, are less successful, and perform more navigational steps than their sighted peers. At the most basic levels, researchers have not yet explored how information seeking by a visually-impaired person using a screen reader differs from information seeking by a sighted individual.

In this dissertation, we present data from a study of four screen-reader users. The research uses both quantitative and qualitative techniques to answer the following questions:

- What navigation techniques do screen-reader users use to navigate the Web, and how can these techniques be defined?

- Does user experience, in terms of years using computers and the Internet, affect navigation techniques or success, and if so, how?
- Are information-seeking techniques similar to those used by sighted individuals?
- If Web sites are compliant with Section 508 guidelines, does the overall success in an information-finding task improve?

By addressing these questions, we hope to provide the basis for understanding the specific navigation techniques of screen-reader users.

2. Literature Review

In this chapter, we review the broad theories of information seeking and then focuses on theories of information seeking on the Web and what has been learned from studies of sighted users. We then consider what is known about screen-reader users' online experiences, and explore the role that individual differences may play in successful information seeking. We examine how researchers have tried to provide visually impaired users with online experiences more similar to those of sighted users, and explore work done with non-visual interfaces in general. We discuss the role that technical accessibility, through compliance with guidelines such as Section 508 and WCAG 1.0, plays in successful interactions with the Web. This comprehensive background provides the foundation for further qualitative and quantitative studies of screen-reader users, forming a framework around which a methodology can be proposed to answer the questions presented in the introduction.

INFORMATION SEEKING AND SEARCHING FOR SIGHTED INDIVIDUALS

In this section, we review the progress of the research on information seeking and searching for sighted individuals, from general theories of information seeking to theories of information seeking on the Web. The goal is to identify elements of information-seeking models that may equally well describe the behavior of screen-reader users. Because the focus is how screen-reader users navigate within Web pages in addition to how they navigate between Web pages, we pay special attention to models that describe a fairly fine granularity of information seeking.

General Theories of Information Seeking and Searching

Early studies of information seeking and information needs focused on document-based information seeking, as well as on interaction with the information system. Mote (1962) and Warner (1973) were among the first to explore information needs and behaviors from the information user's perspective. Since the 1980s, information seeking research has changed in focus from the information system to the information user, which allowed research to include both quantitative and now qualitative methods to understand information use (for example, Dervin & Nilan, 1986).

One of the earliest models of information seeking is Belkin's (1982a, 1982b). The Anomalous States of Knowledge (ASK) model focuses on people in problematic situations whose knowledge of the problem (and potentially the solution) is limited in ways that make it difficult for the individual to describe the problem. Therefore, the person is unable to determine the information needed to resolve the issue. Belkin used free-form interviews to obtain precise descriptions of different problem situations, then analyzed the interviews to form a statistical portrait of the problem based on word occurrence and word association (this was defined as the *problem portrait*). The same statistical portrait technique was used to analyze abstracts from peer-reviewed research papers, and then the abstract portraits were matched to the user's problem portrait. Belkin's method attempted to satisfy a poorly understood and poorly defined information need by creating these portraits through dialog with an information system, then matching relevant information (based on the abstract portrait) to the information need. Oddy (1977) created a similar approach called the Thomas system, although this system did not require the user to make such precise problem descriptions. In addition, the Thomas system used traditional document descriptors to match documents with user problems, whereas the ASK model used free-scanned word roots to create the statistical problem portraits.

Dervin (1983; 1986) posits that people seek information when they encounter a gap in their knowledge that must be filled. Therefore, individuals seek knowledge to bridge that gap, thereby making sense of their world. The sense-making approach focuses on three main steps, which Dervin calls SITUATION-GAP-USE. These three steps correspond to:

1. The situation in which the individual has been stopped;
2. The gap of knowledge that prevents forward movement;
3. The logical bridge constructed to traverse the gap.

Since Dervin's original proposal of this sense-making model in the late 1970s, it has been applied in many different settings and from many different perspectives, enabling practitioners to better understand people's information needs and continues to be widely used.

Through multiple studies of information seekers in the social sciences, physical sciences, and engineering, Ellis (1989, 1993; Ellis, Cox, & Hall, 1993; Ellis & Haugan, 1997) defined the characteristic actions of these information seekers, including:

- Starting – Beginning to look for new information.
- Chaining – Following footnotes and citations in familiar documents to reach new documents.
- Browsing – Searching for new information; can be semi-directed or semi-structured.
- Differentiating – Using differences in information to filter the information obtained.

- Monitoring – Keeping up-to-date on information (such as that found in online news sites).
- Extracting – Identifying relevant material in an information source.
- Verifying – Checking the accuracy of information.
- Ending – Tying up loose ends through a final search.

Ellis asserts that these characteristic actions do not necessarily happen in any particular order, although it is logical that the information seeker must begin with the *starting* stage and should conclude with the *ending* stage; however, browsing, chaining, monitoring, and differentiating need not necessarily take place in any specific sequence or at any specific time during the search process.

Another well-known information-seeking model is Bates' (1989) berrypicking model. Bates argues that the classic information retrieval model, where information seekers enter a single query into an information retrieval system that responds with a single set of matches, is too limited and does not reflect how individuals actually find information. Instead, Bates suggests that searches are continually evolving and branching in new directions, because as users search they encounter new ideas and these ideas may change their search focus. Searches are satisfied with bits of information retrieved at each stage of the search rather than based on the initially encountered single information set. Bates calls this process *berrypicking* and suggests that users may employ many different search techniques at different times during the search process, depending on the information they need at a particular moment. These search techniques include: footnote chasing (backward chaining), citation searching, journal run (searching a set of journals for a topic), area scanning, subject searches, and author searches. Bates presents guidelines for the design of information retrieval systems that support the berrypicking search model – for example, making information easy to read, scan, and highlight.

Kuhlthau's (1991) model of the information search process includes six stages of information seeking that focus on the thoughts, feelings, and actions of the searcher at each stage in the search process:

1. Initiation – The searcher recognizes a knowledge gap, but is uncertain about how to fill it. Thoughts on the topic are vague, and the searcher seeks background information.
2. Selection – The searcher has more clearly identified the knowledge gap and is optimistic about addressing it.
3. Exploration – The searcher investigates the gap by seeking more relevant information, but may be confused, frustrated, or doubtful as he or she narrows the gap even further.
4. Formulation – The knowledge gap is more clearly and narrowly defined as the searcher formulates a better description of the problem focus.
5. Collection – The searcher has a clear sense of direction as he or she gathers specific, focused information about the topic. Interest about the topic increases as the individual learns more about it.
6. Presentation – The information-seeking task is complete, and knowledge about the topic is clear and focused. The searcher may be satisfied or disappointed with the result.

Kuhlthau's model assumes that doubt and anxiety are natural aspects of the information-seeking process that correspond with a lack of knowledge, especially at the beginning of the information-seeking process. Information systems should be designed to help users develop focused queries as early as possible rather than using the "best match" principle because of the assumption that a user knows exactly what he or she is looking for as he or she begins the task.

Pirolli and Card (1995, 1999) developed a model based on the optimal foraging theory, which was in turn further developed by anthropologists and ecologists. This theory focuses on how users search for information. In Pirolli and Card's model, information seekers are constantly carrying out these four actions:

- Making decisions about the type of information to look for,
- Evaluating whether to stay on the same Web page, the same Web site, or to move on,
- Choosing which link to follow when the decision is made to move on,
- Deciding when to stop looking for information.

One of the most important concepts of information foraging is that of "information scent," cues from the environment (for example, a Web page) that tells a user how much useful information he or she is likely to get by following a certain path. The notion of information scent leads a user to continue to follow a path as long as the information scent is getting stronger; otherwise the user will give up and move on to a different information space.

Ingwersen's (1996) model focuses on identifying the cognitive models and processes used at each stage of an information-search-and-retrieval session. For example, information seekers begin with a model of their information need, problem, or goal, and their model changes as they move through the search process. The information system represents how users interact with an interface to access and interpret information sources within the context of their own experiences. A unique feature of Ingwersen's model is that it includes the information retrieval system itself; he argues that this must be included in any comprehensive model.

Wilson's (1999) complex model of information behavior focuses on a subset of information-seeking behavior. His definition of information-seeking behavior includes passive attention, passive search, active search, and ongoing search.

- In a *passive attention* situation, individuals are not intentionally seeking information, yet information may still be acquired. This is referred to as "incidental learning" – for a good overview, refer to Kerka (2000).
- In a *passive search*, individuals end up with information about one area when they are actually looking for information about another area.
- When engaging in an *active search*, individuals are actively seeking information.
- In an *ongoing search*, the person already has information about the subject of interest but occasionally continues to search for new information about it.

Wilson's model assumes that most individuals spend most of their search time engaged in active searching.

Information Seeking on the Web

In this section we narrow this review from the general models and theories of information seeking presented in the previous section to focus on information seeking on the Web. We explore theories and models that describe information seeking on the Web. We consider these Web-specific models in the context of the more general models and theories of information seeking.

There is an extensive body of studies on information-seeking techniques and navigation patterns used by sighted users when exploring the Web. We have chosen several seminal studies for this review. These studies fall into two categories: large-scale studies that consider the browsing or searching behaviors of large numbers of anonymous individuals, and smaller-scale studies that incorporate both qualitative and quantitative data collection and focus on the browsing patterns of individuals. The large-scale studies focus on metrics such as query length, use of Boolean characters in search terms, failure rate, use of search modifiers, and the number of documents viewed during a session (for example, Hoelscher, 1998; Jansen, Spink, Bateman, & Saracevic, 1998; Spink & Jansen, 2004). Spink and Jansen (2004) compiled statistics that showed that most search queries are short (2-3 terms), only one query is typically used, and individuals generally only look at the top ten search results. The authors describe Web searches as “quick and dirty” instead of in-depth and report that over the ten year period from 1994-2004, the most frequent search topics shifted from entertainment to e-commerce as Web content shifted more toward business. On the other hand, the smaller-scale studies focus on individuals or small groups and use both qualitative and quantitative data. Therefore, these studies provide a better comparison for our studies of the individual Web navigation patterns of screen-reader users. The remainder of this section focuses on this category of studies.

A smaller-scale landmark study on information seeking on the Web is by Catledge and Pitkow (1995), who used a modified XMosaic browser to capture the Web-browsing actions of 107 sighted users over a three-week period at Georgia Tech. They found that the majority of these individuals preferred clicking on hyperlinks to move about, which accounted for 52% of all user actions. Using the Back command was the second most popular action, accounting for 41% of all actions. The other most frequently used commands included Open URL, Hotlist, Forward, Open Local, Home Document, and Window History. They also documented the five most frequently visited sites (which did not correspond to the most commonly bookmarked sites) and counted the path length (that is, the number of URLs requested). They found that users tended to focus on one area within a particular site, and that the navigation structure had a hub-and-spoke pattern due to frequent backtracking. Finally, the authors identified three categories of Web users based on the path length of the search and how frequently a particular path occurred. These three categories of Web users, which are based on Cove and Walsh's (1988) model, include:

- **Searcher**, who performs directed searches by using the same short navigation sequences infrequently, but performs long navigational sequences often.
- **General purpose browser**, who consults known sources that have a high likelihood of interest. This individual repeats the same navigation sequences about 25% of the time.
- **Serendipitous browser**, who browses in a random manner and does not appear to be looking for anything in particular. This individual does not repeat long navigation sequences.

Tauscher and Greenberg (1997) used XMosaic for their study of Web revisitation patterns. They analyzed data captured over six weeks from 23 XMosaic 2.6 users, and found that 58% of the page visits were actually revisits. They identified seven browsing patterns, including:

1. Use of Web-based applications
2. Authoring of Web pages
3. Reviewing sets of linear pages
4. First-time visits
5. Hub-and-spoke navigation
6. Guided tour
7. Depth-first search (where individuals use a search engine to go deeply into a site)

Using the formula presented by Tauscher and Greenberg for measuring page revisitation rates, Cockburn and McKenzie (2001) found an even higher rate of page revisits (81%). The authors attribute this increase to the more widespread and popular use of the Web at the time of their study.

To explore individuals' Web use in greater detail, Choo, Detlor, and Turnbull (1998) installed a custom Web-usage tracking application on the computers of 34 knowledge workers and tracked their Web activities for two weeks. The tracking application recorded menu choices, button-bar selections, and keystroke actions. Using these data and interview data, the researchers created a model that described common information-seeking activities based on the four scanning modes identified by Aguilar (1967) and the six information-seeking behaviors identified by Ellis (1989, 1993; Ellis et al., 1993; Ellis & Haugan, 1997). The results suggest that explicitly modeling motivations and movement may be useful for analyzing information-seeking patterns on the Web.

To explore search tactics and strategies and to examine Web revisitation patterns, Kari (2004) had 15 individuals perform free-form Web searches. Kari defined a *tactic* as "a concrete method of moving from one page to another in the Web" and *strategy* as "a pattern of Web moves," that is, a generalization of the specific tactic. Kari found that linking was the most popular tactic (45% of user actions), with backtracking the second most popular (25% of user actions) and performing a search third (8% of user actions). Kari, like Choo et al. (2000), noted that users tended not to use the browser's built-in navigational tools, such as bookmarks. Kari also identified three general strategies of navigation: *pointing*, where the user moves to the next page by clicking something (this is roughly analogous to browsing by following links); *typing*, where the user enters character strings to move to the next page (roughly analogous to searching); and *following*, where the computer takes control over the user's movement.

Cognitive Models of Web Navigation

Research into how people search for information and navigate on the Web has led to the desire to model and predict Web search and navigation behavior. Several cognitive Web navigation models predict the navigation paths that sighted users will take to reach a given information goal. For example, the Web User Flow by Information Scent (WUFIS) model simulates navigation actions based on the user's information need (Chi, Pirolli, Chen, & Pitkow, 2001).

The SNIF-ACT (Scent-based Navigation and Information Foraging in the ACT architecture) model simulates how users perform unfamiliar information seeking tasks on the Web (Pirolli & Wu, 2003). This model, based on the information foraging theory (Pirolli & Card, 1999) and the ACT-R (Adaptive Control of Thought-Rational) theory of cognition (Anderson, 1996; Anderson et al., 2004), assumes that users choose actions with a high "information scent."

Other models, such as the Method for Evaluating Site Architecture (Miller & Remington, 2004), focus on computational algorithms for simulating common Web usage patterns. Huberman et al. (1998) developed a model based on the probability distribution for the number of pages an individual visits within a particular Web site. This model explains the Zipf-like distributions[1] in page hits that have been observed at some Web sites. The model shows that surfing patterns on the Web display strong statistical regularities.

Instead of modeling navigation among Web sites, CoLiDeS (Comprehension-based Linked model of Deliberate Search) examines intra- and inter-page Web navigation patterns (Katajima, Blackmon, & Polson, 2000). The model suggests that sighted

[1] In this context, a Zipf-like distribution indicates that the frequency of the hits to any Web site is inversely proportional to the site's rank in a frequency table.

individuals parse a page into five to ten visually related sub-regions and then attend to the sub-region perceived as most similar to their information goal. Unimpeded progress through a site is considered a *forward search*. An *impasse* occurs when the user backtracks or focuses on a different sub-region.

Application of Information Seeking Models to Screen-Reader Users

As Wilson (1999) points out, there is a variety of models of information seeking, many of which overlap or are complementary. Several of the models seem directly applicable to screen-reader users, and some provide a level of granularity that may be important to understanding both inter- and intra-page Web navigation behaviors. For example, Ellis's (1989) model provides the structure for specific activities that might occur during the search process. Bates' (1989) concept of "berrypicking" relevant bits of information may be applicable to screen-reader users as they browse through a Web site, as is the idea that screen-reader users may employ different search techniques at different times during the search process. Ingwersen's (1996) inclusion of the information retrieval system in the model has interesting implications for a model for visually impaired information seekers. It could be argued that in the case of a screen-reader user, the information-retrieval system is a combination of the browser, the Web site itself, and the features provided by the screen reader. If screen-reader users choose links in the manner suggested by Pirolli and Card's (1995) theory of information scent, the concept of information scent would be a valuable component of an information-seeking model for screen-reader users. Finally, Kuhlthau's (1991) idea that doubt and anxiety are part of the information-seeking process may be particularly applicable to screen-reader users, who are often less successful in reaching their information goal than are their sighted peers (Coyne & Nielsen, 2001).

These studies of individual sighted users' navigation patterns describe several common types of Web navigation behavior. Sighted individuals navigate the Web in a variety of ways. Clicking on a link is the most common type of action, followed by using the Back button. Because sighted individuals use searches frequently and often revisit pages, their Web browsing patterns follow a Zipf-like distribution. These cognitive models indicate that to make progress, sighted individuals divide Web pages into groups of visually-related information, then following the strongest information scent, or information that is most likely to meet their information need. These studies form a picture of how sighted individuals navigate the Web—within pages, between pages, and between Web sites—and also the role that searching plays in their Web experience. In the next section, we explore whether these cognitive models and models of navigation patterns apply to screen-reader users as well.

USER INTERFACES FOR VISUALLY IMPAIRED INDIVIDUALS

Having explored how sighted individuals seek information, both in general and on the Web, this section considers what is known about how visually-impaired individuals seek information. To better understand how these individuals seek information, we first explore the range of interfaces that have been developed to make virtual information accessible to those with visual impairments. Understanding how these interfaces have evolved and the research that has contributed to their development helps highlight challenges faced by screen-reader users navigating the Web.

Auditory Icons and Earcons

Some of the earliest work on auditory interface elements was performed by Gaver (1989), who used sound to provide additional information about visual onscreen actions in his Apple application, SonicFinder. He coined the term *auditory icons*, which are sounds that relate real-world sounds to events that occur on the computer screen. The purpose of auditory icons is to provide additional information about actions that occur on-screen, either visible or not, such as opening or closing a window, arrival of an e-mail, or deleting a file. Although auditory icons were originally developed to provide a richer environment for sighted users via an auditory modality, auditory icons are perhaps even more important as examples in providing non-speech feedback for visually impaired users. This is because auditory icons can indicate actions (such as opening a new window or moving to a different icon) that screen readers do not normally announce.

In general, auditory icons are intended to relate real-world sounds to computerized events. However, identifying sounds that map well to abstract concepts and actions can be challenging. For example, while the sound of crumpling paper might be an appropriate auditory icon for deleting or throwing away a text document, what sort of non-speech sound is appropriate for deleting an mpeg sound file? In addition, would users want this level of detailed feedback? Sonic metaphors can also break down; at some point, there is little to relate certain sounds to certain activities, or vice-versa.

In his discussion of the rationale behind his strategy for developing auditory icons, Gaver points out that sound and vision are complementary but convey different types of information. Thus, sound can provide auditory information that can augment important visual information, such as a warning beep when an error message appears, and it can also provide information that vision cannot. In fact, auditory icons exploit Pavio's (1986) dual encoding theory, where non-speech auditory information is considered complementary to verbal visual information, or even to verbal auditory information.

Hutchins (1986) argues that human understanding of computer behaviors is built upon layers of metaphor. Gaver (1989) discusses at length his use of metaphors to conceptually map auditory icons to their graphical counterparts. Utilizing metaphors to create auditory icons is grounded in the theory of metaphors (Hamilton, 2000). The theory posits that there will always be mismatches between the metaphor and the physical object it is trying to represent. Emacspeak (Raman, 1996), a spoken interface developed for the Emacs desktop (discussed in detail later in this section), makes use of auditory icons that are often random sounds mapped to on-screen actions. That is, in Emacspeak there is no attempt to metaphorically match sound to action.

Auditory icons are an integrated aspect of modern major operating systems, including Windows XP, Mac OS X, and UNIX. Most operating systems allow users to custom-map certain sounds to specific actions. Because auditory icons can provide additional information about the state of the interface and the interaction, this could help prevent some types of mistakes. However, users must be able to determine which information is vitally important and which is not; if there is too much information, the individual faces information overload. Consequences of information overload include having the user become lost in the interface, unable to make decisions, or unable to identify and/or focus on the relevant information.

An *earcon* (Blattner, Sumikawa, & Greenberg, 1989) describes an auditory icon that consists of a series of musical notes. Brewster (1997, 1998; Brewster, Capriotti, & Hall, 1998) has used earcons both to help identify actions in graphical user interfaces and as a navigation tool in telephone interfaces. Instead of trying to match earcons with real-world actions, earcons are randomly associated with an action, object, or place. Thus, the designer does not face semantic limitations when an action has no real-world equivalent. In addition, because earcons represent objects (nouns) and actions (verbs), they can be combined to form short auditory sentences. For example, if an earcon exists for an e-mail application and there is an additional earcon for the "close application" action, then these two earcons can be combined to form a compound "close e-mail application" earcon. In a telephone-based interface where earcons were used as navigational tools to define hierarchical levels, earcons have been combined to represent ever-deeper levels of the hierarchy.

Earcons follow a few simple design rules, presented by Brewster (1995). The rules guide the use of aural characteristics such as timbre, register, pitch, rhythm, duration, and tempo, as well as the length of the earcon, in terms of both time and number of notes. Brewster's rules suggest a spatial description of earcons, where each earcon can be situated along the X, Y, and Z axes, as an aid for differentiating among different earcons (for example, those playing simultaneously).

Brewster's motivation for using earcons appears to explain why auditory icons have come into use. He considers earcons to be a complement to visual output because they can increase the amount of information communicated. In addition, sharing information across different sensory modalities can improve task performance. However, he expresses concern that making the experience sufficiently fine-grained to be useful could potentially be disruptive to the user by providing too much auditory information.

Donker et al. (2002) also placed earcons (which they call *hearcons*) in a three-dimensional (on the X, Y, and Z axes) auditory environment. Their hearcons represent four types of virtual Web objects: headings, paragraphs, images, and links. In their study, users navigated via a mouse to select particular items. The authors found that semantic information conveyed in the visual organization and layout of the Web pages, such as color, shape, and orientation, was apparently not conveyed by the hearcons in their study. The authors suggest that this may account for the poor performance of the visually-impaired users in the study, although we suspect that the unfamiliar task of using a mouse may have been the primary cause of poor performance by these individuals. When sighted individuals used the same system, they performed significantly better than their visually-impaired counterparts, even when the sighted individual was blindfolded. The authors suggested that sighted users are able to develop spatial mental models of abstract material that differ from those of visually-impaired individuals. The authors concluded that because of the difference in mental models, the visually-impaired individuals did not need to know what a Web page looks like, or exactly where the links, text, and images are located on a page. However, they did need to understand the structure of the objects and information within the Web page to navigate it successfully. Thus, while information about the page structure and the information it contains is useful, spatial information may not be helpful to visually-impaired individuals and could even cause confusion.

Speech-based Interfaces

While auditory icons provide complimentary non-verbal feedback about the state of an interface, the primary source of information for a visually-impaired computer user is provided by computerized speech. Computerized speech is delivered via a combination of two mechanisms: a screen reader (such as JAWS) and a speech synthesizer. The screen reader first “translates” information presented on the screen into a linear format (for example, it might read icons on the desktop from the top left corner to the bottom right corner). Then, the speech synthesizer, which can be either a hardware device or software-based, turns the translated information into human-understandable speech.

Screen readers have been in use since the mid 1980s (Raman, 1996) and were initially available for the command-line operating systems for MS-DOS and Unix. Raman explains that early command-line speech interfaces were in many ways easier to use than more modern counterparts because command-line interfaces, like speech, are inherently linear (that is, they are one-dimensional). The development and ensuing popularity of graphical user interfaces starting in the late 1980s sparked a great deal of debate as to how this change in interaction style would affect speech-based interfaces, because the two-dimensional spatial information that made graphical interfaces popular among many sighted users was not easily translatable to a single, linear spoken dimension. Attempts to translate visual information such as spatial layout and organization into speech proved to be quite challenging. Consider, for example, Table 1, which contains part of a syllabus for a class taught at the University of Texas at Austin.

Date	**Topic**	**Reading**	**What's due**
September 10	Blindness & personal narrative	Mehta, Sound Shadows, Chs. 1-7	Post reading response and journal of mouseless week to forum
September 12	Equivalent alternatives	MaxAccess, chs. 7 & 9; checkpoints and standards addressed in these chapters	Place completed ALT text exercises in teacher folder
September 17	Blindness: orientation and mobility	Mehta, Sound Shadows, Chs. 8-end; Slatin, Dillon Chronicles (online)	Sound Shadows 2 reading response to forum
September 19	Orientation and navigation on the Web	WCAG 1.0 guidelines (all checkpoints); Guideline 12; Guideline 15, esp. checkpoints 13.4 and 13.6; Section 508 paragraphs (i) and (o).	Skip navigation orientation, markup exercises to teacher folder

Table 1: Sample syllabus that illustrates challenges of translating graphical interfaces

The transcript of Table 1, when read aloud by JAWS, is as follows:

> “Table with four columns and four rows. Summary: September tenth through September nineteenth. Blindness and Visual Impairments [This is the title of the table in the HTML code]. Date. September tenth. Row two. September twelfth [User has pressed the down arrow key twice to move down the first column of the table]. Row three. Topic. Equivalent alternatives [User has pressed the right arrow key to move one column to the right]. Column two. Reading. Maximum Accessibility, Chapters seven and nine; checkpoints and standards addressed in these chapters [User has pressed the right arrow key again to move to the Reading column]. Column three. What’s due. Place completed alt text exercises in teacher folder [User has pressed the right arrow key a third time to move to the What’s due column]. Column four.”

Note that the information read aloud by JAWS is not quite identical to what is shown in the table (for example, we hear the title of the table but do not see it); this is due to hidden tags in the table’s HTML markup that make the table easier for a screen reader to read, but don not affect the visual aspects of the page. The spatial information of the table is a key tool for sighted users to understand the organization of the information. When presented in a linear format, this information is much more challenging to understand.

Despite the prevalent use of JAWS (Freedom Scientific, 2009) (about 65% of the US market (Theofanos & Redish, 2003)), Windows-Eyes (GW Micro, 2009) (about 35% of the US market (Theofanos & Redish, 2003)), IBM HomePage Reader (IBM, 2009a), and other commercially available screen readers by screen-reader users around the world, there is little published research about the principles guiding the feature choices and designs for these screen readers. Thatcher’s (1994) article about designing the OS/2 Screen Reader focuses on the technical challenges behind creating a screen reader for a GUI. Barnicle (2000) tested the usability of JAWS 3.2. He had screen-reader users complete tasks using several common applications found in the Windows 95 operating system. Barnicle found two common types of errors. The first occurred when the user was not certain of the cursor’s focus due to a lack of appropriate system feedback that informs him or her of the system’s status—in other words, the spoken information is not meeting the user’s needs. The second type of error occurred when the user repeated an action more than the minimal number of times required to complete a task (for example, listening to more than 75 menu items or controls to find the desired one). When the user repeats an action more than the minimal number of times, the user lacks appropriate context to inform him or her of the best choice, or a more efficient way of accessing that choice. In other words, in order to work effectively, the user needs important contextual information that is not conveyed.

Because Raman (1996) developed Emacspeak as part of his doctoral research, he thoroughly documented the design of the interaction. With Emacspeak, Raman attempted to overcome barriers of traditional screen readers by having the tool provide access to the underlying information, rather than interpreting the information based on its spatial and structural layout. For example, when JAWS reads a calendar presented in tabular format, the outcome is much like the example in Table 1, whereas when Emacspeak presents the same calendar, it first considers the underlying information and then reads the contents as one might expect a calendar to be read, for example, “Sunday, September 14, 1997.” This approach conveys not only what information is on the screen, but also context as to why it is there.

In academic research related to speech interfaces, the Mercator project (Mynatt, 1994; Mynatt & Edwards, 1992; Mynatt & Weber, 1994) replaced spatial graphical information with a hierarchical spoken interface. The researchers used this approach based on the observation that many features of graphical interfaces need not be modeled in an auditory interface. Instead of representing every object on the screen in an auditory manner, they chose to represent only the structural features of the application interface, such as buttons, dialog boxes, and menu items. Translating the interface in this way provided a way to scan the interface and interact with objects within the interface. Unfortunately, it appears that Mercator was never tested with visually-impaired users.

The HOME UIMS (Savidis & Stephanidis, 1995a, 1995b) is a speech interface designed to integrate features useful for both sighted and blind users. The two key premises of this system are:

1) Screen readers introduce visually oriented concepts to the non-visual interactions;
2) Any attempts to remove these visually oriented concepts or replace them with 3-D audio output techniques are inherently flawed and lead to significant theoretical drawbacks.

In other words, when the original interface specifically addresses the needs of sighted users, translating this interface to an auditory format will not necessarily meet the needs of visually impaired users. To address these and other issues, Savadis and Stephandis (1995b) developed HOMER, which supports development of dual user interfaces that support both visual and non-visual interactions.

The Mercator and HOMER UIMS projects both aim to supplement the full computer desktop and all of its various applications with spoken output. Other speech interfaces focus purely on providing spoken feedback for Web browsers. Such applications can provide more specialized interactions customized for Web browsing. For example, project BrookesTalk (Zajicek, Powell, & Reeves, 1998) is a screen reader that assists users in making quick decisions about the relevance of the information retrieved from a search or found on a Web site. It also provides tools for orienting the user on the page. Zajicek et al. argue that tools like JAWS, which was developed for desktop navigation, are unwieldy for moving quickly about the Web. BrookesTalk provides the user with a short synopsis of the Web page and creates a list of headings, links, keywords, and bookmarks. An add-on to BrookesTalk, created for older visually impaired adults with little Web experience, provides the user with a spoken menu of choices at each interaction point (Zajick & Morrisey, 2001). The authors found that shorter spoken menus worked better for older users, but were not necessarily beneficial for younger users.

Many non-visual Web browsers only undergo one iteration of development and are often not used outside of the laboratory. The HearSay Web browser, which is currently in its third version, is being used at the Helen Keller School for the Blind. The browser is unique because it allows the user to interact through a flexible dialog interface that enables context-directed browsing. The first version (Ramakrishnan, Stent, & Yang, 2004) used structure and semantic analysis to divide pages into semantically meaningful parts among which the user could then navigate. It also used a clustering algorithm that segments information on the page into elements such as menus, tables, and articles, allowing users to navigate using these elements. Tests with HearSay show that the underlying algorithm can identify the most relevant blocks of content with 91% accuracy (Mahmud, Borodin, & Ramakrishnan, 2008).

The second version of HearSay includes a rich feature set (Borodin, Mahmud, Ramakrishnan, & Stent, 2007), including:

- Extensible dialog written in VoiceXML.
- Context-driven browsing, which enables users to jump directly to the most relevant part of the page and rapidly navigate around the page.
- Continuous reading and pausing modes for navigation.
- Earcons for certain HMTL elements.
- Support for both verbal and textual (keyboard) commands, as well as shortcuts for commands.
- Integration with JAWS.

HearSay3, the most recent version, includes features designed to support use of Web 2.0. The authors suggest that these features are particularly important because blind people tend not to use Web pages that contain dynamic content (Bigham, Cavender, Brudvik, Wobbrock, & Ladner, 2007) and because the popular screen readers tend to lag behind the new Web technologies (Borodin, Bigham, Stent, & Ramakrishnan, 2008). HearSay3 switches seamlessly between different implemented languages, which can be useful on sites that are implemented using multiple languages. Hearsay 3 also allows users to label elements on a Web page; these labels are used each time the individual revisits the page. Most importantly, HearSay3 detects dynamic page updates, notifies the user of the updates, and provides mechanisms that allow the user to review the updated content at their convenience. HearSay developers are collaborating with the Helen Keller School for the Blind to further develop and test the application, which is currently in use on computers at the School (Bigham et al., 2007).

Despite progress over the last decade in providing spoken access to and interaction with graphical Web pages using screen readers, Leuthold et al. (2008) argue that attempts to provide blind individuals with access to graphical user interfaces are inherently flawed. They argue that GUIs lead to auditory clutter. To more directly address the unique needs of blind users, they propose building an enhanced textual interface (ETI). The authors developed a set of nine guidelines for an ETI, based on Schneiderman and Plaisant’s (2005) rules of interface design, WCAG guidelines, and information from interviews with blind users. They used this information to guide the design of an ETI for the University of Basel’s (Unibas) Web site.

To test the ETI, 39 blind individuals were asked to perform a navigation task and a search task. They performed identical tasks on both the regular Unibas Web site and a WCAG-compliant version of the Unibas Web site. The authors found no difference between time on task for the navigation task on the two sites, but users spent significantly less time doing the search task when using the ETI. They found no difference in the number of errors for the navigation task, but found that users made significantly fewer errors when using the ETI for the search task. Users also expressed a preference for the ETI. The authors concluded that the ETI shows promise as an option for blind users, and that guidelines such as WCAG focus too much on accessibility as opposed to usability. However, the visually-impaired users who tested the interface expressed concerns that an ETI might provide inferior content compared to a graphical Web site. In addition, moving to text-based interfaces seems to be a significant loss in progress compared to the current state of the Web, evoking images of early 1990s-era text-only Web sites.

Bigham et al. (2008) took a more traditional path when they developed their screen reader, WebAnywhere. Their Web-based screen reader enables users to access a screen reader from any computer, instead of having to install expensive screen-reading software if they use a computer at a remote location. Users simply browse to webanywhere.googlecode.com, then visit any Web site they wish. WebAnywhere includes navigation features for reading headings, links, tables, and forms, and the ability to conduct a search. It also provides better support for Web pages with dynamic content than any other screen reader to date.

The authors tested WebAnywhere with eight screen-reader users, who independently completed four tasks online using WebAnywhere. All participants were able to complete all the tasks, but reported that WebAnywhere was somewhat tedious to use in comparison to their usual screen readers, and that WebAnywhere was sometimes confusing because it did not provide feedback when pages took time to load. However, they liked the idea of a cost-free screen reader that could be used on any computer with Internet access.

Because screen readers operate by speaking the content of the HTML source code for a Web page, quality of output from a screen reader has as its upper limit the quality of the HTML on the page. If Web pages are not properly marked up or have poor organizational structure, then screen-reader users may have trouble navigating. For example, Brudvik, Bigham et al. (2008) acknowledge the importance of properly marked HTML headings to screen-reader users, but point out that not all Web sites are designed to include appropriate headings. To address this issue, the authors developed HeadingHunter, an application that identifies text on a Web page that should be labeled as a heading. Since headings usually have a different visual format than the surrounding text, HeadingHunter compares surrounding text, including differences in font size, use of bold, text length, and the width-to-height ratio. In field trials, HeadingHunter performed best on sites where the content was organized in a consistent manner, such as on Wikipedia and Google.

Summary of User Interfaces for Visually Impaired Individuals

A common theme in the design of spoken interfaces is that graphical user interfaces generally do not translate well to spoken user interfaces. The primary reasons for this are that important contextual information is often not conveyed, the spoken information is insufficient to meet the needs of visually impaired users, and interfaces include an excess of "noise" that conveys irrelevant visual information. Research has shown that screen-reader users generally spend more time completing tasks and end up performing more actions than do their sighted counterparts (for example, Coyne & Nielsen, 2001); this may be in part because screen-reader users are being supplied with unnecessary visual information and too little contextual information. The HearSay browser seems to mitigate this issue through the use of context-directed browsing.

However, because screen readers function by interpreting the HTML source code on Web pages, users may have trouble navigating Web pages that lack either proper HTML mark-up, a well-designed information architecture, or both. Therefore, applications such as HeadingHunter, which fixes poor mark-up on the fly, may help improve the screen-reader user's browsing experience.

TELEPHONE INTERFACES

Touch-tone telephone interfaces provide unique insights into spoken interfaces. In this context, there is no need to "translate" two-dimensional graphical information into single-dimension auditory information because this type of interface typically has no visual elements. For this reason, it may be less likely for these interfaces to lose important contextual information. In addition, it may be less likely that these interfaces would convey unimportant visual information. The design strategies that are common in this area may address several of the navigation problems encountered by screen-reader users.

A good deal of research on telephone interfaces took place in the early 1990s. These interfaces were intended to keep mobile users in touch with their e-mail, voice messages, and calendar, or let them browse the Web at a time when laptops were new, modem speeds were slow, and wireless Ethernet had yet to be developed. Today, technological advances allow users to carry out these activites (and more) via a graphical interface from wireless laptops, PDAs, or cell phones. As a result, callers commonly encounter telephone interfaces when they need to access a particular piece of information that can be reached by successively choosing from options in an ever-narrowing list (for example, checking one's bank account balance).

Although the complex telephone interfaces of the early 1990s have been replaced by other technologies, the spoken interactions unique to these telephone interfaces makes the innovations in the design of these interfaces of particular interest for this research study. For example, Hyperspeech (Arons, 1991), one of the first speech-only interfaces, included a database of spoken information that users could explore without using any visual cues. After completing two iterations of the spoken interface, Arons offered several observations about designing telephone interfaces. For example, because users tend to be impatient, he recommended streamlining interactions. At the same time, the interface could not be oversimplified, because users need identifiable landmarks in order to navigate successfully. Finally, Arons suggested that the system should allow varying degrees of feedback to keep the interaction smooth and efficient. Arons also mentioned Grice's (1975) maxims on streamlining communication: be as informative as required, be relevant, avoid ambiguity, and be brief. Arons suggested that Grices' maxims may be more relevant to human-machine communications than they are to human-human communications. Brennan (1990) discusses using conversation as a direct manipulator in computer interfaces. She recommends Grice's maxims as guidelines for creating more intuitive interfaces.

HyperVoice (Resnick, 1992) is another auditory-only user interface for telephones. It was designed to facilitate issue discussions: users could call in, leave comments about a particular issue, listen to what others had recorded, and reply to others' comments. Resnick's trials of the system suggested that it was important to chunk information into smaller pieces to make it easier for users to scan, and also suggested that because auditory information is transient, users are forced to remember large collections of information unless the recorded information is broken down into smaller segments. This concept of chunking information so that users do not suffer from memory overload is one element of cognitive load theory (Sweller, 1988), which states that minimizing memory requirements, and thus the cognitive load, are essential goals of interface design.

Unlike Hyperspeech and HyperVoice, PhoneShell (Schmandt, 1993) had a graphical component as well as a telephone-accessed spoken component. PhoneShell provided remote access to a personal desktop database that included functions such as voice mail, e-mail, a calendar, and a Rolodex. The system used touch-tones for input rather than speech recognition. In general, users liked PhoneShell’s ability to convey information concisely with a minimum of user interface overhead, a preference that aligns well with the maxims on streamlining communication.

SpeechActs (Yankelovich, Levow, & Marx, 1995) was a telephone interface that provided access to several graphical applications from the Sun/Solaris operating system. SpeechActs provided natural speech interactions with applications such as e-mail, a calendar, weather reports, and stock quotes. It was designed to provide access to these applications both from a desktop and from a phone. Early designs of SpeechActs were influenced by existing graphical application interfaces. Over iterations, there was a clear trend toward an interpersonal conversational style of interaction. However, the vocabulary used in graphical user interfaces did not transfer well to a spoken interface. In addition, the organization and presentation of information did not transfer well from the graphical domain to the spoken domain. The authors suggested that common principles of conversation would make good guidelines for designing usable speech-only interfaces, but that translating graphical interfaces into spoken interfaces is not likely to produce an effective spoken interface.

Judging by the research on telephone interfaces, it seems that when speech is the primary output, Grice’s maxims of communication produce a more usable interface than trying to “translate” the graphical interface to spoken information. For example, by successfully applying the maxim of being brief, Zajick and Morrisey (2001) decreased the time BrookesTalk's users spent on task. Thus, although the research on telephone interfaces has not been applied to graphical interface design in the past, it does provide a rich source of relevant findings.

IN-CAR MULTIMODAL INTERFACES

Another type of user interface that provides unique perspectives that may be applicable to visually-impaired users are in-car interfaces. The general goal of designs for in-car interfaces is to make minimal use of vision (Barfield & Dingus, 1998; Srinivisan, 1999) and to minimize complexity. The key motivation for this focus is that any distraction from attention to the road severely degrades driver performance (Burnett & Joyner, 1997; Zaidel & Noy, 1997). Burnett and Porter (2001) suggest that, because in-car interfaces are essentially eyes-free, information about the design of interfaces for blind and low-vision users should be applicable when designing interfaces for vehicles.

Although there is extensive literature available about in-car interfaces, much of this work focuses on multi-modal input and feedback in both visual and spoken form. Tijerina, Palmer, and Goodman (1998) report on four commercially available in-car navigation systems, one of which had voice input and output only (no visual display). They found that individuals using systems that combined voice and visual components spent significantly more time looking away from the road than did individuals using the voice-only system. They also found that users preferred the voice-only interaction method.

Marcus (2004) provides a number of guidelines for designing in-car interfaces. While some of the guidelines focus on phenomena particular to vehicles, others, such as reducing complexity, using physical controls, avoiding cognitive and sensory overload, allowing customization, and following user-centered design principles, could be viable design guidelines for Web navigation by screen-reader users. Research in the field of in-car interfaces could help inform the field of screen-reader design about optimal interface and content design that supports eyes-free navigation techniques.

3D Auditory Interfaces

In an effort to provide visually-impaired users with spatial information to improve navigation and overall user experience,[2] a number of 3-D auditory interfaces have been developed that offer spatial information in an auditory manner.

For example, Savindis and Stephandis (1995ab) based their work on a metaphor related to rooms. Each room can have an elevator (to take users to other floors) and a door (which leads to other rooms on the same floor). This “rooms” metaphor was intended to provide visually impaired users with a real-world metaphor that would allow them to better operate within the interaction space because it has similarities to the real world. [3] Lumbreras and Rossi (1995) created a similar metaphor, where users walk along a virtual corridor and interact with “speakers” who provide spoken details about the information contained in the rooms along the corridor. In this way, users can take advantage of the spatial relationships among the speakers in the corridor, allowing them to find information more easily.

Lumbreras and Sanchez (1999) and Baloian et al. (2002) devised similar experiments using a 3-D virtual gaming world called AudioDoom, which was designed for use by visually impaired children. The users navigated through corridors that include

[2] Donker (2002) and Raman (1996) argue that blind users need to understand the underlying structure of the information on a Web page rather than its spatial orientation.
[3] The concept of rooms and other virtual spatial places occurs in other contexts as well. For example, digital gaming environments such as Second Life (www.secondlife.com), Ultima Online (guide.uo.com), and SimCity (simcity.ea.com) provide rich, three-dimensional worlds that include rooms, buildings, streets, and even entire cities.

rooms, doors, and other virtual objects. Game features such as actions, the appearance of the user, and other entities in the game are rendered by spatialized sound (that is, sound that comes from a specific point in space). While testing the game, about half of the test subjects were able to build a reasonably good physical model of the AudioDoom space using Lego blocs. This led the researchers to conclude that spatialized sound is a viable approach to building navigable virtual structures. This type of 3-D interface seeks to use the user's spatial memory capabilities, a phenomenon that has been studied extensively in cognitive psychology (see, for example, Darken & Sibert, 1996; Thorndyke & Hayes-Roth, 1982).

An intriguing possibility is to exploit the innate spatial memory and cognitive mapping capabilities of visually-impaired individuals by presenting them with a 3-D auditory interface. For such an interface to be viable, interface designers must be able to create spatialized sound and users must be able to locate the sound sources. Torihara, Hirano et al. (2002) were unsuccessful in their attempts to create spatialized sound because they could not obtain synchronized responses from each of four loudspeakers. A study by Goose and Moller (1999) showed that individuals using headphones were accurate when tracking a sound source's position on the X-axis, but they were not very accurate when tracking sound sources on either the Y- or Z-axis. Donker (2002) reported similar results when sighted participants used headphones. When the participants used loudspeakers to produce the sound, their spatial location accuracy improved. These results support psychology research in sound localization (for example, Middlebrooks & Green, 1991), which shows that humans are more accurate at finding sound on the X-axis than on the Y-axis, primarily because some sounds on the X-axis (those not at the midline) reach the ears at different times, depending on the location of the sound relative to the head. Other research has shown that users perform nearly identically on sound localization tasks when using headphones or in a natural setting, and that humans localize sound more precisely when they are directly facing the sound source (for example, Wightman & Kistler, 1997).

Although not precisely a 3-D auditory interface, Trewin et al. (2008) have developed a framework that makes 3-D gaming environments accessible to users with disabilities. Instead of providing spatialized sound information, the authors supplement visual effects with auditory cues, for example, the sound of footsteps when a character in the game is walking. They also provide text labels and descriptions for objects in the game. The information on the labels varies depending on the character's proximity to the object and the angle from which the object is viewed. These descriptions help orient the user and provide a sense of place. In addition, the game allows users to search for objects in a non-visual manner. Once the user locates an object, the user's character can be directed to it automatically. This framework is being tested to see how users with disabilities react to a 3-D accessible game and to compare the results with those obtained when using 3-D interfaces that use spatialized sound.

HAPTIC USER INTERFACES

The interfaces we have reviewed so far have focused on auditory information. Another sense available to blind individuals is touch, leading to tactile or haptic interfaces. The most common form of haptic interaction device is a Braille output device, which renders on-screen text into Braille. Because of the high cost (> US$5,000, (TechReady, 2009)), these devices are not commonly used.

Only a few researchers have studied how to integrate haptic interactions (other than those interactions that occur using Braille devices) and auditory interactions. For example, Tzovaras et al. (2002) had participants work in a 3D world using the

CyberGrasp haptic device and auditory feedback. Participants were asked to complete tasks that included recognizing objects, grasping and manipulating objects, exploring haptic maps, and using 2D mathematical graphs. Of the 26 visually impaired users who participated, more than 90% were able to successfully complete the tasks. Landau et al. (2003) have studied another device, the Talking Tactile Tablet (or TTT), for its feasibility in teaching mathematical concepts to visually impaired learners. Users can mount specially prepared raised-line and textured drawing sheets onto the TTT's touch-sensitive surface, then press objects on the sheet to obtain audio responses. The authors suggest that the TTT may be especially useful for presenting multiple-choice mathematics tests to visually impaired users, especially when compared to standard Braille-display testing procedures.

Brewster (1998) explored 3D virtual interfaces that include haptic information as a way to increase the amount of information available on multiple channels (i.e. both audio and tactile). However, he notes that arbitrarily mixing modalities can reduce performance, an observation supported by Pavio's (1986) dual encoding theory and Mayer's (2005) work on mixed modalities in hypermedia learning. Other work, such as that done by Roth et al. (1999), has focused on creating 3D audio interfaces specifically for the Web. They proposed a browser that included a spatial metaphor as the basis for the non-visual presentation. The browser used tactile information to denote spatiality, non-speech sounds (including earcons) to denote virtual elements, and synthesized speech to provide textual information.

Rotard et al. (2008) developed two versions of a tactile Web browser. In the first version, the authors implemented a special tactile browser that rendered XHTML into a tactile display. Among the limitations of this browser were the inability to support form fields, the inability to handle dynamic content, and even the inability to render some Web pages. These limitations led them to develop a second version based on Mozilla Firefox. The second version, which is currently under development, includes algorithms to display tables intelligently. This is difficult because the resolution of the tactile display is significantly less than the resolution of the traditional visually-oriented screen. The tactile Web browser has been successful in rendering graphics, using algorithms to convert color images to monochrome, and using filters to show only the edges or outlines of the graphics. Even three-dimensional graphics can be shown using the tactile display. The authors support the W3C recommendation for using Scalable Vector Graphics (SVGs) (W3C, 2008), because these are easily manipulated into a size that is appropriate for the tactile display. The authors intend to complete this version of their browser and test it with blind users.

While haptic displays are expensive and not widely used, they are a potential tool for improving Web navigation. A detailed discussion of how haptic displays might be used to improve Web navigation is beyond the scope of this paper.

SUMMARY OF AUDITORY INTERFACES

Different types of auditory interfaces have been designed to improve navigation for screen-reader users. The results from testing these interfaces may explain some of the difficulties that visually-impaired individuals have with navigating the Web and other virtual information spaces. For example, graphical user interfaces do not translate well to spoken user interfaces because important contextual information is often not conveyed, while unimportant visual information *is* conveyed, such as spatial information. This leads to auditory information that does not meet the needs of the visually impaired user. Studies on telephonic interfaces concluded that basing these interfaces on Grice’s (1975) communication maxims is key to designing usable auditory-only interfaces. In addition, while it is important not to overload users with too much information, the interface must provide sufficient information to allow the user to navigate. Using earcons and auditory icons may help provide this information, but designers must be careful not to overload the user with too many inputs.

INFORMATION SEEKING USING A SCREEN READER

Thus far, we have reviewed how sighted users find information in general, as well as how they seek information on the Web. We have explored the evolution of user interfaces for visually-impaired users and reviewed the findings from studies of these interfaces. With this background information, we now consider how visually impaired screen-reader users find information on the Web. We first explore how information can be made accessible to this user group and then review studies that examine how screen-reader users access this information using their chosen assistive technology.

Making Information Accessible

When an individual seeks information online to fulfill a particular information goal, they generally assume that the information needed to fulfill the goal is actually available. Unfortunately for a screen-reader user, while the information may be available, it might also be inaccessible—which in effect makes it unavailable. Content that might be obvious to a sighted individual may be challenging for a screen-reader user to find if it the Web page is not designed or coded with accessibility in mind. For example, information contained in a Flash movie that has no sound is inaccessible to a screen-reader user.

Accessibility Guidelines and Standards

To help ensure that individuals with a variety of disabilities, including severe visual impairment, can access information online, in 1998 the United States government passed an amendment to the Rehabilitation Act, commonly referred to as Section 508 (IT Accessibility & Workforce Division, 1998). Section 508 requires all government agencies to provide electronic information that allows access by individuals with disabilities. Many states have adopted similar laws for state agencies; for example, the University of Texas at Austin is required to provide accessible Web sites (The University of Texas at Austin, 2008).

The sixteen guidelines of Section 508 are as follows:

(a) A text equivalent for every non-text element shall be provided (e.g., via "alt", "longdesc", or in element content).

(b) Equivalent alternatives for any multimedia presentation shall be synchronized with the presentation.

(c) Web pages shall be designed so that all information conveyed with color is also available without color, for example from context or markup.

(d) Documents shall be organized so they are readable without requiring an associated style sheet.

(e) Redundant text links shall be provided for each active region of a server-side image map.

(f) Client-side image maps shall be provided instead of server-side image maps except where the regions cannot be defined with an available geometric shape.

(g) Row and column headers shall be identified for data tables.

(h) Markup shall be used to associate data cells and header cells for data tables that have two or more logical levels of row or column headers.

(i) Frames shall be titled with text that facilitates frame identification and navigation.

(j) Pages shall be designed to avoid causing the screen to flicker with a frequency greater than 2 Hz and lower than 55 Hz.

(k) A text-only page, with equivalent information or functionality, shall be provided to make a web site comply with the provisions of this part, when compliance cannot be accomplished in any other way. The content of the text-only page shall be updated whenever the primary page changes.

(l) When pages utilize scripting languages to display content, or to create interface elements, the information provided by the script shall be identified with functional text that can be read by assistive technology.

(m) When a web page requires that an applet, plug-in or other application be present on the client system to interpret page content, the page must provide a link to a compliant plug-in or applet.

(n) When electronic forms are designed to be completed on-line, the form shall allow people using assistive technology to access the information, field elements, and functionality required for completion and submission of the form, including all directions and cues.

(o) A method shall be provided that permits users to skip repetitive navigation links.

(p) When a timed response is required, the user shall be alerted and given sufficient time to indicate more time is required.

Several of these guidelines (a, c, d, j, k, l, m, n, o, and p) can be checked by automated tools such as Watchfire (previously known as Bobby) (IBM, 2009b) and CynthiaSays (HiSoftware, 2009). The other Section 508 guidelines must be checked manually by an accessibility expert.

In Europe and Canada, the Web Content Accessibility Guidelines (WCAG) provide similar guidelines for Web development (W3C, 1999, 2006). There are currently two versions of WCAG, WCAG 1.0, which was released in 1999, and the new 2.0 version, which is still undergoing review. WCAG 1.0 includes 14 accessibility checkpoints, most of which include three different priority levels, Level 1, Level 2, and Level 3. A developer *must* satisfy Level 1 criteria to comply with the checkpoint. To comply with a checkpoint, the developer *should* satisfy Level 2 criteria, and *may* satisfy Level 3 criteria. WCAG version 2.0 provides much more detailed success criteria than version 1.0 and includes an extensive guide for understanding and implementing WCAG 2.0, including examples of accessible HTML code for most criteria. Conformance with WCAG version 2.0 is measured in a manner similar to version 1.0, although the conformance levels have been renamed. Web sites can conform at Level A, which indicates that the site conforms with every success criteria at that level, Level AA, which indicates all Level A criteria and Level AA criteria have been met, or Level AAA, which indicates that all Level A, AA, and AAA criteria have been met. WCAG 1.0 compliance can be assessed with automated tools such as Watchfire and CynthiaSays, but no tools are yet available that assess Web sites for WCAG 2.0 compliance. For many criteria, an accessibility expert must still perform manual checks.

Accessible Information

Compliance with Section 508 guidelines is required for state and federal government Web sites in the U.S., as well as many institutions that receive governmental funding (for example, The University of Texas at Austin). Web developers in many European countries and Canada follow the WCAG 1.0 guidelines to ensure accessibility. Despite these guidelines, several studies, such as those by Kelly (2002) and Romano (2002), have found that overall Web accessibility is extremely poor. For example, in a study of 1000 U.K. Web sites (Disability Rights Commission Disability Rights Commission, 2004), only 19% were WCAG 1.0 Level 1 compliant, and only two sites passed Level 2 WCAG 1.0 criteria. None of the sites were Level 3 compliant.

The Section 508 and WCAG 1.0 guidelines have been available for more than ten years. Despite this, in a study of the accessibility of 154 Web sites over a six-year period, Hackett et al. (2003) found that these sites tended to become both more inaccessible and increasingly complex over the years. Additional work by Lazar et al. (2003) demonstrated that over a one-year period, 50 Web sites from mid-Atlantic American organizations became more inaccessible. Although the relative accessibility of Web sites may be decreasing, there are areas where it is improving. For example, Hacket et al. (2003) considered the guideline “provide alternative text for all images” and reported that the percentage of violations decreased from 63.0% in 2000 to 41.7% in 2002, while the number of images in the sample increased from 37,900 to 127,500. Lazar et al. (2003) found that the number of violations of the same guideline decreased from 45 sites to 33 (out of 50) sites over a one-year period. They found that violations of Section 508 (c), which specifies use of color, increased from 11 to 34 sites. They also found that the number of sites that violated Section 508 (n), which specifies the accessibility of electronic forms, increased from 13 to 21 sites. However, violations of these guidelines may not be as critical as one might think. An *in situ* study by Bigham et al. (2007) of 10 blind and 10 sighted users indicated that violating traditional accessibility issues addressed by various Section 508 guidelines, including omitting features such as skip navigation, alt text, headings, and label elements, did not deter blind users from visiting or navigating Web sites. However, when faced with Web sites built with dynamic Web 2.0 technology, such as AJAX and Javascript, blind individuals did avoid visiting these Web sites.

Hackett et al. (2003) found a direct correlation between a Web site’s complexity and its inaccessibility, especially as it has become more common to build more complex Web sites that are more interactive and more aesthetically appealing to sighted users.

Petrie et al. (2004) sought to dispel the notion that accessible Web sites cannot be visually pleasing to sighted users. The participants were 51 users with a variety of disabilities (blind, partially sighted, dyslexic, profoundly deaf, and physically impaired). Each participant evaluated 100 of the most popular Web sites. Their choice of Web sites was determined by Alexa, a tool that uses the aggregated traffic data from sites that Alexa users browse (data is collected anonymously via a browser plug-in) to rank site popularity (Alexa, 2009). The findings showed that some of the Web sites that turned out to be the most accessible had complex visual designs. This indicates that accessibility need not necessarily constrain visual design.

One of the most complete studies of accessibility to date is the one by the UK's Disability Rights Commission (2004), mentioned at the beginning of this section. Of the 1000 UK Web sites in the study, 81% of them failed to comply with WCAG Level A. Web sites in the government sector were more compliant (32%) than those in the business, e-commerce, entertainment, and Web services sectors (15%). Only two sites were Level AA compliant, and no sites were AAA compliant. On average, there were violations of eight unique checkpoints per page, and a total of 108 separate violations per page (checkpoints could have multiple violations). The study also found that fixing the accessibility issues that can be discovered using automated tools is less important than fixing accessibility issues that require human judgment to assess. In fact, when 50 users tested a subset of the 1000 sites, 45% of the problems they experienced did not violate any WCAG guideline. The study concluded that individuals with disabilities *must* be included in Web site testing to provide an accessible site, since automated testing did not help predict the experience of individuals with disabilities when using a Web site.

A number of studies discuss challenges involved with implementing accessibility guidelines, and several suggest alternative guidelines or addendums to the existing guidelines. The study by Andronico et al. (2006a) is perhaps the most complete. They developed eight guidelines for designing accessible search engine user interfaces and then applied these guidelines to the Google home page. To implement the eight guidelines, they removed the tables that had been used for layout and used CSS to organize the page instead. They used <DIV> tags to divide the page into different areas and headings to structure content within the page. They added tab-index and access keys, labeled interface sections and search edit fields, and associated sound icons with certain actions using aural CSS. They then tested the new search interface with 12 blind users (Andronico, Buzzi, Leporini, & Castillo, 2006b). All users preferred the revised interface and commented how easy it was to access the search box and results. 11 of the 12 users felt that the revised interface was easier to use and reduced the time needed to perform a search. Users indicated that the most important accessibility features included the addition of sounds, shortcuts, and visiting order assigned to links, as well as labels on forms and sections of the interface.

Technical Accessibility

Even if a Web site is fully compliant with guidelines such as Section 508 and WCAG, these guidelines only address "technical accessibility," defined as "conforming to accessibility standards" by Coyne and Nielsen (2001). Technical accessibility does not guarantee a usable Web site (Leporini & Paterno, 2004). Kelly et al. (2005) explain that "technical accessibility does not equate to intellectual accessibility… an ALT tag merely names, not explains an image."

Several studies have explored the gap between technical accessibility and usability. For example, Hanson and Richards (2004) considered the two most common problems exposed by the study by the Disability Rights Commission (2004) of 1000 UK

Web sites: (1) unclear and confusing page layout and (2) confusing and disorienting navigation mechanisms. The results indicated that these problems are in fact usability problems and not covered by the WCAG 1.0 guidelines used to measure accessibility. Thus, Hanson and Richards posit that accessibility is merely a *prerequisite* to usability, rather than a guarantee.

Sullivan and Matson (2000) considered the accessibility and usability of the *content* of the most popular 50 sites on the Web, as defined by Alexa (Alexa, 2009). To calculate the accessibility of a Web site, they determined the number of possible points of accessibility failure (for example, if a page contained 100 images, there were 100 possible points of failure for lack of alt text), compared this number to the number of actual points of failure, then normalized the data by multiplying the resulting percentage by the number of possible points of failure. The authors classified highly accessible sites as those with no accessibility issues, medium accessible sites as those with a normalized accessibility score between one and nine, and a site with low accessibility with a normalized score of 11 to 87. 12 sites had fewer than five accessibility issues. The authors then determined the usability of each site using the LIFT automated usability assessment tool (Usablenet, 2008). When they compared accessibility and usability scores, they found a relationship between content accessibility and overall usability, but the statistical significance was borderline. The authors suggest that because a large number of sites ranked poorly in both usability and accessibility, this relationship may arise because Web developers do not give adequate attention to either accessibility or usability.

Leporini and Paterno (2004) focused on identifying the relationships between accessibility and usability and determining how to bridge the fields. To accomplish this, they created criteria for measuring the usability of accessible Web sites. For example, they suggested that while a technically accessible Web site could have distinct link names that can be understood out of context (a Section 508 guideline), an accessible *and* usable site would limit the number of links on a page to a manageable number. These criteria do not appear to be in use outside of this study.

To determine the relationship between accessibility and usability, Petrie and Kheir (2007) tested six blind and six sighted individuals on two Web sites. Users were asked to perform seven tasks on each site; the tasks were identical between the two sites. When individuals encountered a problem, they were asked to pause and rate the problem from one to four using Nielsen's heuristic evaluation scale (Nielsen, 2005). The authors found no correlation between problem severity ratings assigned by users and the problem severity as rated by WCAG priority levels 1, 2, or 3. Only a small subset of the total problems encountered on both Web sites were encountered by both blind and sighted users, leading the authors to conclude that the set of accessibility problems and the set of usability problems are independent, if overlapping. They suggested that in the case of the WCAG guidelines, this mismatch is due to the lack of research into how screen-reader users interact with the Web.

A possible tool for bridging the gap between accessibility and usability is the new WCAG 2.0 guidelines (W3C, 2006). The introduction to the guidelines explicitly states that the guidelines cover usability concerns that have a direct bearing on accessibility. The new guidelines even support specific navigation techniques. For example, navigation by headings is supported by WCAG 2.0 criteria 2.4.1, which states that a mechanism must be available to bypass blocks of content that are repeated on multiple Web units. One way of fulfilling this criterion is to enable navigation by headings by providing appropriate headings for different levels of information. The same criterion also suggests using "skip to content" links, frames used to group similar information types, and structural elements (such as lists) used to group repeated information so that this information can be skipped easily.

Accessibility Awareness Among Web Professionals

In order to create an accessible Web site, Web professionals must understand both accessibility guidelines and how to implement them appropriately. As part of the study by the Disability Rights Commission (2004) researchers surveyed Web developers about their awareness and understanding of accessibility. The survey found that organizations with more than 250 employees had a higher level of accessibility awareness than those with fewer than 250 employees. In larger organizations, 97% of those surveyed were aware of accessibility, 68% said they took accessibility into account when developing a Web site, and 71% claimed to have conducted some form of accessibility testing (the form of testing was not specified). This survey data is surprising, given that 81% of the Web sites in the study failed to comply with even the most basic WCAG guidelines. The study concluded that developers may lack time, resources, knowledge, and guidance to achieve compliance.

Brophy and Craven (2007) summarized several studies that investigated the awareness of accessibility among Web professionals. They concluded that, despite a growing awareness of Web accessibility among Web designers, these individuals may not understand the reasons behind accessibility guidelines, and they may not have the knowledge needed to implement guidelines effectively. Therefore, end users continue to experience problems with accessing information online.

Summary of Making Information Accessible

Although surveys of Web designers indicate widespread awareness of accessibility guidelines such as Section 508 and WCAG, overall Web accessibility remains poor. However, even if more Web sites comply with accessibility guidelines and become "technically accessible," there is no guarantee that these sites would be usable. Therefore, it is important to test Web sites with end users to catch issues not addressed by the guidelines.

Web Navigation Strategies of Screen-Reader Users

Leuthold et al. (2008) assert that blind users navigate in a completely different manner than sighted individuals, that their strategies for accessing information cannot be compared. Unfortunately, the authors do not describe the differences they observed in navigation strategies. The remainder of this section focuses on user experience and other demographic information, accessibility awareness, success rates, time spent on task, Web navigation patterns, being lost, and feeling frustrated. The goal is to understand the hallmarks of a successful screen-reader user.

Success Rate

Success rates in performing an information-finding task are typically measured by whether or not the user completed the task, regardless of whether the task had a time limit. Barnicle (2000) reported that blind individuals who identified themselves as computer professionals self-reported a success rate of about 80%, whereas the self-reported success rate of non-professionals was about 68%. Coyne and Nielsen (2001) found that the success rate for screen-reader users was only 12.5%, whereas the sighted control group was successful 72.8% of the time. (We suspect that the difference in success rates between the Barnicle (2000) study and the Coyne and Nielsen (2001) study are in part because the Barnicle figures were self-reported by survey respondents). Lewis (2004) reported a significant difference in the success rate of visually impaired users compared to those with learning disabilities or no reported disability. For visually impaired users, the success rate was about 70%, whereas the control group, who had no reported disabilities, experienced a 79% success rate. Petrie and Kheir (2007) reported that blind individuals had a significantly lower average success rate than sighted individuals, 50.7% compared to 70.2%.

The study by the Disability Rights Commission (2004) showed that blind users are particularly disadvantaged by a Web site's lack of WCAG 1.0 compliance. These users succeeded in only 53% of the tasks they attempted, compared to user groups with other disabilities, who succeeded in an average of 82% of their tasks. In these results, *all* the blind individuals, regardless of experience, had trouble completing tasks. In a follow-up study where blind users were asked to perform tasks on three highly accessible sites and three sites with low accessibility ratings (based on WCAG 1.0 compliance), blind users completed only 67% of the tasks on the sites with low accessibility ratings, while sighted users were able to complete *all* of the identical tasks on these sites. On sites with high accessibility ratings, both groups of users completed essentially all their tasks.

User Experience or Skill Level

Given the findings that sighted novice and experienced users differ in how they navigate the Web (for example, Holscher & Strube, 2000), it follows that similar differences might exist for novice and experienced screen-reader users. However, because different studies use different measures to determine user experience, it is challenging to compare the outcomes. Hudson et al. (2005) conducted a study that included three experienced screen-reader users and one who had lost her vision only a few months before the study. They reported that the less experienced individual had more difficulty navigating the Web sites used in the experiment than did the other participants, especially when the screen reader presented page content before it presented navigation elements. Barnicle (2000) examined 13 JAWS screen-reader users as they worked with Graphical User Interfaces (GUIs) and identified obstacles these users encountered while using Microsoft Word 97 and Netscape Navigator. Experience was defined as whether the individual claimed to be a “computer professional” or not, but this rating was self-identified. Gerber (2002) notes that an individual’s level of expertise is one factor of their successful use of the Web, but does not define what levels of expertise are needed. She does suggest that individuals who lost their sight before the advent of the Internet are at more of a disadvantage because they must first create a conceptual sense of a Web page. Gerber observes that more experienced users tend to search for specific information rather than browse and suggests this is because searching is less time-consuming and less frustrating. The study by Lazar et al. (2007) included a demographic survey, the results of which suggested that blind computer users, regardless of experience, tend to have a high level of education.

Perhaps the most comprehensive study of the effect of user experience on screen-reader users is that of Murphy et al. (2008). They conducted interviews of 30 blind and partially sighted users to identify problems the users encountered when using the Internet. As part of the demographic information collected, users were asked to self-identify their experience level on a scale from 1-10, with 10 being the most experienced. Individuals who ranked themselves as 7 or above were considered to be more experienced. The authors found that less experienced individuals tended to use computers for personal use such as e-mail and viewing familiar Web sites. These users tended to navigate in a linear manner, line by line, from top to bottom, making it challenging and time-consuming for them to scan pages, get an overview of a page, or locate relevant information. They expressed concerns about getting lost. They had difficulty filling out forms, and expressed worries about the consequences of downloading files. On the other hand, more experienced users tended to use computers for communication, but also performed tasks similar to those of their sighted counterparts, including extensive Web searching, information retrieval, and downloading files. Many of these users had Web programming experience, including creating and maintaining their own Web pages. They used navigation strategies that enabled them to access content quickly, either by speed-reading through a page, using navigation quick-keys, or JAWS commands such as links list or headings list.

Accessibility Awareness

Awareness of accessibility tools and assistive technologies may also play a role in how screen-reader users search for information on the Web. Barry (1998) found that blind respondents who were unaware of the issues and government requirements for accessibility were less successful, more prone to getting lost, took longer to complete a task, and became frustrated more easily. These individuals saw themselves as less confident and less aware of choices and methods for successful computer interactions. Their greatest cause for concern was that it was difficult to recover from errors (for example, choosing a link to unhelpful information), and the consequences of an error could be significant (for example, having to restart from a site's home page). Craven and Brophy (2003) found that expertise using assistive technology impacted how successful individuals were in completing a task, because individuals who knew more advanced screen-reader options had greater control over how they interacted with a page. The Disability Rights Commission study (2004) showed that the 50 participants (who had a range of disabilities, including blindness) in the user testing were often unaware of the accessibility features available in operating systems and browsers. They often did not know how to use the accessibility tools, possibly due to inadequate training with the assistive technology. Individuals also perceived the technologies to be difficult to learn and use, and many individuals did not have the latest version of assistive technologies (such as screen readers) because of cost. We can conclude from these studies that accessibility awareness and user experience with assistive technology may influence navigation behavior as well as successful Web use.

Time Spent on Task

Time spent on task is one of the most commonly reported metrics in accessibility studies, and it is most often compared to the outcomes on the same measure for a sighted control group. For example, Coyne and Nielsen (2001) tested a group of 84 individuals who were blind, had low vision, or who had motor impairments, as well as a control group of 20 users with no disabilities. They focused on identifying Web site design problems that slowed users down, confused them, or caused them to make errors. They found that screen-reader users spent an average of 16 minutes and 46 seconds on task, whereas the control group spent only 7 minutes and 14 seconds (significance was not indicated).

In the NoVA (Non-visual Access to the Digital Library) project (Craven & Brophy, 2003), 20 visually impaired and 20 sighted users performed four information-finding tasks in a digital library environment. Craven and Brophy reported that visually impaired users needed three to five times as long to complete the tasks than sighted users needed. In addition, visually impaired users spent much longer surveying the page before proceeding with a task, although the study did not report whether the difference was statistically significant.

Burgstahler et al. (2004) assessed the usability and accessibility of the Windows XP operating system and its accessibility features. Study participants included eight individuals with visual impairments, six with mobility impairments, and seven older adults. The authors found that individuals with visual impairments spent 41% more time on tasks then did individuals with mobility impairments.

Lewis (2004) tested sighted individuals, visually impaired individuals, and individuals who reported a learning disability on six different University of Texas at Austin Web sites.[4] The study reported that visually-impaired users spent a significantly more time on task compared to those individuals with learning disabilities or no reported disability. The mean time on task for visually impaired users was 4 minutes 27 seconds, while the mean time on task for individuals with a learning disability was 2 minutes 18 seconds, and for those in the control group was 1 minute 59 seconds (significance was not indicated).

In the study by the Disability Rights Commission (2004), both blind and sighted users performed tasks on three accessible and three inaccessible Web sites. The blind users took five times longer than sighted users to complete the tasks on inaccessible Web sites. On sites with high accessibility ratings, blind users took three times as long to complete tasks.

Evans and Douglas (2008) did a comparative analysis of 10 sighted and 10 blind individuals using e-learning materials about sports injuries. The authors found that blind participants took twice as long as sighted participants to complete the learning task. Par of the time for blind participants was spent "accessing" the materials (using a screen reader), something that sighted users did not have to do. Blind participants also spent more time answering quiz questions, which were presented at certain points throughout the e-learning materials.

---

[4] The data set used for Lewis (2004) is the same data set used for this study, but it includes all 32 participants instead of just the screen-reader users.

Strain et al. (2007) address one concern with measuring time on task—that of using the think-aloud protocol during testing. Because of cognitive limitations, many people have a difficult time talking and listening at the same time. For screen-reader users, this means they must stop the screen reader in order to talk to the testing observer. This increases the time spent on task, sometimes considerably. The authors identified three different methods of using the think-aloud protocol with screen-reader users:

- Synchronized Concurrent Think-Aloud – the user might interrupt the screen reader in the middle of an interaction to discuss their thought process.
- Traditional Retrospective Think-Aloud – the user completes the task and then discusses the experience afterwards.
- Modified Stimulated Retrospective Think-Aloud – the user completes the task, then slowly walks back through it, explaining his or her thought process to the observer.

The authors advise that researchers using think-aloud protocols with screen-reader users must understand the challenges presented by concurrent talking and listening.

These studies consistently report that it takes longer for visually impaired individuals to complete Web tasks than it does for sighted individuals. However, instead of comparing screen-reader users and sighted users, we need to compare screen-reader users amongst themselves to explore what actions contribute to the amount of time spent on task. This difference in task completion times among screen-reader users may be dependent on individual characteristics and navigation behaviors, but more research is needed to understand exactly what factors are the primary influences for this metric. In addition, the think-aloud protocol should be used with care, since using it may serve to further increase the time spent on task during a testing scenario.

Web Navigation Techniques

A number of accessibility studies have noted different search and navigation techniques of visually impaired users. Barry (1998) suggested that experienced screen-reader users use a combination of informed guesses and a methodical approach to navigate the Web. Barnicle (2000) reported that individuals who identified themselves as computer non-professionals listened to approximately 30% more menu items during one set of tasks and 40% more in another. Malone (2003) reported that there was no one consistent pattern and no one clear method that worked better than any other method—the method varied from person to person. In fact, the author noted that, “results were surprising in their inconsistency.”

Gerber (2002) observed that individuals tend to use one of two different techniques when navigating a Web site: scrolling or searching. Scrolling occurs when the user listens to the entire page, or scrolls through the page using arrow keys, jumping from link to link, or other similar strategies. Searching, on the other hand, involves the user actively mining for the information they need. Gerber proposed that an individual’s temperament, experience with the site, time available, and level of expertise all contribute to the technique they use to navigate.

Theofanos and Redish (2003) carried out a study of 16 screen-reader users, 13 of whom used JAWS and three of whom used Windows-eyes. Their observations of screen-reader users “scanning with their ears” resembles Gerber’s (2002) description of users “scrolling” and listening to an entire page. In addition, they noted that many users do not know or use all of the features of the software, which is not surprising given the rich feature set of the most popular screen readers. Many of the users in this study mentioned that they wanted to skip past the repetitive information on the page (that is, the global navigation) but did not do so. The authors also observed many users jumping from link to link or using a Links List box to navigate. Finally, the authors noted that some screen-reader users jumped from heading to heading, possibly to get an outline view of a Web page.

Craven and Brophy (2003) reported that visually impaired individuals used about 16 different keyboard commands on average per task, whereas sighted individuals only used about six. Visually impaired individuals in this study took twice as many steps to complete a task and reported feeling "lost" more often. Although individuals moved from page to page in a similar manner, there were significant differences in how sighted and visually impaired users moved around within a page. Craven and Brophy also reported that experienced screen-reader users used the Links List, Sort Alphabetically, and Search in Page functions, which reduced the time spent browsing.

Hudson et al. (2005) noted that the experienced JAWS users did not use the Skip Links navigation option, which can be added to Web pages using HTML. All four of the participants in their study employed different strategies and screen-reader techniques when using the Web sites; unfortunately the authors do not describe these strategies. In a follow-up survey, five respondents reported using Skip Links, and eight reported using headings for navigation.

The study by Andronico et al. (2006a) included a survey for both sighted and blind users about their Internet search habits. These researchers found that only 15% of the blind users in their study explored more than 2 pages of search results, and 80% of blind users reported viewing only the first two search results. 46% of the blind users reported having difficulty reading the search results, and 38% reported finding useful information only "some of the time."

Bigham et al. (2007) presented an *in situ* study that tracked how 10 blind and 10 sighted individuals used the Web for a one-week period using the Web-proxy tool

UsaProxy. The authors found that the blind individuals spent significantly more time (on average) on each page than did sighted users. The blind participants frequently visited pages that had inaccessible elements – for example, only 53% of the pages that they visited contained headings, and only 41% contained label elements. Blind users were less likely to visit pages with dynamic content, Flash content, or pages that used AJAX. The blind participants only followed available Skip Links about 5% of the time, suggesting that these individuals used other techniques to skip to content. They were more likely to click on images that contained alt text than on those that did not.

Because several studies have noted that screen-reader users use headings to navigate, Watanabe (2007) studied the effectiveness of properly marking up a Web site with headings, using the tags h1-h4, which is one way to meet WCAG 2.0 success criteria 1.3.1. He found that task completion time was reduced up to 50% for the four blind subjects when proper HTML markup was used for heading elements. On sites that did not use proper HTML markup, blind users needed about three times as long to complete tasks. User satisfaction was also higher for the sites that used proper HTML heading markup.

Petrie and Kheir (2007) found that sighted individuals visited an average of 5 more distinct pages than did blind individuals, and made more page visits as well. The authors suggest that this is because sighted users spend less time looking for information on a page but view more pages, whereas blind users spend more time on fewer pages and are less likely to return to a page.

While outside the scope of their study, Leuthold et al. (2008) suggest that blind individuals do not use trial and error to navigate because moving back and forth between Web pages to explore requires too much effort. They also suggest that it takes too much time to return to the same point once a blind user has moved in the wrong direction.

However, Bigham et al. (2007) suggest that blind users tend to “probe”—that is, leave a page and then quickly return as a method of exploration—significantly more than their sighted counterparts. The authors suggest this behavior is due to lack of context.

A recent study by WebAIM (2009) surveyed 1121 screen-reader users (including a few individuals who were not visually impaired but used screen readers for accessibility testing purposes) about their preferences. The authors found that when encountering the home page of a Web site for the first time, 46% of the individuals surveyed read through the home page, while 35% navigated through or listened to the links. Interestingly, more proficient individuals (proficiency was self-reported) were more likely to read through the home page than less proficient individuals. 76% of individuals surveyed said that they always or often navigated by headings, and over 50% reported using site search always or often when it was available. Survey respondents reported avoided Flash-based sites, social networking sites such as MySpace and Facebook, new sites, and shopping sites due to accessibility issues. The authors conclude that there are no typical screen-reader users, but accommodating the needs of this diverse group of users is important.

Making Mistakes, Feeling ‘Lost,’ and Being Frustrated

In several studies, screen-reader users have mentioned that they fear making a navigation mistake (for example, Barry, 1998; Coyne & Nielsen, 2001; Craven & Brophy, 2003). Some researchers have reported that making mistakes can lead the searcher to backtrack, encounter impasses, and feel “lost”. The study reported by Barry (1998) explored the perceptions, experiences, and ideas of Web use of visually impaired students and staff at the Royal National College for the Blind in England. Interviews with seven students and three staff members suggested that more experienced users tended to be more confident that mistakes could be corrected, and that these participants used a combination of informed guesses and a methodical approach for navigation. Coyne and Nielsen (2001) reported that screen-reader users encountered an average of 2.0 errors, while the sighted control group encountered an average of only 0.6 errors. Gerber (2002) observed that blind users tended to revisit the same sites over and over again once they had become familiar with the sites, and that these users seemed to rely on memory rather than navigation to get around a site. Presumably, once an individual is thoroughly familiar with a site, they are less likely to make mistakes navigating. Craven and Brophy (2003) found that visually-impaired users reported feeling "lost" more often than did sighted users. Petrie and Kheir (2007) found that the blind users encountered significantly more problems than did the sighted users. Murphy et al. (2008) reported that less experienced screen-reader users tended to be more concerned about getting lost and also preferred to visit familiar Web sites, or sites that had been recommended to them, perhaps to avoid becoming lost.

Being lost can result in feeling frustrated. Lazar et al. (2007) used time diaries to explore frustration experienced by screen-reader users. They found the top reason for users becoming frustrated was a sense of lostness, due to confusing page layout, poorly designed or unlabeled forms, and problems with the assistive technology. Other frustrations included no alt text for images, misleading links, inaccessible PDFs, and screen readers crashing. Over 30% of the time spent at the computer was unproductive due to frustrating experiences. Participants in the study by Murphy et al. (2008) also reported that navigating the Web was a frustrating experience.

Top Navigation Challenges

Several studies have reported specific issues that screen-reader users encounter that are due to poor HTML coding or a badly designed information architecture. In a survey performed by Strain et al. (2007), screen-reader users reported that the top navigation challenges included unlabeled images, unclear navigation, and Flash-based websites. Bigham et al. (2007) reported that screen-reader users in their study tended to avoid pages with dynamic content, including AJAX and Flash. Lazar et al. (2007) discussed the difficulties that screen-reader users can encounter during Web navigation, especially when standard navigational components have been disabled, Web pages have been encoded to automatically refresh, or pop-up windows occur. Murphy et al. (2008) reported that users found pages with large numbers of links to be confusing, and that they found repetitive content annoying. Some users even mentioned navigating from the bottom up to avoid repetitive content. Users had difficulty filling out forms, especially if the form fields were improperly labeled. Other troublesome Web elements for the screen-reader users in this study were combo-boxes, Flash, JavaScript (especially pages that automatically refreshed), and embedded files.

Summary of Web Navigation Strategies of Screen-Reader Users

These studies build a general profile of screen-reader users. Screen-reader users may use a “scrolling” navigation technique, where they listen to large sections of the page, or they may use a “searching” technique, where they actively look for information on the page. Screen-reader users may “probe” an unknown page to determine its usefulness. They probably do not use Skip Links to bypass repetitive information on a page, but instead use other functions available in the screen-reader, including Headings List and Links List. This results in very individualistic and varied navigation techniques. These users tend to make mistakes more often than do sighted users, and may have difficulty recovering from their mistakes. Screen-reader users also report frequently feeling lost within a Web site. Finally, one of the greatest accessibility challenges faced by screen-reader users appears to be pages with dynamic content, although more traditional accessibility issues also affect these users.

Individual Differences

Since Nielsen's (1989) landmark study that found that individual differences play the largest role in successful learning in a hypermedia environment, many studies on sighted users have focused on determining exactly what differences affect success, and how. Although many types of individual differences have been studied in the sighted population, here we focus on cognitive and learning styles, spatial ability, and mental representations, because Dillon and Jobst (2005) suggested that these factors are the most influential in predicting successful hypermedia experiences in sighted individuals.

Cognitive and Learning Styles

Approximately 40 percent of humans are visual learners (as opposed to haptic or auditory learners) (Dunn & Dunn, 1979), and sighted humans can process huge amounts of visual information very rapidly. While visual interfaces may put visually impaired users at a disadvantage because of the need for alternate interaction methods, these interfaces may also put non-visual learners (whether visually impaired or sighted) at a disadvantage at a cognitive level.

There are a number of established tools for assessing cognitive and learning style for the sighted population, such as Kolb's Learning Style Inventory (Kolb, 1984), the Visualizer/Verbalizer Questionnaire by Kirby (1988), the Edmonds Learning Style Identification Exercise (Reinert, 1976), and Riding's Cognitive Styles Analysis (Riding, 1991, 1998). These assessments have not been used with visually impaired subjects, and certain elements of the tests may be inappropriate for some visually impaired individuals.

For example, congenitally blind subjects would presumably have little or no context for answering questions about color.

One test for cognitive and learning styles, the Group Embedded Figures Test (GEFT), has been adapted for visually impaired users. The GEFT divides learners into field independent and field dependent categories. According to Witkin et al. (1971), field independence/dependence is “the extent to which the organization of the prevailing field dominates perception of any of its parts” (p. 7). Field independent learners are good at finding simple figures within more complex ones, which may be helpful in a Web navigation situation since these individuals should, in theory, be better able to distinguish important information from background “noise.”

Witkin (1968; 1971) developed tactile and auditory embedded figures tests to assess field independence/dependence in the visually impaired. He then used these tests to investigate whether congenitally blind children were more field dependent than sighted children. He hypothesized that a congenitally blind child’s experiences would be more field dependent because of their lack of vision. Witkin found that, when compared to sighted individuals, visually impaired students did not perform as well on the tactile embedded figures tests. He suggested that this indicated that visually impaired individuals were more field dependent. However, on the auditory embedded figures test, visually impaired individuals performed significantly better than sighted individuals. Witkin, despite some difficulties with his study, concluded that visually impaired individuals are more field dependent than sighted individuals.

If Witkin is correct, the field dependence in visually impaired users may affect their information seeking on the Web. Unfortunately, no studies have focused on the cognitive styles of visually impaired individuals and how they navigate on the Web; instead, we must turn to studies of sighted users and their navigation habits based on cognitive style. Although there are many tools that analyze cognitive and learning styles, we focus on studies that use the GEFT so that to allow comparison of the results with Witkin's (1971) findings.

Palmquist and Kim (2000) used the GEFT with 48 sighted undergraduate students to determine field dependence and also asked for their level of online experience. the researchers then asked the students to locate information on a university Web site. They reported a significant effect for field dependence, but only for those individuals with little or no online experience. As experience level increased, cognitive style ceased to correlate with navigation success.

Using the GEFT, Chou and Lin (1998) tested 121 sighted students at a Taiwanese university to see if cognitive style affected searching, attitude, or cognitive map development while using a hypermedia entitled "Introduction to Computer Networks." Cognitive style did not affect students' search efficiency, the number of search steps used, or their ability to complete the search task. However, field-independent students were better able to estimate the number of nodes in the hypermedia, and they scored significantly better on the cognitive mapping test, showing that they were better able to reconstruct relationships between nodes in the hypermedia.

Parkinson and Redmond (2002) used the GEFT (along with several other cognitive tests) to determine the cognitive styles of 47 sighted final-year undergraduate Information Science students, and then had the students complete a six-hour online Introduction to Artificial Intelligence course. Only field dependence/independence was found to have any interaction with overall learning performance, and field independent learners performed better overall. Field independent learners also performed better using the Internet version of the course than using the CD-ROM or Text version of the course.

Kim (2001) studied the effects of cognitive styles, as determined by the GEFT, and online search experience on search performance and Web navigation patterns in 48 sighted undergraduate students. The results showed that field dependent individuals with little online search experience navigated in a fairly linear mode, navigated more nodes, and returned to the home page more often. However, as field dependent individuals gained more online search experience, their navigation styles changed to resemble that of field independent users.

Chen and Macredie (2002) reviewed a number of studies that focused on field dependence and hypermedia learning and navigation. They found that sighted field dependent users tended to prefer linear pathways and follow a sequence from beginning to end. These users also tended to use the Home or Back button when navigating. Field independent individuals, on the other hand, tended to do better with information searching tasks, using search engines, the Find option, and URLs.

In these studies of sighted users, in hypermedia learning and Web navigation situations, field independent individuals tended to have better outcomes than did individuals who were field dependent. However, experienced field dependent individuals showed characteristics similar to field independent individuals and were similarly successful. In addition, field dependent individuals tended to follow linear pathways and used the Home and Back buttons when navigating, whereas field independent individuals tended to use search engines, the Find command, and typing URLs to navigate.

Because experience may compensate for field dependence when navigating the Web, we would not be able to use navigation style to predict the field independence or dependence of screen-reader users. However, screen-reader users may exhibit other traits, such as requiring more context, that could provide clues about their learning style since we cannot test for it using traditional tools such as the GEFT.

Spatial Ability

Research on sighted users over the past 25 years has shown that a user's spatial ability is a strong predictor of their potential for success with a variety of user interfaces. For example, Egan and Gomez (1985) determined that age and spatial memory were the best predictors of how well an individual would learn to use a text editor, and Gagnon (1985) showed that successful computer gaming correlated with spatial memory test scores. Studies by Vicente, Hayes et al. (1987) and Leitheiser and Munro (1995) also found that spatial ability predicted performance in hierarchical file browsing and file management tasks. On the other hand, research by Jones and Dumais (1986) demonstrated that users were better able to retrieve information using semantic labels rather than spatial organization information, and that combining semantic and spatial organization techniques improved performance most. Nilsson and Mayer (2002) found that individuals with highly developed spatial skills were able to navigate more efficiently in hypertext learning situations. Dillon and Jobst (2005) discovered that, in multimedia learning and interaction, spatial ability may be a predictor of measures of success, including navigation performance.

In order to leverage computer users' spatial abilities, many GUIs base their designs on spatial metaphors, such as a desktop, a file folder, or a street. These metaphors are intended to give users something familiar to relate to from the physical world, help them locate objects, and provide navigational waypoints (refer to Boechler, 2001). In addition, providing metaphors may help reduce disorientation that both sighted and visually impaired users describe both in GUIs (for example, Craven & Brophy, 2003; Nielsen, 1989) and in auditory-only interfaces (Barnicle, 2000; Craven & Brophy, 2003; Mynatt & Edwards, 1992; Wolf, Koved, & Kunzinger, 1995).

Several studies have demonstrated that spatial metaphors can support users in improved navigation and successful information finding. For example, Padovani and Landsdale (2003) tested sighted individuals performing an information-finding task using both spatial and non-spatial metaphors. They found that sighted individuals using the spatial metaphor performed better in the information-finding. A study by Mayes (1998) demonstrated that sighted people using a graphical interface appeared to use their memories of the spatial positioning of objects within the interface to help them navigate. Robertson (1997) showed that the navigation success of individuals with low spatial abilities was improved by providing a visual tool that demonstrated the layout of the information space. Conversely, in a study by Allen (1998), individuals with high spatial abilities were negatively affected by organizing information spatially. Hook and Dahlback (1997) found that people with high spatial abilities could visualize the organization of information better than those with low spatial abilities.

Since spatial skills have been found to be beneficial to sighted individuals in an environment based on spatial metaphors, we must ask whether these skills are also beneficial to a screen-reader users when navigating an online information space. However, there are no tools available to assess the spatial skills of blind individuals, because existing spatial skills tests have a visual component. Only the Stanford Multi-Modality Imagery Test has been used to assess visually impaired individuals in mobility and orientation training (Dauterman, 1972). Most research on blind individuals navigating in physical space (Jacobson, 1998; Kamel, Roth, & Rashimi, 2001; Schneider & Strothotte, 2000) does not assess spatial skills, and in general, research on wayfinding in physical spaces focuses on the types of mental or cognitive maps individuals build of the area or route in question.

It is not clear that using visual and spatial tools, such as visual metaphors, to demonstrate the layout of an information space is applicable to blind individuals, since individuals with severe visual impairments typically rely on sequential information gathered using tactile, kinesthetic, or auditory senses to create spatial knowledge (Bigelow, 1996). Gerber (2002) suggests that congenitally blind individuals may rely entirely on these experiences, whereas adventitiously blind individuals may use the knowledge gained before they became blind. In fact, for most of the 20th century, it was widely thought that individuals with severe visual impairments experienced the world in a way that is spatially different from those who are sighted (Gollege, 1999). This was because of one of three competing limitation theories for blind individuals:

- Deficiency theory – the spatial skills of blind individuals are deficient compared to those of sighted people. Vision is *essential* to developing a spatial schema of the world; tactile information is not enough to comprehend spatiality.
- Inefficiency theory – the spatial abilities of congenitally blind individuals is underdeveloped compared to sighted and adventitiously blind individuals. Although the *potential* for spatial knowledge is comparable to sighted individuals, because tactile and auditory information must be processed differently than visual information, the resulting spatial knowledge is less effective.
- Difference theory – spatial abilities and knowledge for blind individuals are different than for sighted individuals. Spatial representations may be functionally equivalent, but are created differently and contain different information.

In the past decade, several studies have suggested that these three theories are incorrect, and that the spatial abilities of visually impaired and sighted individuals are equivalent (Golledge, 1999; Jacobson, 1998). If this is the case, then perhaps results regarding the spatial abilities of sighted users can be applied to better understand how spatial abilities affect the navigation behaviors of visually impaired individuals.

If spatial skills are equivalent between sighted and blind individuals (an assumption that must be tested), then we must ask in what other ways these two groups differ that would affect their navigation and information seeking behaviors. The study by Bradley and Dunlop (2002) suggests that these groups differ in the *type* of information needed while navigating in physical space. Bradley and Dunlop interviewed six visually impaired individuals and asked them to describe how to reach a particular location on foot. They found the following categories of contextual information described by the interviewees:

- Directional (right/left, north/south)
- Structural (road, monument, etc)
- Textual-structural (Border's bookshop, Graeve Sports)
- Textual-area/street based (e.g. George Square)
- Environmental (hill, river, tree)
- Numerical (first, second, 100m)
- Descriptive (steep, tall)
- Temporal/distance based (e.g. walk until you reach…)
- Sensory (the sound of the go-kart engines or the smell of hops near a brewery)
- Motion (cars passing, doors opening)
- Social contact (asking someone for directions)

Bradley and Dunlop found that visually impaired individuals used three times more directional information, seven times more structural and environmental information, six times more numerical information, and nine times more descriptive information. The visually-impaired individuals also used a greater number of categories to describe routes than did sighted users (an average of 9.75 categories compared to 6.33 categories). The study showed that each person's descriptions were unique and tailored to his or her needs. The authors concluded that directions for people with visual impairments should include more structural and descriptive information, instead of directional, numerical, and textual information, which is more tailored for sighted individuals.

From our review, it appears that the spatial skills of sighted and visually impaired individuals may be similar, although more research is needed to confirm this. However, if we consider Bradley and Dunlop's (2002) study, the key way in which these two groups differ in their navigational styles in physical space is in the information they need to navigate. While sighted individuals needed minimal directional, numerical, and textual information, visually impaired individuals needed structural and descriptive information, and their descriptions of a route tended to be elaborate and informative. Thus, visually impaired individuals may need a different type of information when navigating in either physical or virtual space. We need to explore how information and information structure on Web pages supports the information-finding needs of screen-reader users.

Mental Representations

Craik (1943) suggested that the mind constructs "small-scale models" of the world that it then uses to reason, provide explanations, and anticipate events. Some researchers argue that people create mental models or representations of their environment that include information about how and why things work within that environment (for example, Johnson-Laird, 1983; Norman, 1983). Representations are often fragmentary and contextually dependent (C. Lewis, 1986), and users may have different representations for different purposes, or even several representations of the same device, especially if it is complex. The interpretation of these models can specify how users will interact with the system, and if the model has incorrect elements, this may lead individuals to have more difficulty using the system. Borgman (1984) attempted to help users build good mental representations of interactions with an information seeking system on the theory that an accurate mental representation would improve the user's understanding of the system, thereby making it easier to use. However, Borgman's theory was later challenged, and subsequent studies (such as O'Malley & Draper, 1992) indicated that mental representations were not necessary for interacting with computer systems.

As Donker et al. (2002) suggests, there is some question as to whether blind individuals, especially those who are congenitally blind, create different mental representations than do sighted individuals, especially when processing spatial information such as that found on the Web. The interviewees in Jobst's (2005) study describe a Web page in a linear manner: generally they hear a big list of links first (the global and left navigation), followed by the content, and finally (if they listen long enough), another (usually smaller) list of links at the end (footer links). The CoLiDeS model (Blackmon, Polson, Kitajima, & Lewis, 2002), however, suggests that sighted users break a Web page into blocks of information based on visual groupings. These studies indicate that there may indeed be a difference in the mental representations created by different user groups.

It is possible that different life experiences, such as the inability to see an object's spatial orientation, combined with auditory and haptic information, may induce the brain to create a mental representation based on these experiences. However, if a good mental representation is not necessarily critical to successfully interacting with computer systems, this area of study may be less important than others for determining how screen-reader users navigate the Web.

CONCLUSIONS FOR SCREEN-READER USERS

This review of the literature leads to a tentative profile of the Web navigation patterns of screen-reader users in comparison to sighted individuals. Screen-reader users tend to be less successful, spend more time on task, and make more navigation mistakes. Screen-reader users who have more experience and are more aware of accessibility show more willingness to take navigation risks and seem to believe that they can successfully recover if they make a mistake; they also tend to be more successful overall. Finally, researchers consistently report that screen-reader users follow a variety of navigation behaviors to navigate the Web. Experienced individuals seem to use functions such as Links List and Headings List, although Skip Links, a Section 508 requirement, does not seem to be widely used. More research is needed to better understand specific Web navigation behaviors used by screen-reader users.

When considering individual differences among visually-impaired users and how these differences compare with sighted users, there is very little relevant research in the areas of learning and cognitive styles, spatial skills, and mental representations for blind users. The primary reason for this is that the tools that have been developed for analyzing these individual differences in sighted individuals generally cannot be used with visually-impaired individuals. A theory about the visually impaired must therefore arise from other fields of research. For example, we know that sighted field dependent individuals have more difficulty navigating in hyperspace, especially those who have little experience. A single study (Witkin et al., 1971) has shown that visually impaired individuals may be more field dependent; thus, some visually impaired individuals (especially those with less experience) may be at a disadvantage when navigating the Web because of their field dependence, and because of this may tend to navigate more linearly.

Similarities between sighted individuals and screen-reader users with regards to spatial skills and mental representations are even less clear. Both sighted and visually impaired individuals are thought to have similar spatial skills, but how spatial skills come into play in a non-visual environment is unknown. There is also some question as to whether spatial information is even needed by visually-impaired individuals when navigating online, with the implication that the question of spatial skills may be of little importance. The importance of good mental representations is apparently minimal for sighted individuals to navigate successfully online, yet descriptions of mental representations of sighted and visually impaired individuals are quite varied. It also seems that the type of information needed by these two user groups to navigate virtual and physical spaces is quite different.

3. Research Questions

We now use the tentative profile of the Web navigation patterns of screen-reader users that we created in the literature review to guide our research questions. The existing research on screen-reader users provides hints about some of the information structure that is important to successful Web navigation, but to truly understand the navigation techniques of screen-reader users, we need to answer the following questions:

- What navigation techniques do screen-reader users use to navigate the Web, and how can these navigation techniques be defined?
- Does user experience affect navigation techniques or success for screen-reader users, and if so, how?
- Are information-seeking techniques for screen-reader users similar to those used by sighted individuals?
- Does compliance with Section 508 guidelines improve the overall success in an information-finding task for screen-reader users?

In this dissertation, we focus on addressing these questions.

4. Hypotheses

To investigate the questions put forth in the previous section, we have developed four hypotheses, as presented in the remainder of this section.

> **Hypothesis I:** For screen-reader users, user experience will affect successful task completion, as well as successful navigation techniques (as defined by quantitative measures).

We hypothesize that user experience will not only play a role in the successful completion of tasks, but will also affect the navigation techniques a user selects to complete tasks. Less experienced users will tend to use scrolling techniques more frequently (Gerber, 2002), browse (listen to) more information on the page, and encounter impasses (situations that impede forward progress toward the information goal) more frequently (Murphy et al., 2008). More experienced users will use searching techniques more frequently (Gerber, 2002), and will be more likely to successfully overcome any impasses they encounter (Murphy et al., 2008).

> **Hypothesis II:** The Web navigation techniques of screen-reader users across Web sites will be similar to those in models developed for sighted users.

We hypothesize that screen-reader users will follow links less often and will use the back button less frequently than observed for sighted users (Catledge & Pitkow, 1995; Kari, 2004), primarily because the majority of the navigation actions for screen-reader users will be within pages rather than between pages. We also hypothesize that screen-reader users (especially experienced screen-reader users) will carry out more searching tasks than what Kari (2004) reports for sighted users.

We hypothesize that both novice and experienced users will better fit Herder and Juvina's (2004) description of flimsy navigation than they fit Herder and Juvina's description of laborious navigation, for several reasons. Because of the scenario-based lab setting, we expect users to do minimal exploration of sites (Murphy et al., 2008), resulting in a small number of pages visited overall (this is contrary to Bigham et al. (2007)). In addition, because it can be difficult for screen-reader users (especially novices) to recover from a mistake (for example, Barry, 1998), we expect these individuals to use the back button infrequently, to visit the home page infrequently, and to have relatively low overall page revisitation and page-return rates, unless the user encounters a problem.

> **Hypothesis III:** Screen-reader users will employ a variety of Web navigation techniques that can be described by both qualitative and quantitative measures.

We will use grounded theory (Glaser, 1995, 1998) to analyze the users' comments from the think-aloud protocol and from the post-task survey interview performed at the end of each Web experience. Because grounded theory is explicitly *not* for hypothesis testing, but rather for discovering emergent theory based on the situation and the individuals involved, we do not include as part of this hypothesis a prediction about what this theory might be. However, we will use the grounded theory analysis techniques to develop categories and sub-categories (properties) that we anticipate will inform an emergent theory. We will compare this theory with existing literature on screen-reader users to explore similarities and differences.

> **Hypothesis IV**: When using a Web site that is Section 508 compliant, screen-reader users will demonstrate a higher overall success rate, spend less time searching for the information goal, incur fewer impasses, use fewer actions, and report a more satisfying user experience than when using a Web site that is not Section 508 compliant.

We hypothesize that for Web sites that are Section 508 compliant, users will have a higher task completion rate (Disability Rights Commission, 2004), spend less time searching for the information goal (Disability Rights Commission, 2004), and will use fewer navigation actions to reach the information goal. In addition, we hypothesize that users will report a more satisfying experience when using Web sites that are Section 508 compliant.

5. Methods

In this section, we describe the methods we used to gather and process the data for this dissertation.

IDENTIFYING THE FOCUS WEB SITES

In 2002, the Accessibility Institute at the University of Texas at Austin evaluated 407 university Web sites' home pages for Section 508 compliance (Slatin, Lewis, Liaw, & Burt, 2002) using both automated and manual checks. From this group of 407 Web sites, we chose three of the most accessible and three of the least accessible Web sites for what we refer to as the in-depth study. We chose these sites because their content could be seen as relevant to a wide audience. The sites and scenarios/tasks used during the study are shown in Table 2.

Web Site (Abbreviation)	URL	Scenario/Task	Section 508 Compliant Home Page?
Department of French and Italian (F&I)	www.utexas.edu/cola/ depts/frenchitalian/	Find out if an Italian graduate program is available.	Yes
Center for Lifelong Engineering Education (LENG)	lifelong.engr.utexas.edu	Find a class on software programming that costs less than $500.	No
Texas Memorial Museum (TMM)	www.utexas.edu/tmm	Determine how much parking costs on the weekends.	Yes
University Extension Evening Credit Courses (UEX)	www.utexas.edu/cee/uex/	Find a class in computer programming that you can take in Fall 2003.	Yes
LBJ Library and Museum (LBJ)	www.lbjlib.utexas.edu	Determine when LBJ got married.	No
StarDate (SD)	stardate.org	Find a radio program about Skylab.	No

Table 2: Web sites and scenarios used in the study

The exact scenarios read aloud by the observer for testing purposes can be found in Appendix D. Screen shots of each Web site's home page can be found in Appendix H.

THE PARTICIPANTS

The in-depth study involved 32 individuals with a variety of disabilities, including visual, hearing, mobility, and cognitive impairments. All participants were recruited from among students and faculty at The University of Texas at Austin. Of the 32 participants, four were screen-reader users; these four individuals are the focus of this dissertation. The four participants were college-educated (one Ph.D., one Ph.D. candidate, one Master's student, and one undergraduate student), ranged in age from 21-50 years, and included three men and one woman. Three of the users were either blind or significantly visually impaired and used JAWS exclusively. The fourth user (#31) used JAWS extensively but occasionally used his very limited vision.

In accessibility studies, it is common to consider only a small number of users. The majority of studies reviewed have at most ten participants (for example, Bigham et al., 2007; Byerley & Chambers, 2002; Evans & Douglas, 2008; Hudson et al., 2005; Malone, 2004; Petrie & Kheir, 2007), a few have between 11 and 20 individuals (Andronico, Buzzi, Leporini et al., 2006; Coyne & Nielsen, 2001; Craven & Brophy, 2003; Theofanos & Redish, 2003), and only two studies had more than 20 participants (Leuthold et al., 2008; Murphy et al., 2008). Because of the exploratory nature of this dissertation, as well as the in-depth nature of the data analysis methods, a smaller group of users was desirable.

THE PROCEDURE

All testing was performed at the Accessibility Institute at The University of Texas at Austin. Once the participant had arrived for the testing session, he or she was shown around the testing facility. The observer explained the purpose of the study, reiterated that it was voluntary, and asked the individual to sign a release form because sessions were being videotaped. Participants were then asked to complete a demographic survey. For screen-reader users, the survey questions were read aloud by the observer and the participant's responses were written down. Finally, participants were invited to adjust

JAWS according to his or her preferences (several users increased the speech speed of JAWS).

Once the participant had completed the pre-test tasks, the observer asked the participant to enter the URL of one of the six Web sites (site order was randomly selected for each participant) and asked the participant if he or she had ever visited the site before. Only one participant had visited one site, and it was several years before this study. The observer then read the first scenario aloud, asked the participant if he or she had any questions, and asked the participant to begin. Although there were a total of six Web sites, and each Web site had three scenarios, the total number of Web sites visited and scenarios attempted depended on the time the participant required to complete each scenario. Only the data for the first scenario for each Web site was analyzed. Testing sessions were no more than two hours in total length.

Each participant was asked to complete scenarios on as many of the six Web sites as time allowed. After each Web site, participants completed a short post-task satisfaction survey, which was again read aloud by the observer. At the end of the testing session, participants were given a cash incentive for their time.

THE INSTRUMENTS

We used four data collection methods in this study:

- Survey of demographic information (refer to Appendix J).
- Videotape of users performing information-finding tasks on up to six Web sites (screen shots of the home pages for each Web site are available in Appendix H).
    - Participants were asked to think aloud while performing the information-finding tasks. Coyne and Nielsen (2001) noted the most useful information gathered in their accessibility study was from user's think-aloud

comments, and several other accessibility studies have used this technique as well (Burgstahler et al., 2004; Craven & Brophy, 2003). The transcripts of participant's think-aloud comments are available in Appendix E.

- Post-test survey of user satisfaction for each Web site for which they completed the tasks (Coyne & Nielsen, 2001; Craven & Brophy, 2003). For screen-reader users, this survey was read aloud and the user's answers written down by the observer (refer to Appendix B for the exact wording of the survey and to Appendix E for a transcript of participant comments).
- Section 508 compliance rating of the six Web sites' home pages. Web sites' home pages were either Section 508 compliant or not (refer to Appendix C for a detailed description of each site's Section 508 compliance rating).

PROCESSING

Once the initial data was collected, we transcribed the user's (and observer's) think-aloud comments from the videos, as well as any comments the user made during the interview to fill out the post-task questionnaire at the end of each Web experience. Working with another researcher at the Accessibility Institute, Dr. Kay Lewis[5], we created logs of each user's keyboard actions by watching the videos. The resulting *action transcripts* included each action the user performed during their search for the information goal. Craven and Brophy (2003) also used this action transcription technique rather than keystroke logging software because the latter can interfere with screen-reader functionality. One problem that we encountered with this technique of logging user actions is that participants frequently used the same keystroke repeatedly, often very quickly and for extended periods of time. This made it challenging to determine how

[5] Dr. Kay Lewis was a research associate at the Accessibility Institute and ran the original 32-participant study. She assisted with creating and verifying the action transcripts for this study.

many times a particular keystroke was used; therefore, these repeated actions were logged as a single action so that each action can be interpreted as composite distinct actions. We recorded the time each user spent searching for the information goal and whether or not the information-finding task was successfully completed.

6. Data Analysis

In this section, we first overview the metrics used to analyze the data we collected. We then show the calculations (where appropriate) and calculated values for the metric associated with each hypothesis.

DEFINING METRICS

The small number of participants in the study limits the options for analysis approaches. We use descriptive metrics to develop a picture of how the four participants navigated the Web and how a Web site's compliance with Section 508 affected the use of that site. For most metrics, we calculate values both on a per-user basis and a per-Web site basis. We introduce a notation to make each calculated value easier to track.

For some hypotheses, users are ranked based on the values of a particular metric. Using rank order allows us to more easily compare performance; however, because using an interval ranking scale from 1-4 would reduce the fidelity of the data, we normalize each metric by converting to a 100-point scale, then rank individuals based on this normalized value. In calculations, a particular individual's rank order for metric M is denoted as **Rank[M]**.

Time Spent Searching for the Information Goal

We define *time spent searching for the information goal* as the amount of time the user spent on a single Web site navigating toward the information goal. The time is measured from the moment the user began navigating (after the observer had read the scenario and identified the information goal) to the moment the user either (1) identified the information goal based on the information found on the Web site, or (2) said they could not find the information goal and wanted to abandon that task. These metrics, all of which are expressed in seconds, include:

- **$\text{Time}_{\text{total}}$ –** For each user, the total number of seconds spent navigating toward the information goal for a particular Web site.
- **$\text{Time}_{\text{avg user}}$** – For each user, the sum of **$\text{Time}_{\text{total}}$** for each Web site visited, divided by the number of the six Web sites that user encountered during the session. **Rank[$\text{Time}_{\text{avg user}}$]** is the rank of each user out of a possible of 100 points, calculated by dividing the **$\text{Time}_{\text{avg user}}$** value for each user into the lowest **$\text{Time}_{\text{avg user}}$** value (since faster users should have a higher rank value), then multiplying by 100.
- **$\text{Time}_{\text{avg site}}$ –** For each Web site, the sum of **$\text{Time}_{\text{total}}$** over all the users who visited the site, divided by the number of users who explored that site.

Successful Task Completion

Successful task completion indicates whether the user correctly identified the information goal. This is a binary yes/no measure. Even if users landed on the page that contained the information goal, if they did not correctly identify the information goal, then they did not successfully complete the task. Task completion metrics, both of which are expressed in percentages, include:

- **$\text{Comp}_{\text{avg user}}$** – For each user, the number of information-seeking tasks successfully completed divided by the total number of information-seeking tasks attempted. **Rank[$\text{Comp}_{\text{avg user}}$]** is the rank of each user out of a possible of 100 points, calculated by dividing the **$\text{Comp}_{\text{avg user}}$** value for each user into the highest **$\text{Comp}_{\text{avg user}}$** value, then multiplying by 100.

- **Comp$_{\textbf{avg site}}$** – For each Web site, the number of information-seeking tasks successfully completed divided by the number of individuals who explored the site, regardless of whether the information-seeking task was completed successfully.

Number of Actions

The *number of actions* metric is the total number of keyboard commands a participant used during the **Time$_{\textbf{total}}$**. The total number of actions is the sum of two metrics defined in the next two sections, the number of scrolling actions and the number of searching actions. Action metrics include:

- **Actions$_{\textbf{total}}$** – For each user, the total number of actions performed during the **Time$_{\textbf{total}}$** for a particular Web site. A whole number.
- **Actions$_{\textbf{sum user}}$** – For each user, the sum of the **Actions$_{\textbf{total}}$** for all Web sites explored. A whole number.
- **Actions$_{\textbf{avg user}}$** – For each user, the sum of the **Actions$_{\textbf{total}}$** for all Web sites explored, divided by the number of Web sites explored. A real number.
- **Actions$_{\textbf{avg site}}$** – For each Web site, the **Actions$_{\textbf{total}}$** performed by each user divided by the number of number of users who explored the site. A real number.
- **Actions$_{\textbf{total site}}$** – For each Web site, the sum of the **Actions$_{\textbf{total}}$** for all users who explored the site. A whole number.

Number of Scrolling Actions Used

The *number of scrolling actions* metric is a subset of the number of actions performed. Scrolling actions include the following keyboard commands:

- *Enter* (go to a new page)
- *Ctrl+back arrow* (go to previous page)

- *Tab / shift-tab* (jump to the next link/previous link)
- *Up / down arrow* (jump to the next line/previous line)
- *Left / right arrow* (move left or right one character)
- *Ctrl+home* (return to top of page)
- *Ctrl+down arrow* (JAWS "say all" - begin reading at current cursor location)

The following six measures are calculated for scrolling actions:

- **$ScrComm_{unique}$ –** Total number of unique scrolling commands used by one user for all Web sites. A whole number.
- **$ScrComm_{total}$ –** Total number of scrolling commands used by one user for one Web site. A whole number.
- **$ScrComm_{total\ site}$ –** Total number of scrolling commands used by all users for one Web site. A whole number.
- **$ScrComm_{avg\ user}$ –** Average number of scrolling commands used by one user, for all sites visited by that user. A real number. **Rank[$ScrComm_{avg\ user}$]** is the rank of each user out of a possible of 100 points, calculated by dividing the **$ScrComm_{avg\ user}$** value for each user into the highest **$ScrComm_{avg\ user}$** value, then multiplying by 100.
- **$ScrComm_{total\ user}$ –** Total number of scrolling commands used by one user for all Web sites visited by that user. A whole number.
- **$ScrComm_{avg\ site}$ –** Average number of scrolling commands used by all users for one Web site. A real number.
- **$ScrComm_{total\ site}$** – For each Web site, the sum of **$ScrComm_{total}$** for all users who explored the site. A whole number.

- **ScrComm$_{percent}$ –** Percent of scrolling actions used. Calculated by using the following formula:

$$\frac{ScrComm_{total}}{Actions_{total}} \times 100 = ScrComm_{percent}$$

Number of Searching Actions Used

The *number of searching actions* metric is a subset of the number of actions performed. Searching actions include the following keyboard commands:

- *Ctrl+F* (JAWS virtual find – searches the page for keywords, starting where the cursor is located and moving to the end of the page)
- Site search (using a search built into the Web site
- *Insert+F7* (open a dialog box that lists all the links on the page)
- *F* (jump to next form control)
- *Insert+F6* (open a dialog box that lists all the headings on the page)
- *Ctrl+ins+home* (return to the top of the page
- All other recorded actions not defined as scrolling actions

The following measures are calculated for searching commands:

- **SearComm$_{unique}$ –** Total number of unique searching commands used by one user for all Web sites. A whole number
- **SearComm$_{total}$ –** Total number of searching commands used by one user for one Web site. A whole number.
- **SearComm$_{total\ site}$ –** For each Web site, the sum of **SearComm$_{total}$** for all users who explored the site. A whole number.
- **SearComm$_{avg\ site}$ –** Average number of searching commands used by all users for one Web site. A real number.

- **$\text{SearComm}_{\text{total user}}$ –** Total number of searching commands used by one user, for all sites visited by that user. A whole number.
- **$\text{SearComm}_{\text{avg user}}$ –** Average number of searching commands used by one user, for all sites visited by that user. A real number. **Rank[$\text{SearComm}_{\text{avg user}}$**] is the rank of each user out of a possible of 100 points, calculated by dividing the **$\text{SearComm}_{\text{avg user}}$** value for each user into the highest **$\text{SearComm}_{\text{avg user}}$** value, then multiplying by 100.
- **$\text{SearComm}_{\text{percent}}$ –** Percent of searching actions used. Calculated by using the following formula:

$$\frac{SearComm_{total}}{Actions_{total}} \times 100 = SearComm_{percent}$$

Searches Performed

The *number of searches* metric includes searches performed using a site search (if available) and searches performed using the JAWS Virtual Find command, which searches a page for an exact match of the search string. The five search metrics include:

- **$\text{Search}_{\text{total}}$** – For each user, the total number of searches performed during the information-seeking task on a particular Web site. A whole number.
- **$\text{Search}_{\text{sum user}}$** – For each user, the sum of **$\text{Search}_{\text{total}}$** for all Web sites explored by that user. A whole number.
- **$\text{Search}_{\text{avg user}}$** – For each user, the sum of **$\text{Search}_{\text{total}}$** for all Web sites explored by that user, divided by the number of Web sites explored. A real number.
- **$\text{Search}_{\text{avg site}}$** – For each Web site, the sum of **$\text{Search}_{\text{total}}$** performed by each user divided by the number of number of users who explored the site. A real number.
- **$\text{Search}_{\text{percent user}}$** – For each user, divide **$\text{Search}_{\text{sum user}}$** by **$\text{Action}_{\text{sum user}}$** to determine the percent of actions that are searching actions. A percent.

Hyperlink Selections

Individuals can use several methods to move from page to page on a Web site; one way of doing so is by selecting a hyperlink. This metric counts the number of times an individual moves to a new page by following a hyperlink. These metrics include:

- **$\mathbf{Link_{total}}$** – For each user, the total number of hyperlink selections performed during the information-seeking task on a particular Web site. A whole number.
- **$\mathbf{Link_{sum\ user}}$** – For each user, the sum of **$\mathbf{Link_{total}}$** for each Web site explored. A whole number.
- **$\mathbf{Link_{avg\ user}}$** – For each user, the sum of **$\mathbf{Link_{total}}$** for each Web site explored, divided by the number of Web sites explored. A real number.
- **$\mathbf{Link_{percent\ user}}$** – For each user, divide **$\mathbf{Link_{sum\ user}}$** by **$\mathbf{Action_{sum\ user}}$** to determine the percent of actions that are hyperlink selections. A percent.

Impasses Encountered

According to Kitajima et al. (2000), impasses occur whenever a user's forward progress toward the information goal is impeded. In the context of this study, the total number of impasses is the sum of two types of impasses, between-page and within-page. Between-page impasses (also called backtracking) occur when an individual uses the back button or the JAWS command for "back to the previous page" (Ctrl+Shift+Back Arrow) to return to a previous page. Backtracking metrics are also used in studies with sighted users (for example, Herder & Juvina, 2004). Within-page impasses occur when the user changes navigation tactics within the page to progress toward the information goal. For example, if the user tries to look at a list of all the headings on the page, but there are no headings on the page, the user has encountered an impasse because forward progress had been impeded and the user must try a different navigation tactic. The thirteen metrics for impasses include:

- **Back$_{total}$** – For each user, the total number of backtracks performed during the information-seeking task on a particular Web site. A whole number.
- **Back$_{sum\ user}$** – For each user, the sum of **Back$_{total}$** for each Web site explored. A whole number.
- **Back$_{avg\ user}$** – For each user, the sum of **Back$_{total}$** for each Web site explored, divided by the number of Web sites explored. A real number.
- **Back$_{avg\ site}$** – For each Web site, the sum of **Back$_{total}$** for each user divided by the number of users who explored the site. A real number.
- **Back$_{percent\ user}$** – For each user, divide **Back$_{sum\ user}$** by **Action$_{sum\ user}$** to determine the percent of actions that are backtrack selections. A percent.
- **Within$_{total}$** – For each user, the total number of within-page impasses performed during the information-seeking task on a particular Web site. A whole number.
- **Within$_{sum\ user}$** – For each user, the sum of **Within$_{total}$** for each Web site explored. A whole number.
- **Within$_{avg\ user}$** – For each user, the sum of **Within$_{total}$** for each Web site explored, divided by the number of Web sites explored. A real number.
- **Within$_{avg\ site}$** – For each Web site, the sum of **Within$_{total}$** for each user divided by the number of users who explored the site. A real number.
- **Within$_{percent\ user}$** – For each user, divide **Within$_{sum\ user}$** by **Action$_{sum\ user}$** to determine the percent of actions that are within-page impasses. A percent.
- **Imp$_{total}$** – For each user, the total number of impasses encountered during the information-seeking task on a particular Web site. A whole number.
- **Imp$_{avg\ user}$** – For each user, the sum of **Imp$_{total}$** for each Web site explored, divided by the number of Web sites explored. A real number. **Rank[Imp$_{avg\ user}$]** is the rank of each user out of a possible of 100 points, calculated by dividing the

Imp$_{\mathbf{avg\ user}}$ value for each user into the lowest **Imp$_{\mathbf{avg\ user}}$** value (since faster users should have a higher rank value), then multiplying by 100.

- **Imp$_{\mathbf{avg\ site}}$ –** For each Web site, the sum of **Imp$_{\mathbf{total}}$** for each user divided by the number of users who explored the site. A real number.

User Demographics

The four metrics derived from the demographic survey will be calculated as follows:

- **Exp$_{\mathbf{comp}}$ –** The number of years of experience a user has with computers. A whole number. **Rank[Exp$_{\mathbf{comp}}$]** is the rank of each user out of a possible of 100 points, calculated by dividing the **Exp$_{\mathbf{comp}}$** value for each user into the highest **Exp$_{\mathbf{comp}}$** value, then multiplying by 100.
- **Exp$_{\mathbf{web}}$ –** The number of years of experience a user has using the Web. A whole number. **Rank[Exp$_{\mathbf{web}}$]** is the rank of each user out of a possible of 100 points, calculated by dividing **Exp$_{\mathbf{web}}$** value for each user into the highest **Exp$_{\mathbf{web}}$** value, then multiplying by 100.
- **Exp$_{\mathbf{time}}$ –** The number of hours per day a user spends using the computer. A whole number. **Rank[Exp$_{\mathbf{time}}$]** is the rank of each user out of a possible of 100 points, calculated by dividing **Exp$_{\mathbf{time}}$** value for each user into the highest **Exp$_{\mathbf{time}}$** value, then multiplying by 100.
- **Rank[Exp$_{\mathbf{overall}}$] –** The overall rank of each user, calculated by adding the rank values for each individual and then dividing by the number of rank values (3). This value is calculated using the following equation:

$$\frac{\left[Rank\left[Exp_{time}\right]+Rank\left[Exp_{web}\right]+Rank\left[Exp_{comp}\right]\right]}{3}=Rank\left[Exp_{overall}\right]$$

Metrics from Herder and Juvina (2004)

For hypothesis II, we will compare the results for our screen-reader users to the results presented by Herder and Juvina (2004) of sighted users. To compare the results from our study to theirs, we calculate the following ten metrics:

- **$PageTime_{median}$** – The median time a user spends viewing a page during on a specific Web site. A whole number that indicates the number of seconds.
- **$Home_{total}$** – The total number of times a user visits the home page of a specific Web site. A whole number.
- **$Back_{percent\ user}$** – The percent of actions that are back button selections (defined in the Impasses section above). A percent.
- **$Links_{followed}$** – Equal to **$Links_{total}$** / **$Pages_{distinct}$** - The ratio between the number of links followed and the number of distinct pages visited. A real number.
- **$Page_{return\ rate}$** – The number of times that a page was revisited. This value is calculated by averaging the number of visits to all pages that were visited at least twice. A real number.
- **$Pages_{total}$** – The total number of pages an individual user visits on a specific Web site. A whole number.
- **$Pages_{distinct}$** – The total number of *distinct* pages (revisits are not counted) an individual user visits on a specific Web site. A whole number.
- **URL_{total}** – The total number of URLs visited during the exploration of a Web site for a specific information-finding task.
- **$URL_{distinct}$** – The total number of *unique* URLs visited during the exploration of a Web site for a specific information-finding task.

- **Rate$_{\textbf{revisitation}}$** – The probability that any URL visited is a repeat of a previous visit. This equation was originally presented by Taucher and Greenberg (1997) as follows, and is expressed as a percent:

$$\textbf{Rate}_{\textbf{revisitation}} = \left[\frac{(URL_{total} - URL_{distinct})}{URL_{total}}\right] \times 100$$

Web Site Metrics

During this study, we collected data on the Section 508 compliance of each Web site's home page. We asked participants to answer six questions about the usability of each Web site they visited (refer to Appendix B for the list of questions). Each answer was a value that ranged from 1 to 7 on a Likert scale. For each of the six Web sites used in this study, we use this data to determine the following metrics:

- **Section508$_{\textbf{compliance}}$** – Whether the home page of the Web site was Section 508 complaint. A binary yes/no measure.
- **Rating$_{\textbf{site}}$** – For each user, the sum of the Likert-scale answers for a particular Web site divided by the number of questions. A real number.
- **Rating$_{\textbf{avg site}}$** – For each Web site, the sum of the **Rating$_{\textbf{site}}$** values divided by the number of users who explored the site. A real number.

In addition to using the above metrics to analyze the Web sites, we use the two-tailed t-test to determine whether the differences between the sites are significant for certain calculated metrics.

Qualitative Analysis

Grounded theory, which was introduced by Glaser and Strauss (1967), was at the forefront of the qualitative movement in the mid-1960s because it challenged the idea that quantitative research was the only hard scientific method and suggested that qualitative methods could be used to develop theory. Grounded theory provides guidelines for collecting data, most of which is in the form of interviews and observations, and then analyzing that data; inquiry is inductive. However, one does not begin with a theory and then prove it; rather, the most relevant concepts are allowed to emerge from the data by using constant comparative analysis, the end result of which is a substantive theory that is "grounded" in the data from which it emerged. The emergent theory is not a grand theory, but rather a theory specific to the context of the study, although with further research it may be generalizable.

Because Glaser and Strauss parted ways in their concepts about how grounded theory should be implemented (for example, Strauss and Corbin, 1990), there is some dispute as to which version is the "real" grounded theory. Charmaz (2000) argues that there is no such thing, because grounded theory offers flexible strategies. While the theory specifies analysis methods (namely constant comparison), it does not specify data collection methods, although most data is in the form of interviews or observations.

Analysis of data for an emerging grounded theory begins with coding (Merriam, 2002). The coding process involves examining each line of data and creating short codes that begin to define and categorize the data. As the researcher is coding, he or she is constantly comparing the data against itself, a process that is stressed by Glaser. As comparisons are being made, the researcher also writes memos recording any insights or connections that arise.

Central to grounded theory is the identification of a core category, a conceptual idea that links as many of the categories together as possible. The resulting theory can be assessed using four criteria (Glaser 1978, 1992): (1) it must fit the data; (2) it must be a useful explanation; (3) it must be relevant to real-world problems; and (4) it should be usable in future studies.

We have chosen to use grounded theory (Glaser, 1967, 1995, 1998) to analyze the qualitative data in this study for several reasons. First, Glaser's version of grounded theory allows the researcher significant leeway in the data collection methods or data sources. While grounded theory is often based on interview data, in this study, individuals were asked to think aloud during each testing session, the result of which was interview-like data that we later transcribed for analysis. Secondly, we have data from the action transcripts and the quantitative analysis that we want to combine with the think-aloud data to form a broader understanding of these data in context. Finally, we want to ensure that the experiences of the participants are analyzed in a way that preserved their meaning. This is important because Web developers often apply accessibility guidelines such as Section 508 without understanding how compliance with these guidelines affects end users. We want to tell a story about the participants in a way that provides Web developers with a more personal understanding of these individuals and how accessibility compliance benefits them directly.

As always with qualitative research, there are concerns about outside influence. One concern is the effect the observer has on the individual being observed. In this study, the observer was limited to reading the scenarios aloud and asking the post-task survey questions. If a participant asked a question about the Web site, the observer was instructed to encourage the participant to do whatever he or she would do at home. In a few cases, the observer asked probing questions to elicit more details from the participant. Another concern is the possibility of researcher bias. However, in this study the researcher was not the observer/interviewer, and the original think-aloud data was not specifically intended to address questions about the navigation techniques of screen-reader users. Therefore, we believe this bias has been minimized.

We will use a selective coding process to analyze the data, in part because it is a more conceptual process than line-by-line coding. Also, the nature of the transcripts produced by the think-aloud protocol does not lend itself well to line-by-line coding. Each discrete incident, event, or idea will be given a code. Codes should evolve as the transcripts are being coded.

After developing the initial codes, we will sort the data into common categories that appear most frequently. Next, we will use the frequency of these categories to determine which categories are the most common. We will look for a common theme that explains the interrelationship of these categories; this theme will be used as the basis for the emerging theory, which will be grounded in the data and will reflect the experiences of the participants involved.

Finally, we will consider ways in which the categories and sub-categories (properties) that come out of the grounded theory analysis support (or do not support) the findings from the quantitative measures discussed in previous sections.

DATA ANALYSIS FOR HYPOTHESIS I

> *For screen-reader users, successful task completion, along with successful navigation techniques (as defined by quantitative measures), will vary depending on user experience.*

Overall User Experience

For the purposes of this study, overall user experience is based on the years of computer experience ($\mathbf{Exp_{comp}}$), years of Web experience ($\mathbf{Exp_{web}}$), and number of hours spent per day using a computer ($\mathbf{Exp_{time}}$). A rank value for each of these metrics, out of a possible of 100 points, was also calculated for each individual ($\mathbf{Rank[Exp_{comp}]}$, $\mathbf{Rank[Exp_{web}]}$, and $\mathbf{Rank[Exp_{time}]}$). To calculate the overall experience rank of each user $\mathbf{Rank[Exp_{overall}]}$, we used the following equation:

$$\frac{\left[Rank[Exp_{time}] + Rank[Exp_{web}] + Rank[Exp_{comp}]\right]}{3} = Rank[Exp_{overall}]$$

The individual with the highest value for **Rank[Exp$_{overall}$]**, out of a possible of 100, is considered to have the most experience. The calculation of overall user experience for the participants in this study is shown in Table 3. Please note that "-" indicates no value for that metric.

	#6		#20		#24		#31	
	Response	Rank[M]	Response	Rank[M]	Response	Rank[M]	Response	Rank[M]
Exp$_{comp}$	3 yrs.	20	15 yrs.	100	9 yrs.	60	8 yrs.	53.3
Exp$_{time}$[6]	Up to 4 hrs/day	50	8-12 hrs/day	100	All day	100	95% of time	100
Exp$_{web}$	3 yrs.	28.6	10+ yrs.	100	10 yrs.	95	7-8 yrs.	71
Rank[Exp$_{overall}$]	-	**32.9 (4th)**	-	**100 (1st)**	-	**85 (2nd)**	-	**74.8 (3rd)**

Table 3: Overall user experience (based on demographic survey)

Overall Success Indicator

In this study, a successful Web experience is defined as one where the information-finding task is completed relatively quickly (**Comp$_{avg\ user}$**, **Time$_{avg\ user}$**) with few impasses (**Imp$_{avg\ user}$**). A rank value for each of these metrics, out of a possible of

[6] For this question, participants #24 and #31 did not give answers based on the number of hours per day. However, their answers seemed to indicate that they use computers all day (presuming a normal 8 hour work day), which appears to be equivalent to the answer from participant #20. For consistency, we chose to give participants #20, #24, and #31 the same rank for this question.

100 points, was also calculated for each individual (**Rank[Comp$_{avg\ user}$],** **Rank[Time$_{avg_user}$**], and **Rank[Imp$_{avg\ user}$]**). To calculate the overall success rank of each user)**Rank[Success$_{overall}$])**, we used the following equation:

$$\frac{\left[Rank\left[Comp_{avguser}\right]+Rank\left[\operatorname{Im}p_{avguser}\right]+Rank\left[Time_{avguser}\right]\right]}{3}=Rank\left[Success_{overall}\right]$$

The individual with the highest overall score (out of a possible of 100) is considered the most successful. The calculation of overall success is shown in Table 4. Please note that “-“ indicates no value for that metric.

	#6		#20		#24		#31	
	Response	Rank[M]	Response	Rank[M]	Response	Rank[M]	Response	Rank[M]
Imp$_{avg\ user}$	1.7	47.1	0.8	100	2.8	28.6	3.4	23.5
Time$_{avg\ user}$	345.3	35.2	121.4	100	422.5	28.7	802.0	15.1
Comp$_{avg\ user}$	66%	66	100%	100	75%	75	60%	60
Rank[Success$_{overall}$]	-	**49.4**	-	**100**	-	**44.1**	-	**32.9**

Table 4: Overall success rank

Comparing User Experience and Overall Success

The rankings for overall user experience and overall success are compared in Table 5. With the exception of participant #20, user experience ranking does not appear to indicate overall success ranking (or lack thereof).

	#6	#20	#24	#31
Rank[Exp$_{overall}$]	32.9 (4th)	100 (1st)	85 (2nd)	74.8 (3rd)
Rank[Success$_{overall}$]	49.4 (2nd)	100 (1st)	44.1 (3rd)	32.9 (4th)

Table 5: Comparing user experience and overall success

Comparing User Experience and Navigation Techniques

As discussed in the literature review, other studies of screen-reader users have provided the basis for five factors that we use to quantitatively describe navigation technique. These five factors are calculated in this section.

Average Time Spent Searching for the Information Goal

In other studies, the *average time spent searching for the information goal* is commonly called "time on task" (for example, Burgstahler et al., 2004; Coyne & Nielsen, 2001; Craven & Brophy, 2003; Disability Rights Commission, 2004; Evans & Douglas, 2008). This metric is generally used to compare the amount of time screen-reader users and sighted users spend trying to find an information goal online. However, in this study, we are interested in comparing this value among our participants, as shown in Table 6. Please note that "n/a" indicates that the task was not attempted.

	#6	**#20**	**#24**	**#31**
F&I	n/a	77 sec.	91 sec.	n/a
SD	n/a	71 sec.	60 sec.	648 sec.
LBJ	512 sec.	81 sec.	620 sec.	367 sec.
TMM	253 sec.	n/a	n/a	325 sec.
UEX	271 sec.	133 sec.	n/a	399 sec.
LENG	n/a	245 sec.	919 sec.	1469 sec.
Average Time Spent Searching:	345.3 sec.	121.4 sec.	422.5 sec.	802 sec.
Rank[$\text{Time}_{\text{avg user}}$]:	**34.2 (2nd)**	**100 (1st)**	**28.7 (3rd)**	**15.1 (4th)**

Table 6: Average time spent searching for the information goal

Participant #20, who was the most experienced, took an average of approximately 2:00 to search for the information goal, about three times faster than both participants #6 and #24, who averaged approximately 6:00 and approximately 6:40, respectively. Participant #31 had the longest average time of 11:52; however, this average was skewed by the nearly 25 minutes he spent on the LENG site before deciding to end the task. His average time on task was further lengthened by the fact that he provided extensive verbal feedback during the information-finding tasks.

Whether the Information-finding Task was Successfully Completed

Many studies have compared the success rate of screen-reader users and sighted users (for example, Barnicle, 2000; Coyne & Nielsen, 2001; Disability Rights Commission, 2004; K. Lewis, 2004; Petrie & Kheir, 2007). However, in this study we are interested in comparing success rate among the four users, as shown in Table 7. Please note that "n/a" indicates that the task was not attempted.

	#6	**#20**	**#24**	**#31**
F&I	n/a	Success	Success	n/a
SD	n/a	Success	Success	Success
LBJ	Failed	Success	Failed	Success
TMM	Success	n/a	n/a	Success
UEX	Success	Success	n/a	Failed
LENG	n/a	Success	Success	Failed
Average Task Completion Rate:	66%	100%	75%	60%
Rank[$\mathbf{Comp}_{\mathbf{avg\ user}}$]:	**66 ($\mathbf{3^{rd}}$)**	**100 ($\mathbf{1^{st}}$)**	**75 ($\mathbf{2^{nd}}$)**	**60 ($\mathbf{4^{th}}$)**

Table 7: Average task completion rate

For this study, the first information-finding task on each Web site was analyzed, for a total of 17 information-finding tasks. Four tasks were not successfully completed. Only participant #20, the most experienced, was able to successfully complete all the information-finding tasks he attempted. Participant #24 was the second most successful with a 75% success rate, and users #6 and #31 had success rates of 66% and 60%, respectively.

Scrolling and Searching Actions Used

Gerber (2002) suggested that screen-reader users navigate using two different types of commands: scrolling commands, where users passively listen for information, and searching commands, where users actively look for information. The following tables summarize the average number of scrolling (Table 8) and searching actions (Table 10) used by each participant, as well as how many and which *unique* keyboard commands were used (Tables 9 and 11). Please note that "n/a" indicates that the task was not attempted.

	#6	**#20**	**#24**	**#31**
F&I	n/a	7	5	n/a
SD	n/a	10	8	52
LBJ	24	8	27	11
TMM	12	n/a	n/a	14
UEX	20	22	n/a	9
LENG	n/a	23	38	49
$ScrComm_{total\ user}$	56	70	78	135
$ScrComm_{avg\ user}$	**18.7**	**14**	**19.5**	**27**
$Rank[ScrComm_{avg\ user}]$	**74.9 (2^{nd})**	**100 (1^{st})**	**71.8 (3^{rd})**	**51.9 (4^{th})**

Table 8: Average number of scrolling actions used

As shown in Table 8, participants #6 and #24 used almost the same average number of scrolling commands (18.7 and 19.5, respectively). Participant #20 used the fewest average scrolling command, 14 per site. Participant #31 used an average of 27 scrolling commands per site.

Table 9 shows the number of unique keyboard scrolling commands used by each participant. Please note that "-" indicates that the participant did not use that particular command.

	#6	#20	#24	#31
New pages	x	x	x	x
Revisited pages	x	-	x	x
Same pages	x	-	x	x
Overview played	x	-	x	x
Tab	-	x	x	x
Shift-tab	-	x	x	x
Up arrow	x	x	x	x
Down arrow	x	x	x	x
Left arrow	-	-	x	x
Right arrow	-	-	-	x
Jaws read all	x	x	x	x
Ctrl-Home	x	x	x	-
Ctrl back arrow	x	-	x	x
$\text{ScrComm}_{\text{unique}}$	**9**	**8**	**12**	**12**

Table 9: Unique keyboard scrolling commands used

Table 9 shows that participants #6 and #20 used the fewest number of unique scrolling commands, 9 and 8, respectively. Participants #24 and #31 each used 12 unique scrolling commands.

Table 10 shows the average number of searching actions used by each participant on each site. Please note that "n/a" indicates that the task was not attempted for a particular site.

	#6	#20	#24	#31
F&I	n/a	2	6	n/a
SD	n/a	4	15	20
LBJ	5	3	33	6
TMM	8	n/a	n/a	5
UEX	3	5	n/a	5
LENG	n/a	11	63	13
$\text{SearComm}_{\text{total user}}$	**16**	**25**	**117**	**49**
$\text{SearComm}_{\text{avg user}}$	**5.3**	**5**	**23.4**	**9.8**
Rank[$\text{SearComm}_{\text{avg user}}$]	**21.7 (3rd)**	**21.4 (4th)**	**100 (1st)**	**41.9 (2nd)**

Table 10: Average number of searching actions used

Table 10 shows that participants #6 and #20 used an average of 5 and 5.3 searching commands, respectively. Participant #31 used an average of 9.8 searching commands per site. However, participant #24 used an average of 29.3 searching commands per site, which is from five to seven times more searching commands than any other participant.

Table 11 shows the unique keyboard searching commands used by each participant. Please note that “-“ indicates that the participant did not use that particular command.

	#6	#20	#24	#31
Skipped overview	x	x	x	-
Site search	-	x	x	x
JVF	x	x	x	x
Links list	-	-	x	x
Up/down arrow in LL	-	-	x	x
Letter find in LL	-	-	x	x
Close LL	-	-	x	-
Skip Nav	-	-	x	-
F to go to form control	-	-	x	-
Headings list	-	x	x	-
Ctrl-Shift	-	-	x	-
Page down	x	-	-	-
Unknown command	x	-	x	x
New window (Ctrl+Enter)	-	x	-	-
Ctrl+Ins+Home	-	-	-	x
Top of LL (home button)	-	-	x	-
Alt+M	-	-	x	-
Up/down arrow in HL	-	-	x	-
Exit HL	-	-	x	-
Open PFD	-	-	x	-
Use browser menu	-	-	x	-
Tab in LL	-	-	x	-
Alt+F	-	-	x	-
$SearComm_{unique}$	**4**	**5**	**20**	**7**

Table 11: Unique keyboard searching commands used

Table 11 shows that participants #6, #20, and #31 only used 4, 5, and 7 unique searching commands, respectively. However, participant #24 used 20 unique searching commands, from three to five times as many as any other user.

Table 12 compares the number of searching and scrolling actions used by each participant.

	#6	#20	#24	#31
$\mathbf{ScrComm}_{\textbf{total user}}$	56	70	78	135
$\mathbf{SearComm}_{\textbf{total user}}$	16	25	117	49
$\mathbf{Actions}_{\textbf{sum user}}$	72	95	195	184
$\mathbf{ScrComm}_{\textbf{percent}}$	78%	74%	40%	73%
$\mathbf{SearComm}_{\textbf{percent}}$	22%	26%	60%	27%

Table 12: Comparison of searching and scrolling actions

For Table 12, we calculated the percent of scrolling actions and searching actions to the overall total number of actions. Participants #6, #20, and #31 had very similar scrolling to searching ratios: 78% / 22%, 74% / 26%, and 73% / 27% respectively. Participant #24 had a scrolling to searching ratio of 40% / 60%, and was the only individual to use proportionally more searching actions than scrolling actions.

Impasses Encountered

We identified two types of impasses: *between-page impasses*, which are indicated by using the Back button (or an equivalent JAWS command) to move to a previously visited page; and *within-page impasses*, which are indicated by the user changing navigation tactics on a particular page. Tables 13, 14, and 15 show how many impasses of each type each user encountered. Please note that “n/a” indicates that the participant did not attempt a task for that Web site.

	#6	#20	#24	#31
F&I	n/a	0	0	n/a
SD	n/a	1	1	7
LBJ	3	0	6	0
TMM	0	n/a	n/a	1
UEX	2	1	n/a	2
LENG	n/a	2	4	7
Imp_{total}	**5**	**4**	**11**	**17**
$Imp_{avg\ user}$	**1.7**	**0.8**	**2.8**	**3.4**
$Rank[Imp_{avg\ user}]$	**47.1**	**100**	**28.6**	**23.5**

Table 13: Average total impasses per participant

As shown in Table 13, different participants encountered different impasses at different rates. Participant #31 encountered the highest average number of impasses at 3.4 per site, and participant #24 had the second highest average at 2.8 impasses per site. Participant #6, the least experienced participant, encountered an average of only 1.7 impasses per site. Participant #20 only encountered an average of 0.8 impasses per site.

	#6	#20	#24	#31
F&I	n/a	0	0	n/a
SD	n/a	0	0	3
LBJ	3	0	2	0
TMM	0	n/a	n/a	0
UEX	1	0	n/a	0
LENG	n/a	0	1	5
$Back_{sum\ user}$	**4**	**0**	**3**	**8**
$Back_{avg\ user}$	**1.3**	**0**	**.8**	**1.6**

Table 14: Average between-page impasses (backtracking incidents) per participant

	#6	#20	#24	#31
F&I	n/a	0	0	n/a
SD	n/a	1	1	4
LBJ	0	0	4	0
TMM	0	n/a	n/a	1
UEX	1	1	n/a	2
LENG	n/a	2	3	2
$\text{Within}_{\text{sum user}}$	**1**	**4**	**8**	**9**
$\text{Within}_{\text{avg user}}$	**0.3**	**0.8**	**2**	**1.8**

Table 15: Average within-page impasses per participant

To compare the types of impasses encountered by each participant, we review the results in Tables 14 and 15. In Table 14, we see that there were no between-page impasses for participant #20, meaning that all of his impasses occurred within the page. However, Table 15 shows that 76% of user #6's impasses were between-page, that is, they were backtracks. Only about 29% of user #24's impasses were between pages, whereas 47% of user #31's impasses occurred between pages, caused by backtracking.

Summary of Data for Hypothesis I

To create a rough measure of how effective a particular user was based on the five metrics presented in this section, we added the averaged Rank[M] values of the five metrics. The summary of the values calculated for these quantitative navigation measures is shown in Table 16.

	#6	#20	#24	#31
Rank[Time$_{avg\ user}$]	34.2	100	28.7	15.1
Rank[Comp$_{avg\ user}$]	66	100	75	60
Rank[ScrComm$_{avg\ user}$]	74.9	100	71.8	51.9
Rank[SearComm$_{avg\ user}$]	21.7	21.4	100	41.9
Rank[Imp$_{avg\ user}$]	47.1	100	28.6	23.5
ΣRank[M]	**243.9**	**421.4**	**304.1**	**192.4**
Avg(Rank[M])	**48.9 (3rd)**	**84.3 (1st)**	**60.8 (2nd)**	**38.5 (4th)**

Table 16: User experience vs. navigation technique factors

Table 16 shows the calculations for each participant. If we average the rank values for the five navigation metrics (**Avg(Rank[M]))**, the participant with the highest rank value indicates the most effective navigation technique for comparison with user experience. Therefore, according to our metrics, participant #20 should be considered to have the most effective navigation technique. Participant #24 is the second most effective, #6 is the third most effective, and participant #31 had the least effective navigation technique.

Of the five factors used to quantitatively describe navigation technique, all but **ScrComm$_{avg\ user}$** and **SearComm$_{avg\ user}$** were used to calculate the overall success indicator. Thus, only these two factors were compared to overall success, as shown in Table 17.

	#6	#20	#24	#31
Rank[ScrComm$_{avg\ user}$]	74.9	100	71.8	51.9
Rank[SearComm$_{avg\ user}$]	21.7	21.4	100	41.9
ΣRank[M]	**96.6**	**121.4**	**171.8**	**93.8**
Avg(Rank[M])	**48.3 (3rd)**	**60.7 (2nd)**	**85.9 (1st)**	**46.9 (4th)**

Table 17: Overall success and average number of scrolling and searching commands used

Table 17 shows the calculations to compare searching and scrolling commands used to overall success. If we average the rank values for the average number of searching and scrolling commands used (**Avg(Rank[M]))**, the participant with the highest rank value indicates the most effective combination of searching and scrolling commands. Therefore, according to our metrics, participant #24 has the most effective combination of searching and scrolling commands. Participant #20 is the second most effective, #6 is the third most effective, and participant #31 had the least effective combination of searching and scrolling commands.

DATA ANALYSIS FOR HYPOTHESIS II

The Web navigation techniques of screen-reader users across Web sites will be similar to those in models developed for sighted users.

For this hypothesis, we compared the navigation techniques of screen-reader users to the results from two different types of studies of between-page navigation for sighted users. The first type of study reports the percentage of certain actions for sighted users; the second type of study looks at different metrics that determine a flimsy or laborious navigation style.

Comparing to Page-Level Navigation Models

To simplify comparison of results from this study to the measures reported in the studies of sighted users by Catlege and Pitkow (1995) and Kari (2004), we calculated six metrics, as shown in Table 18.

	#6	#20	#24	#31
Search$_{\textbf{sum user}}$	2	9	9	6
Link$_{\textbf{sum user}}$	16	20	27	39
Back$_{\textbf{sum user}}$	4	0	3	8
Search$_{\textbf{percent user}}$	3%	9%	5%	3%
Link$_{\textbf{percent user}}$	22%	21%	14%	21%
Back$_{\textbf{percent user}}$	6%	0%	2%	4%

Table 18: Percent of searches, hyperlinks, and backtracks used

For this study, searching, linking, and backtracking actions accounted for at most 30% of the users' total actions. However, in the study reported by Kari (2004), linking, searching, and backtracking actions accounted for 78% of all actions, while Catlege and Pitkow (1995) reported that linking and backtracking accounted for 93% of all actions. Therefore, to make the comparison equivalent, we normalized the percentages reported above to make them account for 85% of the total actions (85% is midway between the percentages that Kari (2004) and Catlege and Pitkow (1995) reported). We used the following formula for the conversion:

$$\frac{(Search_{sum\_user} + Link_{sum\_user} + Back_{sum\_user})}{Actions_{converted\_total}} = \frac{85}{100}$$

Actions$_{\textbf{converted total}}$ is equal to the total number of Search, Link, and Back actions for each person if considered on a 100 point (percent) scale.

Using this formula, we recalculate the values for **Search**$_{\textbf{converted percent}}$, **Link**$_{\textbf{converted percent}}$, and **Back**$_{\textbf{converted percent}}$ as shown in Table 19.

	#6	#20	#24	#31
Search$_{\textbf{sum user}}$ + **Link**$_{\textbf{sum user}}$ + **Back**$_{\textbf{sum user}}$	22	29	39	53
Actions$_{\textbf{converted total}}$	26	34	46	62
Search$_{\textbf{converted percent}}$	8%	26%	20%	10%
Link$_{\textbf{converted percent}}$	61%	59%	59%	63%
Back$_{\textbf{converted percent}}$	15%	0%	7%	13%

Table 19: Converted number of searches, hyperlinks, and backtracks used

Comparing to Models of Navigation Styles

In addition to comparing the screen-reader users' use of searching, backtracking, and linking to studies of sighted users, we also wanted to compare their navigation techniques to models of sighted users' navigation techniques. Specifically, we used Herder and Juvina's (2004) study as the basis for analyzing how experience effects navigation technique. We used the same measures[7] as those used in the Herder and Juvina study to compare their data with the data from this study.

The following four tables, Tables 20 to 23, show the results for participants #6, #20, #24, and #31, respectively. For brevity, all measures are included in a single table for each user.

[7] Due to the limitations of the data collected for this study, the following measures in Herder and Juvina were not calculated:

- Average connected distance (the length of the path between any two connected pages in the navigation graph)
- Compactness (compares the average distance between two pages in the navigation graph to a theoretical maximum and minimum)
- Path density (compares the navigation graph to the fully connected graph of the Web site)
- Number of cycles (the formula for this metric was not clear from the Herder and Juvina paper)

	LBJ	TMM	UEX	Average
$\text{Pages}_{\text{total}}$	7	3	5	**5**
$\text{PageTime}_{\text{median}}$	68	47	67	**60.7**
$\text{Home}_{\text{total}}$	3	1	1	**1.7**
$\text{Back}_{\text{percent user}}$	10.3%	0%	4.3%	**4.8%**
$\text{Links}_{\text{followed}}$	1.4	1	1.25	**1.26**
$\text{Rate}_{\text{revisitation}}$	28.6%	0%	20%	**16.2%**
$\text{Page}_{\text{return rate}}$	3%	0%	2%	**1.7%**

Table 20: Participant #6: Navigation measures used by Herder and Juvina (2004)

	F&I	SD	LBJ	UEX	LENG	Average
$\text{Pages}_{\text{total}}$	3	3	3	5	6	**4**
$\text{PageTime}_{\text{median}}$	19	19	25	24	35	**24.4**
$\text{Home}_{\text{total}}$	1	1	1	1	1	**1**
$\text{Back}_{\text{percent user}}$	0%	0%	0%	0%	0%	0%
$\text{Links}_{\text{followed}}$	1	1	1	1	1	**1**
$\text{Rate}_{\text{revisitation}}$	0%	0%	0%	0%	0%	**0%**
$\text{Page}_{\text{return rate}}$	0%	0%	0%	0%	0%	**0%**

Table 21: Participant #20: Navigation measures used by Herder and Juvina (2004)

	F&I	SD	LBJ	LENG	Average
$\text{Pages}_{\text{total}}$	3	3	9	10	**6.25**
$\text{PageTime}_{\text{median}}$	13	17	54	50.5	**33.6**
$\text{Home}_{\text{total}}$	1	1	1	1	**1**
$\text{Back}_{\text{percent user}}$	0%	0%	3%	1%	**1%**
$\text{Links}_{\text{followed}}$	1	1	1.29	1.25	**1.14**
$\text{Rate}_{\text{revisitation}}$	0%	0%	22%	20%	**10.5%**
$\text{Page}_{\text{return rate}}$	0%	0%	2%	3%	**1.25%**

Table 22: Participant #24: Navigation measures used by Herder and Juvina (2004)

	TMM	LBJ	SD	UEX	LENG	Average
$\text{Pages}_{\text{total}}$	3	3	10	6	17	**7.8**
$\text{PageTime}_{\text{median}}$	76	122	48	43	48	**67.4**
$\text{Home}_{\text{total}}$	1	1	1	1	2	**1.2**
$\text{Back}_{\text{percent user}}$	0%	0%	4%	0%	8%	**2.4%**
$\text{Links}_{\text{followed}}$	1	1	1.43	1.16	1.7	**1.26**
$\text{Rate}_{\text{revisitation}}$	0%	0%	30%	14.3%	41.2%	**17.1%**
$\text{Page}_{\text{return rate}}$	0	0	2.5	2	2.3	**1.36**

Table 23: Participant #31: Navigation measures used by Herder and Juvina (2004)

Herder and Juvina describe two types of navigation: *flimsy* navigation, which is characterized by short navigation paths and page revisits made using the back button instead of by following links; and *laborious* navigation, which is characterized by following links to see whether they are useful or not, for the purpose of exploring the Web site (Bigham et al. (2007) called this "probing"). Because Herder and Juvina defined these navigation styles by determining "high" or "low" scores on the seven measures shown in Tables 20 to 23, in Table 24, we ranked each user on each measure. The individuals who were ranked first and second for each metric were considered to be "high" or "large", and the third and fourth ranked individuals "low" or "small."

	#6	#20	#24	#31
$\text{Pages}_{\text{total}}$	5 (low)	4 (low)	6.25 (high)	7.8 (high)
$\text{PageTime}_{\text{median}}$	60.7 (high)	24.4 (low)	33.6 (low)	67.4 (high)
$\text{Home}_{\text{total}}$	1.7 (large)	1 (small)	1 (small)	1.2 (large)
$\text{Back}_{\text{percent user}}$	4.8% (large)	0% (small)	1% (small)	2.4% (large)
$\text{Links}_{\text{followed}}$	1.26 (high)	1 (low)	1.14 (low)	1.26 (high)
$\text{Rate}_{\text{revisitation}}$	16.2% (high)	0% (low)	10.5% (low)	17.1% (high)
$\text{Page}_{\text{return rate}}$	1.7 (high)	0 (low)	1.25 (low)	1.36 (high)

Table 24: Summary of navigation measures used by Herder and Juvina (2004) for all participants

Based on the characteristics defined for flimsy navigation, and the rankings shown in Table 24, the individuals who demonstrated characteristics of flimsy navigation were #6 and #31, with #20 showing flimsy navigation with regards to the $\mathbf{Pages_{total}}$ metric. The individuals who demonstrated characteristics of laborious navigation were #6 and #31, with #24 showing laborious navigation with regards to the $\mathbf{Page_{return\ rate}}$ and $\mathbf{Pages_{total}}$ metrics.

Participant #6 had high values for all of the flimsy navigation metrics, and three of the five metrics of laborious navigation. Interestingly, the most experienced individual, participant #20, did not rank highly on any of the metrics for laborious navigation, but did demonstrate one metric for flimsy navigation. Participant #24 demonstrated only two of the metrics for laborious navigation. Participant #31 ranked highly on all of the metrics for laborious navigation, as well as three of the four metrics for flimsy navigation.

It is important to note that the "high" and "low" ratings for some metrics may be misleading, since some of the metrics have a very small range of values. For example, the range of values for $\mathbf{Home_{total}}$ was only 0.7, and for $\mathbf{Links_{followed}}$ the range was only 0.26, as seen in Table 24. This low range of values may indicate that the participants in this study did not clearly exhibit one style of navigation over the other.

Summary of Data for Hypothesis II

For this hypothesis, we based the data analysis techniques on techniques used in page-level navigation models of sighted users and navigation styles of sighted users. For page-level navigation, we found that:

- Participant #6's navigation technique included 8% searching actions, 61% hyperlink following actions, and 15% back button (or equivalent) selections.

- Participant #20's navigation technique included 26% searching actions, 59% hyperlink following actions, and no back button selections.
- Participant #24's navigation technique included 20% searching actions, 59% hyperlink following actions, and 7% back button selections.
- Participant #31's navigation technique included 10% searching actions, 63% hyperlink following actions, and 13% back button selections.

We also analyzed individuals' navigation patterns and compared them to Herder and Juvina's (2004) descriptions for *flimsy* and *laborious* navigation styles. Participant #6 exhibited all the metrics for flimsy navigation, and three of the five metrics of laborious navigation. Participant #20 exhibited no metrics for laborious navigation and one metric for flimsy navigation. Participant #24 exhibited none of the metrics for flimsy navigation, and only two of the metrics for laborious navigation. Participant #31 exhibited all the metrics of laborious navigation, as well as three of the four metrics for flimsy navigation. Why participants do not clearly exhibit one navigation type or the other is explored in detail in the discussion section.

DATA ANALYSIS FOR HYPOTHESIS III

> *Screen-reader users will employ a variety of Web navigation techniques that can be described by both qualitative and quantitative measures.*

The analysis for this hypothesis blends the quantitative data calculated in hypotheses I and II with qualitative data gathered from the think-aloud transcripts in order to better describe the participants' navigation techniques. To analyze the qualitative data, we employed the methodology described in Glaser's (1995, 1998) grounded theory, which also allowed us to uncover an emerging theory about how screen-reader users navigate the Web.

Analyzing Think-aloud Transcripts

To analyze the data from the think-aloud transcripts, we first highlighted key phrases, commented them using codes, and made memos noting similar themes or phrases (Glaser refers to this process as coding and memoing). Once the entire transcript was coded and memos written (refer to Appendix E for the detailed transcripts with codes and memos, as well as tables showing correspondence between the emergent categories and specific user utterances), we used the codes to sort users' comments into several categories, the list of which can be found in Appendix E. Of the initial list of 20 categories, user comments most commonly fell into the following four categories, in order of frequency:

1. Comments about code, markup, site structure, or accessible features, or lack thereof
2. Mismatch of user's expectations and content or functionality
3. Looking for specific information
4. Making navigation decisions based on the information found on the page

Analyzing Action Transcripts

In addition to using the transcripts from the think-aloud protocol, we also analyzed the action transcripts from each session to identify key action sequences for each user (Choo et al., 1998). Appendix F shows the action transcripts in detail; excerpts of each participants' key action sequences are presented below.

Participant #6

From the TMM Web site, the following navigation sequence illustrates this individual's preference to use the down-arrow key to slowly explore the entire content of the site's home page, sometimes all the way to the page footer, then use Ctrl-home to return to the top of the page to access whatever link sounded like it was the best one to follow. Participant #6 performed similar action sequences on the LBJ site and the UEX site.

1. New page – Home page – Listen to overview
2. Down-arrow through left navigation menu and main content (slowly)
3. Ctrl-home to get to top of page
4. Down arrow through left navigation menu (somewhat faster)

Participant #20

This participant frequently searched to find what he was looking for, often before accessing any other content on the page. For example, on the SD Web site's search results page, he immediately searched on "lab" to find his search results:

1. New page – Search Results – Skip overview
2. JAWS Virtual Find (JVF) – use search term 'lab' – **success**
3. Tab through several links for Skylab

In addition to frequently using search, he also often truncated his search terms, as demonstrated on the LBJ site, where he searched for "marr" instead of "married" and found exactly what he was looking for:

1. New page – LBJ Biography – Skip overview
2. Down-arrow through main content (quickly)
3. JAWS Virtual Find (JVF) – use search term 'marr' – **success**
4. Let JAWS read page (from point of search term)

Participant #24

From the F&I Web site, the following sequence demonstrates participant #24's use of the Links List dialog box to navigate. This participant never actually explores any content on the page – his entire navigation sequence for this page occurs in the Links List dialog box.

1. New page –French and Italian home page – Listen to overview
2. Open links list dialog box
3. Use links list letter find – press ‘g’
4. Up-arrow through links list dialog box
5. Down-arrow through links list dialog box
6. Up-arrow through links list dialog box
7. Choose ‘Graduate Courses’ link from links list

He also frequently chose to use the list of headings on a page to navigate, as shown in this excerpt from the LBJ Web site.

1. New page – Search results – Listen to overview
2. Let JAWS read the page
3. Open headings list dialog box
4. Down-arrow through headings list dialog box
5. Up-arrow through headings list dialog box
6. Down-arrow through headings list dialog box
7. ESC to exit headings list dialog box

Participant #31

On almost every page he explored, participant #31 first let JAWS read at least the page overview (which includes the page title and number of links on the page) before choosing any navigation actions. He also often let JAWS read partly through the page before making any navigation choices. For example, on the TMM site, he let JAWS read until he found a link that interested him, then he went back to that link and selected it:

1. New page – Visiting Museum Info – Listen to overview
2. Let JAWS read up to Parking link
3. Up-arrow a few times (past Parking link)
4. Tab through links to Parking link
5. Select Parking link

Summary for Hypothesis III

For this hypothesis, we analyzed two sets of data: think-aloud transcripts (Appendix E) and action transcripts (Appendix F). With the think-aloud transcripts, we used grounded theory to create categories of users' comments. The four top categories of user comments are (in order of frequency):

1. Comments about code, markup, site structure, or accessible features, or lack thereof
2. Mismatch of user's expectations and content or functionality
3. Looking for specific information
4. Making navigation decisions based on the information found on the page

From the action transcripts, we identified key navigation sequences for each user. Participant #6 preferred to use the down arrow key to slowly explore the entire content of the site's home page before making any navigation decisions. Participant #20 often performed a search, even before accessing any other content on the page. Participant #24 preferred to use the Links List dialog box or Headings List dialog box to navigate, often to the exclusion of exploring any page content. Participant #31 generally let JAWS read the page overview and part of the page before making any navigation choices. These varied navigation techniques will be explored in greater detail in the discussion section.

DATA ANALYSIS FOR HYPOTHESIS IV

> *When screen-reader users use a Web site that is Section 508 compliant, the overall success rate will be higher, the time spent searching for the information goal will be lower, fewer impasses will occur, fewer actions will be needed to find the information goal, and users will report a more satisfying user experience than when navigating a Web site that is not Section 508 compliant.*

The Section 508 guidelines, along with WCAG 1.0 and 2.0, are designed to provide guidelines for creating more accessible Web sites. This hypothesis evaluates five metrics to determine how these Section 508 compliant and non-compliant sites compare.

Section 508 Compliance and Average Task Completion Rate

The first metric where we compare the performance of the three Section 508 compliant Web sites to the three sites that were non-compliant is average task completion rate (**Comp**$_{\textbf{avg site}}$), in Table 25.

<table>
<tr><th></th><th>Section508$_{\text{compliance}}$</th><th>Comp$_{\text{avg site}}$</th><th>Average Overall Completion Rate</th></tr>
<tr><td>F&I</td><td>Yes</td><td>100%</td><td rowspan="3">88.7%</td></tr>
<tr><td>TMM</td><td>Yes</td><td>100%</td></tr>
<tr><td>UEX</td><td>Yes</td><td>66%</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>SD</td><td>No</td><td>100%</td><td rowspan="3">72%</td></tr>
<tr><td>LBJ</td><td>No</td><td>50%</td></tr>
<tr><td>LENG</td><td>No</td><td>66%</td></tr>
</table>

Table 25: Comparison of Section 508 compliance and average task completion rate

As seen in Table 25, the three Web sites that were Section 508 compliant had an average task completion rate 16% higher than the three sites that were not. Although the SD Web site was not compliant, the average completion rate was 100%. We hypothesize that the high average completion rate for this site was due to the availability of a site-wide search[8], which was used by all three participants who encountered the site to access the information goal directly.

Figure 1 shows the calculations for the two-tailed t-test to compare average task completion rate between Section 508 compliant Web sites and non-compliant Web sites.

$n_1 = 3$	$n_2 = 3$	
$\sum X_1 = 266$	$\sum X_2 = 216$	$t = 0.903$
$\sum X_1^2 = 24{,}356$	$\sum X_2^2 = 16{,}856$	$df = 4$
$\overline{X}_1 = 88.7$	$\overline{X}_2 = 72.0$	$p = .10$
$\left(\sum X_1\right)^2 = 70{,}756$	$\left(\sum X_2\right)^2 = 46{,}656$	

Figure 1: Two-tailed t-test calculations for significant difference in average task completion rate for 508 compliant and non-compliant sites

The calculated value of t was 0.903. For df=4 and p=0.10, the tables of the t-distribution show t=1.533. Therefore, we cannot reject the null hypothesis; in this study, there is not a significant difference in average task completion rate between the sites that were Section 508 compliant and those that were not.

Section 508 Compliance and Average Time Spent Searching for the Information Goal

The second metric where we compare the performance on the three Section 508 compliant Web sites to the three sites that were non-compliant is average time spent searching for the information goal (**$\text{Time}_{\text{avg site}}$**), in Table 26.

[8] The SD site was the only Web site of the six sites in this study with a site-wide search. The LBJ Web site included a search, but it was not site-wide and caused difficulties for participant #24.

	Section508$_{compliance}$	Time$_{avg\ site}$	Average Overall Time
F&I	Yes	1:21	212 sec 3:32
TMM	Yes	4:49	
UEX	Yes	4:27	
SD	No	4:23	512 sec 8:32
LBJ	No	6:35	
LENG	No	14:38	

Table 26: Comparison of average time spent searching for the information goal on 508-compliant and non-compliant Web sites

As shown in Table 26, it took users a combined average of over 300 seconds (5 minutes) longer to complete information-finding tasks on the non-compliant Web sites than on the Section 508 compliant sites.

Figure 2 shows the calculations for the two-tailed t-test for average time spent searching for the information goal between Section 508 compliant Web sites and non-compliant Web sites.

$$\boxed{\begin{array}{l} n_1 = 3 \\ \sum X_1 = 637 \\ \sum X_1^{\ 2} = 151{,}371 \\ \overline{X}_1 = 212 \\ \left(\sum X_1\right)^2 = 405{,}769 \end{array}} \quad \boxed{\begin{array}{l} n_2 = 3 \\ \sum X_2 = 1536 \\ \sum X_2^{\ 2} = 996{,}078 \\ \overline{X}_2 = 512 \\ \left(\sum X_2\right)^2 = 2{,}359{,}296 \end{array}} \quad \boxed{\begin{array}{l} t = 1.55 \\ df = 4 \\ p = .10 \end{array}}$$

Figure 2: Two-tailed t-test calculations for significant difference in average task completion rate for 508-compliant and non-compliant Web sites

The calculated value of t was 1.55. For df=4 and p=.10, the tables of the t-distribution show t=1.533. Therefore, we can reject the null hypothesis; in this study, there was a significant difference in average time spent searching for the information goal between sites that were Section 508 compliant and those that were not.

Section 508 Compliance and Average Number of Impasses Encountered

The third metric where we compare the performance of the three Section 508 compliant Web sites to the three sites that were non-compliant is average number of impasses encountered ($\mathbf{Imp}_{\mathbf{avg\ site}}$), in Table 27.

	$\mathbf{Section508}_{\mathbf{compliance}}$	$\mathbf{Imp}_{\mathbf{avg\ site}}$	**Average Overall Impasses**
F&I	Yes	0	
TMM	Yes	.5	0.7
UEX	Yes	1.7	
SD	No	3	
LBJ	No	3	3.4
LENG	No	4.3	

Table 27: Comparison of Section 508 compliance and average number of impasses encountered

Table 27 demonstrates that participants encountered nearly five times more impasses on non-compliant Web sites than on compliant sites.

Figure 3 shows the calculations for the two-tailed t-test for the average number of impasses encountered between Section 508 compliant Web sites and non-compliant Web sites.

$$n_1 = 3 \quad \sum X_1 = 2.2 \quad \sum X_1^{\ 2} = 3.14 \quad \overline{X}_1 = 0.7 \quad \left(\sum X_1\right)^2 = 4.84$$

$$n_2 = 3 \quad \sum X_2 = 10.3 \quad \sum X_2^{\ 2} = 36.49 \quad \overline{X}_2 = 3.4 \quad \left(\sum X_2\right)^2 = 1331.52$$

$$t = 0.12 \quad df = 4 \quad p = .10$$

Figure 3: Two-tailed t-test calculations for significant difference in average number of impasses encountered for 508-compliant and non-compliant Web sites

The calculated value of t was 0.12. For df=4 and p=0.10, the tables of the t-distribution show t=1.533. Therefore, we cannot reject the null hypothesis; in this study, there was no significant difference in average number of impasses encountered between sites that were Section 508 compliant and those that were not.

Section 508 Compliance and the Total Number of Actions

The fourth metric where we compare the performance of the three Section 508 compliant Web sites to the three sites that were non-compliant is total number of actions, both searching actions and scrolling actions, in Table 28. We also look at the overall percentages of searching and scrolling actions.

	Section $508_{compliance}$	$ScrComm_{total\ site}$	$SearComm_{total\ site}$	$Actions_{total\ site}$	Overall Average Number of Actions	$ScrComm_{percent}$ / $SearComm_{percent}$	Percent Overall
F&I	Yes	12	8	20	40	60% / 40%	70% / 30%
TMM	Yes	26	13	39		66% / 33%	
UEX	Yes	51	23	61		83% / 17%	
SD	No	70	39	109	141.7	64% / 36%	59% / 41%
LBJ	No	70	48	118		59% / 41%	
LENG	No	110	88	198		55% / 45%	

Table 28: Comparison of Section 508 compliance and total number of actions

As shown in Table 28, participants performed almost four times as many actions when using non-compliant sites than when using Section 508 compliant Web sites. Participants also used an average of 10% more scrolling actions on Section 508 compliant sites then they did on non-compliant sites (70% and 59%, respectively).

Figure 4 shows the calculations for the two-tailed t-test for total number of actions encountered between Section 508 compliant Web sites and non-compliant Web sites.

$n_1 = 3$	$n_2 = 3$	$t = 1.67$
$\sum X_1 = 120$	$\sum X_2 = 425$	$df = 4$
$\sum X_1^2 = 5642$	$\sum X_2^2 = 65009$	$p = .10$
$\overline{X}_1 = 40$	$\overline{X}_2 = 141.7$	
$\left(\sum X_1\right)^2 = 14400$	$\left(\sum X_2\right)^2 = 180{,}625$	

Figure 4: Two-tailed t-test calculations for significant difference in total number of actions for 508-compliant and non-compliant Web sites

The calculated value of t was 1.67. For df=4 and p=0.10, the tables of the t distribution show t=1.533. Therefore, we can reject the null hypothesis; in this study, there was a significant difference in total number of actions between sites that were Section 508 compliant and those that were not.

Section 508 Compliance and User Satisfaction Rating

Finally, we compare the average user satisfaction rating of the three Section 508 compliant Web sites to the three sites that were non-compliant in Table 29.

	Section508$_{compliance}$	**Rating$_{avg\ site}$**	**Overall Average Satisfaction Rating (out of 6)**
F&I	Yes	4.65	5.05
TMM	Yes	5.5	
UEX	Yes	5	
SD	No	4.8	3.65
LBJ	No	3.25	
LENG	No	2.9	

Table 29: Comparison of Section 508 compliance and user satisfaction rating

Table 29 shows that participants gave Section 508 compliant sites an overall satisfaction rating of 5.05/6, while non-compliant sites received a satisfaction rating of 3.65/6. If we convert these ratings to percents, Section 508 compliant sites received an average satisfaction rating of 84%, while non-compliant sites received an average satisfaction rating of just 61%.

Figure 5 shows the calculations for the two-tailed t-test for user satisfaction rating between Section 508 compliant Web sites and non-compliant Web sites.

$$
\begin{array}{|l|}\hline
n_1 = 3 \\
\sum X_1 = 15.15 \\
\sum X_1^{\ 2} = 76.87 \\
\overline{X}_1 = 5.05 \\
\left(\sum X_1\right)^2 = 229.52 \\ \hline
\end{array}
\quad
\begin{array}{|l|}\hline
n_2 = 3 \\
\sum X_2 = 10.95 \\
\sum X_2^{\ 2} = 42.01 \\
\overline{X}_2 = 3.65 \\
\left(\sum X_2\right)^2 = 119.9 \\ \hline
\end{array}
\quad
\begin{array}{|l|}\hline
t = 2.20 \\
df = 4 \\
p = .10 \\ \hline
\end{array}
$$

Figure 5: Two-tailed t-test calculations for significant difference user satisfaction ratings between 508-compliant and non-compliant Web site

The calculated value of t was 2.20. For df=4 and p=0.10, the tables of the t distribution show t=1.533. Therefore, we can reject the null hypothesis; in this study, there was a significant difference in user satisfaction ratings between sites that were Section 508 compliant and those that were not.

Summary of Data for Hypothesis IV

In Hypothesis IV, we used five metrics to compare the Web sites with Section 508 compliant home pages with the Web sites with non-compliant home pages. Participants' average task completion rate was an average of 16% higher on the sites that were compliant, but this difference was not significant for p=0.10. On the Section 508 compliant sites, users performed nearly 100 fewer actions per information-finding task (significant for p=0.10), encountered approximately five times fewer impasses (not significant for p=0.10), and took less than half as much time to complete the information-finding task (significant for p=0.10). The three Section 508 compliant sites had 84% overall user satisfaction rating, over 20% higher than sites that were not compliant (significant for p=.010). Section 508 compliant sites rated more highly on each of the five metrics analyzed than the non-compliant sites, although only three of the five differences were statistically significant.

SUMMARY OF DATA ANALYSIS

In this section, we have used both quantitative and qualitative analysis methods to analyze the data from this study. For Hypothesis I, we examined the relationship between user experience, successful task completion, and six navigation metrics. In Hypothesis II, we used analysis techniques suggested by two studies of sighted users to assess the within-page and between-page navigation techniques of the study participants. For Hypothesis III, we applied grounded theory to analyze the think-aloud protocol transcripts, and also analyzed the action transcripts of each session to find common navigation sequences for each user. In Hypothesis IV, we compared five metrics for three Web sites with Section 508 compliant home pages with three Web sites with non-compliant home pages. In the next chapter, we discuss the implications of the outcomes for each hypothesis.

7. Discussion

DISCUSSION OF HYPOTHESIS I

For screen-reader users, successful task completion, along with successful navigation techniques (as defined by quantitative measures) will vary depending on user experience.

With the exception of user #20, whose experience directly corresponds with his success, there appears to be little relationship between user experience and overall success for the participants in this study, as shown in Figure 6. Please note that the Overall Experience Rank for participant #20 is hidden behind Overall Success Rank for that participant.

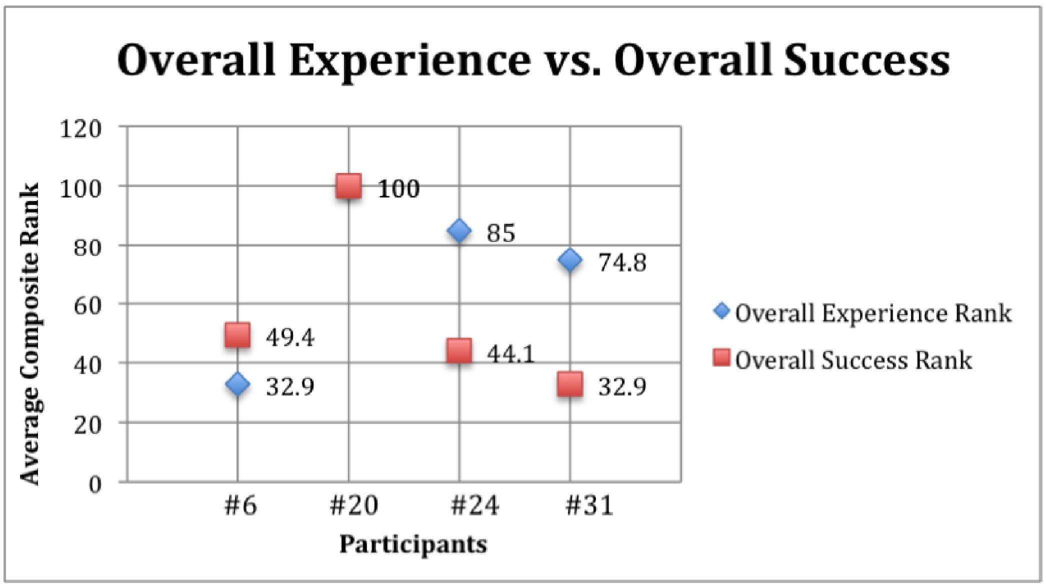


Figure 6: Overall experience vs. overall success

For example, participant #6, the least experienced individual, was the second most successful, while participant #24, the second most experienced, was the third most successful by a slim margin (his **Rank[Success$_{\text{overall}}$]** score was about 5 points less than the score for participant #6). Participant #6's success is even more impressive when we consider that her composite experience score (**Rank[$\mathbf{Exp_{overall}}$]**) was over 50 points less than the composite experience score for participant #24. Thus, in the context of this study, experience did not appear to guarantee a successful outcome, nor did lack of experience predict a less successful outcome.

With the exception of participant #20, who was both the most experienced user and had the fastest average time spent on task, experience did not seem to affect average time on task. Participant #6, who was the least experienced, had the second fastest overall time on task, while participant #24, who was the second most experienced user, had the third fastest time on task. What is perhaps the most telling is how much faster participant #20 was on average for the tasks; his **Rank[$\mathbf{Time_{avg\ user}}$]** score was 65 points higher than the next fastest participant, #6, while the other three participants had **Rank[$\mathbf{Time_{avg\ user}}$]** scores within 20 points of each other.

In some cases, user experience may have affected the average completion rate of a task. For example, participants #20 and #24, who were the first and second most experienced, respectively, also had the highest average completion rates. However, although participant #31 had more experience than participant #6, he had a lower average task completion rate (their **Rank[$\mathbf{Comp_{avg\ user}}$]** scores were 60 and 66, respectively). Given these results, it is likely that factors other than user experience play a role in average task completion rate.

The data for this study does not support other research (Gerber, 2002) that more experienced individuals use more searching commands. In fact, participant #6, the least experienced, and participant #20, the most experienced, used both the fewest average number of searching commands and the fewest number of unique searching commands (Tables 10 and 11). They also used the fewest number of scrolling commands and had the fewest unique number of scrolling commands (Tables 8 and 9). The metrics for the most experienced participant and the least experienced participant were relatively similar for both average number of searching and scrolling commands used and the number of unique commands used.

In the interviews for another study (Jobst, 2005), participant #20 was asked for details about why he used the navigation commands that he did. He replied that because he used both JAWS and Window-Eyes, he preferred to use commands that he knew would work with both screen readers. He also mentioned that he had tried other commands, but they did not work well on Web pages with poor HTML coding; therefore, he uses the small subset of commands that he knows will work regardless of how well or poorly the page is coded. In contrast, participant #6 may have used a small set of commands because of her relative inexperience—she may not have known many JAWS commands.

Compare these results to those of participant #24, who was the second most experienced individual. He used between four and five times the number of searching commands used by either participant #6 or participant #20. Participant #24 was the only participant to use a higher ratio of searching commands to scrolling commands (Table 12). He used the greatest number of unique searching commands on the LENG site, where he had difficulty finding content that matched his information goal and was ultimately unable to complete the task. When asked about his navigation techniques in later interviews (Jobst, 2005), he mentioned that he was familiar with many JAWS commands, in part because he had participated as a JAWS beta tester, and in part because of his knowledge of accessibility. However, he noted that it is not always beneficial to know a large number of commands because he is likely to try many different commands to work around an impasse; he suggested that instead he might be better off using a few commands that work more reliably on a variety of Web sites.

Participant #31, who was the third most experienced, used substantially more scrolling commands than any other individual (Table 12). Interestingly, he used the same number of unique scrolling commands as participant #24, but one-third as many unique searching commands. The discussion of the qualitative analysis data in Hypothesis III will shed more light on how this individual navigates than we were able to glean from the quantitative measures here.

To further investigate participants' preferred navigation techniques, we compared the percent of scrolling and searching actions. Participants #6, #20, and #31 all had very similar scrolling to searching ratios (approximately 75% scrolling and 25% searching, refer to Table 12), indicating that these individuals prefer using scrolling techniques. However, participant #24 used 40% scrolling actions and 60% searching actions (Table 12), indicating that he preferred using searching actions to navigate. For future studies, the ratio of scrolling to searching actions can be a useful metric for describing a user's preferred navigation technique.

For Hypothesis I, we explored whether overall success was related to the number of scrolling or searching actions. There was an inverse relationship between overall success rank and both the average number of scrolling commands used, and the average number of searching commands used. This inverse relationship would indicate that 1) that users who take a less direct the route to the information goal will use more commands; and 2) individuals who navigate directly to the information goal use fewer commands. Thus, the ratios of scrolling and searching commands to the total number of actions are a useful measure for understanding navigation techniques. In this study, users #6, #20, and #31 used proportionally more scrolling commands than searching commands, whereas user #24 used proportionally more searching commands. When these ratios are compared to overall success, individuals who preferred to use searching commands were not necessarily more successful than those who preferred to use scrolling commands. This finding is contrary to Hypothesis I as well as to the findings reported in Gerber (2002). The low use of searching commands may be indicative of a poorly-coded or poorly-organized Web site that supports only the most basic scrolling navigation techniques.

When considering impasses, with the exception of participant #20, who was the most experienced and had the fewest average number of impasses, user experience did not seem to be related to the number of impasses encountered. However, experience may be related to the type of impasses the individual encountered. Participant #20 encountered no between-page impasses; 100% of his impasses occurred within-page. In contrast, the least experienced participant, #6, had the second fewest average number of impasses, but 76% of her impasses occurred between pages. The more experienced participants, #24 and #31, had higher average numbers of impasses than participant #6, but the majority of their impasses occurred within-page.

Examination of each of the five navigation metrics individually ($\mathbf{Time}_{\mathbf{avg\ user}}$, $\mathbf{Comp}_{\mathbf{avg\ user}}$, $\mathbf{ScrComm}_{\mathbf{avg\ user}}$, $\mathbf{SearComm}_{\mathbf{avg\ user}}$, $\mathbf{Imp}_{\mathbf{avg\ user}}$) shows that with the exception of participant #20 (who was both the most experienced user and the most successful user), neither user experience nor success appears to be related to these navigation metrics (Figure 7). To investigate the effectiveness of each individual's navigation techniques based on these five metrics as a whole, using a scale of 1 to 100, we ranked each navigation metric across participants and averaged the rankings, with a higher composite navigation ranking indicating a more effective navigation technique (Table 16).

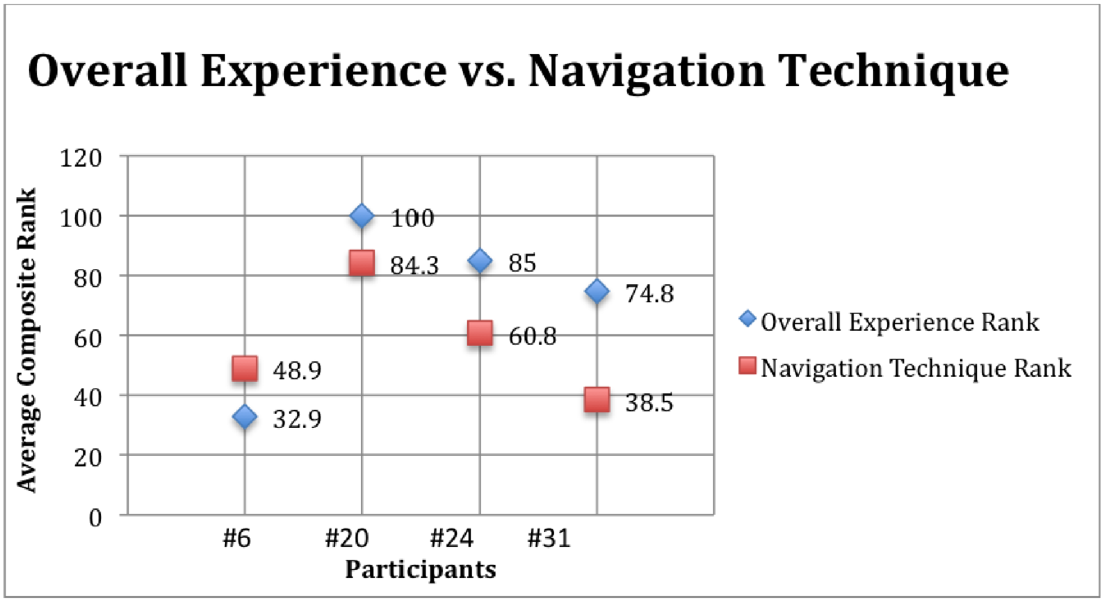


Figure 7: Overall experience vs. navigation technique

Based on the composite ranking of the five metrics, participant #20 had the most effective navigation technique, with an average composite score (**Avg(Rank[M])**) of 84.3/100. In fact, participant #20 ranked first for every navigation factor except search commands used (**SearComm**$_{\textbf{avg user}}$). His lower ranking on this metric was based on the finding from Gerber (2002), which indicated that individuals who used more searching commands should be ranked as more effective because searching commands had been found to be more effective than scrolling commands. Indeed, because user #20 ranked so highly in all other navigation factors, we question whether use of searching commands is really as effective as the existing literature indicates.

Despite his experience, participant #31's navigation technique was the least effective based on the metrics used for this study, with an average composite score (**Avg(Rank[M])**) of 38.5/100. However, he spent a great deal of time providing feedback out loud, which negatively impacted the metric for time spent searching for the information goal. This problem using the think-aloud protocol was also reported by

Strain et al. (2007). Therefore, his poor composite ranking may be a contrivance of our measures of navigation and the context of the study rather than ineffective navigation techniques.

Summary of Hypothesis I

For Hypothesis I, when considering whether user experience affected overall success or navigation technique, we found little evidence that user experience is an indicator of overall success. For example, the least experienced user was the second most successful. Experience did not appear to be related to average time on task, although in some cases it may affect the average completion rate of a task, with more experienced individuals having higher task completion rates. More experienced users did not necessarily use more searching commands; in fact, the participants in this study generally preferred to use scrolling commands, including the most experienced participant. One possible reason they might have preferred scrolling commands is that these commands do not rely on well-structured HTML code to work, unlike most searching commands. Therefore, scrolling commands work regardless of how well or poorly a Web page has been coded.

We discovered an inverse relationship between overall success rank and both the average numbers of scrolling commands and searching commands used. This relationship makes sense because users who take a less direct the route to the information goal are likely to use more commands; conversely, individuals who go directly to the information goal are likely to use fewer commands. Therefore, the ratio of scrolling to searching commands is a viable indicator of preferred navigation style.

Although user experience did not appear to be related to the number of impasses encountered, it may be related to the type of impasses encountered. The most experienced participant, #20, encountered no between-page impasses. While the least experienced participant, #6, encountered the second fewest average number of impasses, 76% of her impasses occurred between pages. In other words, a more experienced individual may be more likely to move more steadily toward the information goal, while a less experienced person may make a greater number of unnecessary side trips.

To perform an overall comparison of navigation technique, we ranked each of the five navigation metrics out of a possible of 100 points, then averaged the rankings to provide a composite navigation ranking. Based on this calculation, participant #20 had the most effective navigation technique (84.3/100 composite score), followed by participant #24 (60.8/100). Participant #6 had the third most effective navigation technique (48.9/100), and despite his experience, participant #31 had the least effective overall technique (38.5/100). However, his low ranking may be a contrivance of our measures of navigation and the context of the study rather than an ineffective navigation technique. Regardless, the range of scores hints at the differences in navigation techniques, which we see more clearly in the discussion of Hypothesis III.

In summary, normalizing the ranks for each metric used in this hypothesis was key for analysis, as was defining composite metrics for overall success, overall user experience, and navigation technique. Quantitative analysis shows that user experience does not necessarily indicate overall success nor does it necessarily indicate a more successful navigation technique. However, user experience may affect the type of impasses users encounter, with less experienced individuals encountering a higher percentage of within-page impasses. We also found that the ratio of scrolling to searching commands is a viable indicator of preferred navigation style.

DISCUSSION OF HYPOTHESIS II

The Web navigation techniques across Web sites of screen-reader users will be similar to those in models developed for sighted users.

Comparing to Page-Level Navigation Models

We focused on two studies of sighted users that reported page-level navigation metrics: Catledge and Pitkow (1995) and Kari (2004). These studies reported on the percentage of searching actions, linking actions, and backtracking actions for sighted individuals. However, because these three actions accounted for 78% of total actions in Kari's study, and linking and backtracking accounted for 93% of all actions in Catledge and Pitkow's study, we converted the percentages of the actions for screen-reader users to be in line with these numbers for comparison purposes. [9]

Kari (2004) reported that searches constituted about 8% of sighted individuals' navigation actions. When considering our converted scale, our two most experienced users (#20 and #24) used about three times as many searching actions (26% and 20%, respectively) as do sighted individuals. Our two least experienced users had approximately the same percentage of searches reported by Kari. Thus, more experienced screen-reader users searched nearly three times as often as did sighted users, and less experienced screen-reader users searched about the same amount as did sighted users.

Catledge and Pitkow (1995) and Kari (2004) reported that the sighted individuals in their studies used links to move from page to page for about 52% and 45% of total actions, respectively. On the converted scale, our screen-reader users all tended to follow hyperlinks for approximately 60% of their actions, or about 10-20% more than sighted users. However, our participants' use of the back button was lower than that of sighted

[9] As explained earlier, we chose 85% because it is midway between the percentages that Kari (2004) and Catlege and Pitkow (1995) reported.

users. While Catledge and Pitkow (1995) and Kari (2004) reported that 41% and 25% of all actions were back-button use, respectively, even our least experienced user (#6), who used the back button the most frequently (15% of the time), used it from 10-25% less frequently than did sighted users. Our most experienced individual, #20, did not use the back button at all.

Comparison to Navigation Styles

Herder and Juvina (2004) defined two types of navigation style: *flimsy* and *laborious*. *Flimsy* navigation is characterized by short navigation paths and page revisits made using the back button instead of by following links. Flimsy navigation is centered on the site's home page, which is used as a starting point. Individuals who use flimsy navigation often have less Internet expertise. *Laborious* navigation is characterized by following links to see whether they are useful or not, for the purpose of exploring the Web site. This type of navigation is characterized by a high number of page revisits, where pages such as site indexes serve as a navigation base. Laborious navigation helps users construct an overview of the site and is often used by individuals with low spatial ability.[10] We expected users #6 and #31, who are less experienced, to exhibit flimsy navigation characteristics and expected the more experienced users, #20 and #24, to exhibit laborious navigation characteristics.

Participant #6 exhibited all of the characteristics used to define flimsy navigation, but also exhibited a high rate of links being followed ($\mathbf{Links_{followed}}$) and a high rate of page revisitations ($\mathbf{Rate_{revisitation}}$), both of which are qualities of laborious navigation. Our most experienced participant, #20, did not exhibit any of the characteristics for laborious navigation, but scored highly on one of the flimsy navigation metrics, visiting a small

[10] There are no reliable tests for spatial ability in blind individuals. Witkin (1971) developed one, but it has not been used outside of his initial trials.

number of pages (**Pages$_{total}$**). Participant #24, our second most experienced individual, exhibited two of the laborious navigation characteristics, a high rate of returning to a page (**Page$_{return\ rate}$**) and high number of total pages visited **(Pages$_{total}$)**. Participant #31 showed the most skewed profile, exhibiting every characteristic for both flimsy and laborious navigation except for small **Pages$_{total}$**. According to Herder and Juvina (2004), this mix of flimsy and laborious navigation styles is to be expected, since the two styles are not mutually exclusive. Still, mutually inclusive navigation styles did not explain why the most experienced participant, #20, only exhibited flimsy navigation characteristics, when we expected him to exhibit the most laborious navigation characteristics. Therefore, we explored visualizing the data in a different way.

Because the navigation metrics did not provide a clear idea of which participants used which navigation style, we created maps of users' navigation sequences from the action transcripts (Appendix F). The first set of maps, shown in Figure 8, demonstrates very short, direct paths to the information goal—by definition, flimsy navigation. All of these navigation sequences ended in successfully finding the information goal.

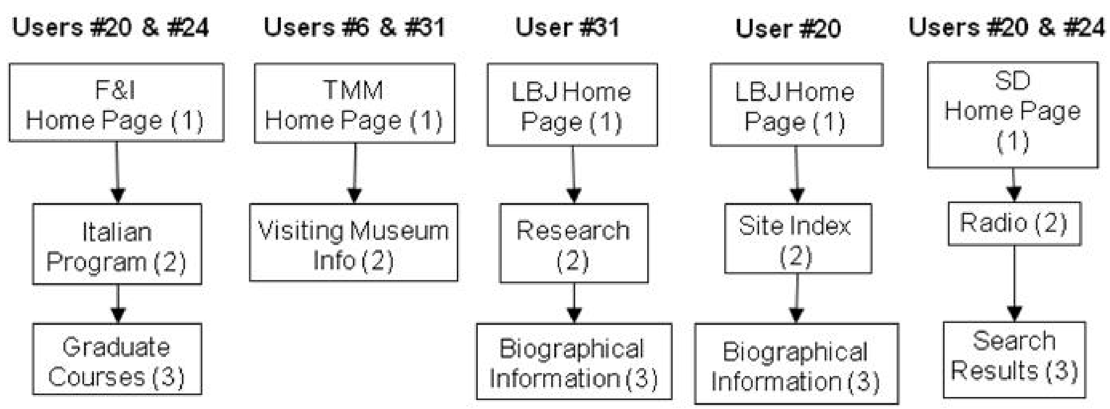


Figure 8: Direct, short paths to the information goal.

The next set of navigation maps, shown in Figure 9, also demonstrates a direct (flimsy) path to the information goal, although the paths are somewhat longer than those in Figure 8.

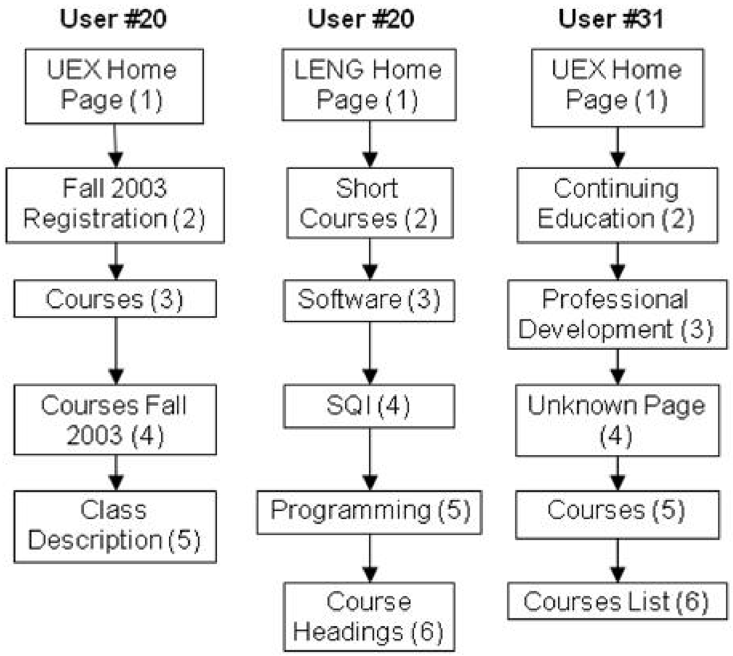


Figure 9: Direct, longer paths to the information goal.

The final set of flimsy navigation maps, shown in Figure 10, demonstrates a relatively direct path to the information goal, but with a few sidetracking actions indicated by double-ended arrows. The users may have been trying out different links to determine how relevant these links were to the information goal (Bigham et al. (2007) call this "probing").

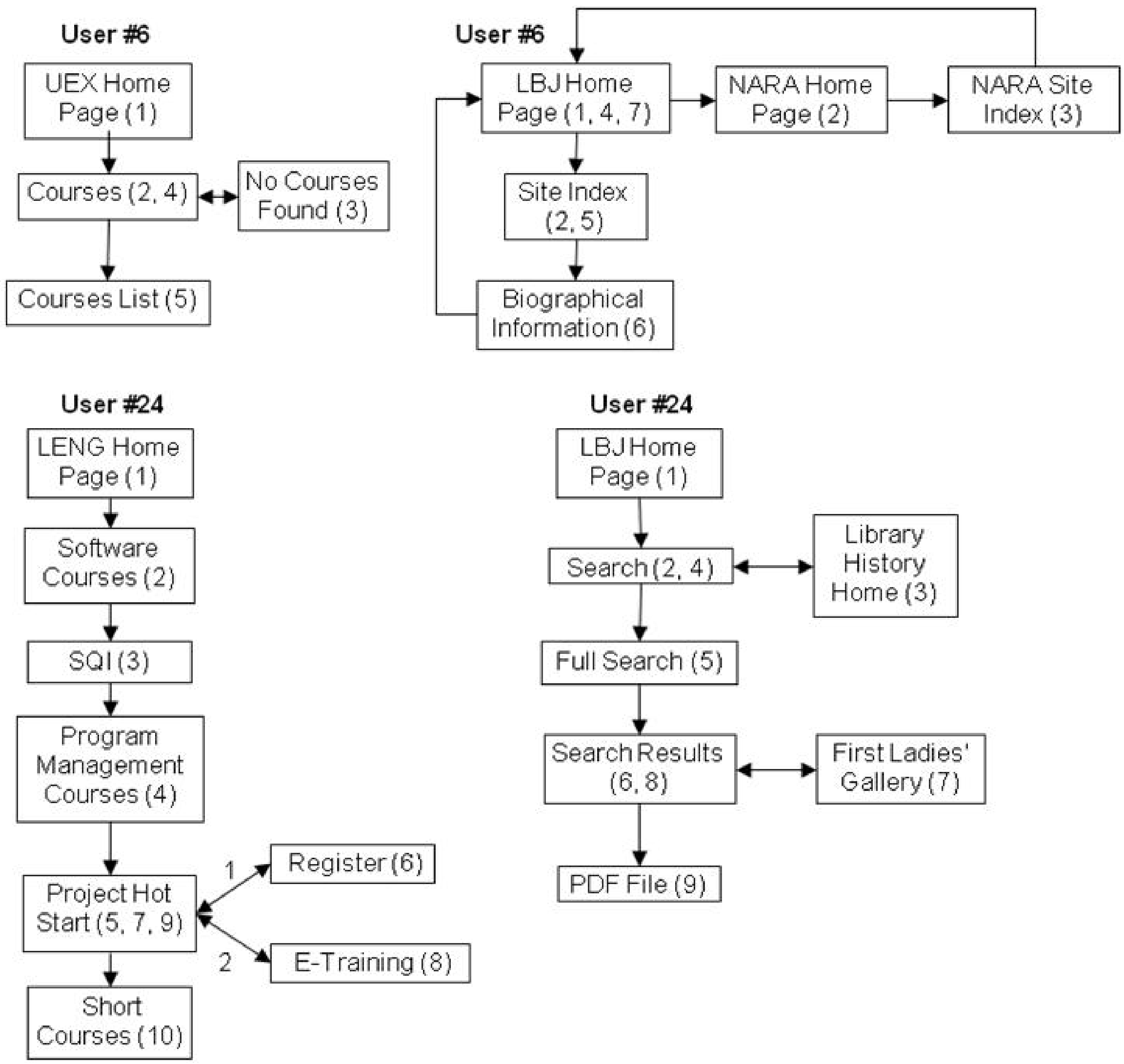


Figure 10: Direct paths with a few sidetracking actions.

The final navigation maps, given in Figure 11, demonstrates the more laborious navigation used by one participant. This participant, #31, used links instead of the back button to navigate from page to page, as indicated by one-way arrows. There were also several instances of hub-and-spoke navigation, where the individual used a single page as the base for trying several different links, as indicated by double-ended arrows.

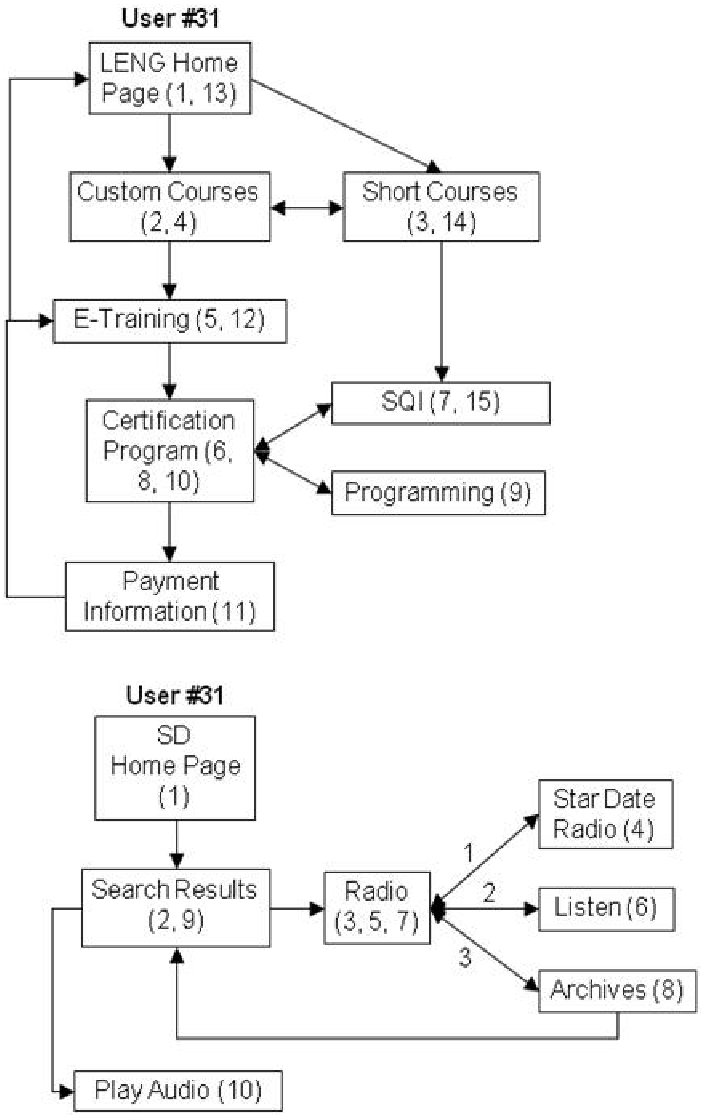


Figure 11: A more laborious navigation style

For this study, the metrics used to determine flimsy and laborious navigation styles did not clearly group the participants into a particular navigation style. For example, in the case of participant #31, the metrics showed significant overlap between the two navigation styles. In the case of participant #20, only one flimsy navigation metric applied. The lack of clear groupings of navigation styles may be because many of the calculated values for the metrics had a very small range, and when the range is so small it is difficult to argue that the ranked values of “high” and “low” are meaningful.

Contrary to the findings of Herder and Juvina (2004) and our hypothesis, the most experienced individual, #20, used the shortest, most direct navigation paths, which are described in the literature as a flimsy navigation style. Participant #31, who exhibited the most laborious style of navigation, was the third most experienced user.

Although the navigation metrics were of minimal use for determining navigation style, the navigation maps show that participants in this study generally preferred a very linear, flimsy style of navigation, with minimal exploration of the Web sites except in situations where a page was explored and then the user returned to the previous page using the back button. These findings are supported by Petrie and Kheir (2007), who found that blind individuals spent more time on fewer pages and were less likely to return to a page than sighted individuals. The linear navigation maps also support Leuthold et al. (2008), who suggested that blind individuals do not use trial and error to navigate; conversely, only the most laborious navigation maps support Bigham et al.’s (2007) suggestion that blind individuals tend to “probe.”

Summary of Hypothesis II

For Hypothesis II, which stated that Web navigation techniques of screen-reader users across Web sites would be similar to those techniques in models developed for sighted users, we first compared the data for this study to two studies of page-level navigation of sighted users. As we had hypothesized, the more experienced screen-reader users performed more searches, using either the site search or JAWS Virtual Find command, than sighted individuals. What was surprising was that the two most experienced users employed about three times as many searches as reported for sighted individuals. The two least experienced users employed approximately the same number of searches as reported for sighted users. Thus, we conclude that searches are more effective, and are thus more frequently used, for screen-reader users than for sighted users.

The four study participants tended to follow hyperlinks for approximately 60% of their actions, or about 10-20% more frequently than reported for sighted users. However, participants performed as expected when using the back button; even the least experienced user, who used the back button the most frequently, used it from 10-25% less often than sighted users. The most experienced individual did not use the back button at all and, as discussed in the next section, employed a completely linear (flimsy) between-page navigation style. It may be that the relatively low use of the back button was due at least in part a concern about becoming lost within the Web site.

For Hypothesis II, we also analyzed the participants' navigation styles to determine whether they fit a more flimsy or laborious navigation pattern, as defined by Herder and Juvina (2004). We expected the less experienced users, #6 and #31, to exhibit flimsy navigation characteristics, and the more experienced users, #20 and #24, to exhibit laborious navigation characteristics. However, the navigation metrics did not clearly indicate which participants used which navigation styles. In fact, participants #6 and #31 demonstrated several characteristics for both styles, and participant #20, who was the most experienced, only exhibited one characteristic for flimsy navigation. The lack of clear groupings of navigation styles may be because many of the calculated values for the metrics had a very small range.

For further analysis, we created maps of users' navigation sequences. The maps show that study participants generally used a linear, flimsy style of navigation when compared with maps of sighted users from the Herder and Juvina (2004) study. Contrary to our expectations, the most experienced individual, #20, had the flimsiest navigation style. Why he preferred this style of navigation is not clear. Some potential explanations are (1) this navigation style may be the most efficient for screen-reader users, (2) using a direct navigation style may mitigate disorientation, and (3) this style of navigation may be related to task or context. Another possible issue may be that the navigation sequences required to find the information goals in this study were not sufficiently long or complex to provide the opportunity for laborious navigation.

In summary, this is the first study to compare the searching, backtracking, and hyperlinking habits of screen-reader users and sighted users. We found that screen-reader users performed up to three times as many searches, followed hyperlinks approximately 10-20% more frequently, and used the back button much less often than reported for sighted users. This is also the first study to attempt to apply navigation models for sighted users to screen-reader users. We found that while the concept of flimsy and laborious navigation models seems to apply to screen-reader users, as a group the users in this study tended to exhibit a very flimsy navigation style when compared to sighted individuals. More research is needed to determine whether screen-reader users continue to exhibit this navigation style outside of a limited, prescribed context such as the one used in this study.

DISCUSSION OF HYPOTHESIS III

> *Screen-reader users will employ a variety of Web navigation techniques that can be described by both qualitative and quantitative measures.*

The goal of the analysis related to Hypothesis III was to combine the quantitative measures from Hypotheses I and II and the qualitative data developed from the think-aloud transcripts using grounded theory in order to create a more complete picture of these screen-reader users' navigation techniques. Using grounded theory as a research methodology provided the basis for an emerging theory of Web navigation for screen-reader users.

Participant #6

Participant #6 was the least experienced of these four users. Although she did not provide many think-aloud comments, she did mention on several occasions that her expectations did not match the content or functionality of the Web sites. For example, on the UEX site, she commented that, "I'm just too used to the UT web site and I would have expected that another site that had classes to be similar to that one since both are UT" (Appendix E, line 82). She also made some suggestions for how the UEX site could be modified to better match her expectations: "I think one thing that it would be neat if they could do it is like when you click on a course that you're wanting to look at or when you pulled up a list of courses, if they have links to the courses to be able to directly register" (Appendix E, line 108).

From her comments, it appears that participant #6 had minimal knowledge of HTML or accessibility. She was frustrated when she had to maneuver past the navigation content repeatedly, saying, "I really wish it wouldn't do that when you click on something everything else comes back up and you have to go get past it all again" (Appendix E, line 38). When the observer asked her specifically if she meant adding skip navigation, she replied, "I don't know, because I'm not real experienced with using it but that might make it less frustrating when using the site" (Appendix E, line 43). Thus, although she was interested in the functionality that skip links could provide, she was unfamiliar with the terminology for this accessibility feature. Her lack of familiarity with skip navigation is in line with the Disability Rights Commission study (2004), which reported that individuals were often unaware of accessibility features in browsers.

One indication of this individual's inexperience was her unwillingness to attempt other navigation tactics to reach the information goal. For example, on the LBJ site, she had reached the page that contained the information goal, but she decided that, "You would have to know what year you were looking for to be able to click on that to find it and that would take too long" (Appendix E, line 143), so she did not complete the information-finding task. She did not use a search or any other navigation technique to attempt to overcome the problem. The limitations of her knowledge of JAWS were also revealed by the relatively few unique searching and scrolling commands she employed.

Identifying the key navigation sequence for this user was somewhat challenging because the action transcripts do not include time stamps for each action; however, the sequence became clear when watching the video of her actions. She tended to use the down-arrow key very slowly to navigate the entire home page of the site, often going all the way to the footer information, then jumping back to the top of the page using Ctrl-home, and then moving back down the page to follow a link. For example, on the LBJ site, she used the down arrow to go through the top navigation, side navigation, main content, and finally the footer at the bottom of the page. She then used Ctrl-home to go back to the top of the page, and then returned to a link of interest using JAWS Virtual Find. On the TMM site she went through the left navigation and some of the main content before using Ctrl-home to go back to the top of the page, then used the down-arrow key to return to the link of interest. On the UEX page she used the down-arrow key to get through the left navigation, then used the up arrow to return to the link of interest.

This description of participant #6's navigation style supports Murphy et al. (2008), who reported that less experienced screen-reader users tended to navigate in a linear manner going line by line from the top of the page to the bottom. These individuals may use this navigation method because they are more concerned about getting lost.

While this method may be time consuming, we suggest that it may result in a fairly clear overview of the page, thereby giving such a user a better understanding of a Web page than can be gained by an individual who uses more of a searching technique.

Participant #20

Participant #20 was both the most experienced participant and the most successful. The average time he spent searching for the information goal was very brief, approximately two minutes. He was the only individual to successfully complete all the tasks. He encountered the fewest number of impasses and never backtracked between pages. He also used either the site search (if available) or JAWS Virtual Find quite frequently.

It was interesting how closely some of his navigation tactics resembled those of participant #6, who was the least experienced individual. For example, both participants had similar ratios of scrolling commands to searching commands, indicating a preference for scrolling commands. They also both used a relatively small subset of unique scrolling and searching commands, which was unexpected because we had anticipated that the more experienced users would use a wider variety of commands. Another similarity between users #20 and #6 was that both took relatively direct paths to the information goal, as demonstrated by the navigation maps. For user #20, this seems to have been the result of making excellent and extremely fast choices when selecting links, as well as using appropriate search terms at the appropriate points in the tasks. The major differences between the two users were (1) user #20 performed a comparatively large number of actual searches, and (2) he set JAWS to a high speech rate (a metric that was not recorded but that can easily be discerned when observing the videos).

As part of the think-aloud protocol, user #20 provided a great deal of commentary about code, markup, site structure, and lack of accessibility features. Several of his comments, such as, “They’ve got quotes, quotation marks inside their alt tags,” “They’re using the headings inappropriately” (Appendix E, line 429), and “Needs some structure on the page, like the skip to content links and the headings links” (Appendix E, line 236), indicate a strong knowledge and understanding of HTML and the proper coding needed to meet accessibility standards such as Section 508. [11] He commented that pages needed better HTML structure, and after performing several information-finding tasks on the SD site, he commented, “I still don’t know what the layout of this site is” (Appendix E, line 253). Looking at the underlying HTML code, it was clear that this site lacked structure.

Participant #20 also commented on several instances where the site did not match his expectations. For example, when looking at courses on the UEX site, he said that he “… would expect there to be links to the descriptions from the registration pages” (Appendix E, line 354). On the home page of the LBJ site, he said, “I didn’t actually see what I wanted” (Appendix E, line 183). Later, he explained this comment in more detail, saying that he “… didn’t see a meaningful tag for what I was looking for so I went to the site map,” (Appendix E, line 185). This indicates that he changed navigation tactics when his expectations were not met.

It appears that participant #20 often had specific content in mind as he was navigating Web pages. He only mentioned this aloud once, when exploring the LBJ site, saying that he was looking for a link, “like, bio, or something like that,” (Appendix E, line 187). However, his frequent use of the search feature demonstrated that he often had

[11] All four participants mentioned skip navigation as an accessibility feature. However, none of the participants in the study used it, even though it was available on all three Web sites with Section 508 compliant home pages. Hudson et al. (2005) also reported that screen-reader users did not use skip links, and Bigham et al. (2007) found that screen-reader users only followed available skip links 5% of the time.

an idea of what he was looking for. For example, after using the Site Search feature on the SD Web site, he then immediately used JAWS Virtual Find on the Search Results page to find the searched-for term within the page, instead of using a scrolling technique (such as the down arrow) to find the search results. This direct approach to accessing the information goal, demonstrated by using both site search and JAWS Virtual Find, can be considered a key navigation sequence.

Participant #20's frequent use of site search and JAWS Virtual Find supports Gerber's (2002) observation that more experienced users tend to search for specific information rather than browsing, as well as the WebAIM survey (2009) where 50% of respondents reported using search whenever it was available. However, when visiting site home pages, participant #20 tended to quickly scan through the top of the page using the down-arrow key, explaining "First I have to see what the site is," (Appendix E, line 175) or "Just listening to this," (Appendix E, line 221). This home-page scanning behavior was also reported in the WebAIM survey, where nearly half of respondents reported reading through the home page, and by Murphy et al. (2008), who reported that more experienced individuals tended to speed-read through a page.

Participant #24

Participant #24 was unique among the users because he was the only one for whom the metrics indicated that he preferred using searching actions to using scrolling actions. He showed an incredible knowledge of JAWS, exhibited by the large number of unique searching commands he used, especially when he had difficulty finding the information goal, such as on the LBJ site. He also demonstrated his accessibility knowledge by providing feedback about code, markup, site structure, and lack of accessibility features. He especially commented about the lack of skip navigation and headings features, and how difficult navigation was when these accessibility features were missing: “There is no skip nav link, there are no headings, so I had to listen to all the navigation stuff in order to get to the part of the page where the information I wanted might be” (Appendix E, line 603). He also suggested some accessibility improvements, such as, “They should ‘quote quote’ that graphic divider” (Appendix E, line 475). Although Craven and Brophy (2003) suggested that expertise with assistive technology should positively impact an individual’s success when completing an information-finding task, participant #24 was only the third most successful overall. In a subsequent interview (Jobst, 2005), he suggested that his knowledge of the assistive technology and accessibility might not always be beneficial because he could spend a lot of time trying to work around an impasse; instead he might be better off using a few commands that work more reliably.

Participant #24 demonstrated two key navigation sequences: using Headings List and using Links List. On the F&I Web site, he used the Links List command twice in a row, on two consecutive pages, to navigate directly to the information goal. Because navigating by headings was one of his preferred methods, he encountered significant problems when headings weren’t available:

> “…there were relatively few headings and on the pages I was most concerned about, … but sort of critical information wasn’t set off with headings so I couldn’t use the headings list to jump to it. But that wasn’t really available as a meaningful way to bypass the navigation.” (Appendix E, line 502)

Participant #24’s navigation style supports the findings of Murphy et al. (2008), who reported that experienced users tended to use Headings List and Links List. Over 75% of the WebAIM (2009) survey respondents reported using Headings List as well, regardless of experience level.

When participant #24 thought he was on the page with the information goal, his navigation tactics changed. For example, on both the F&I site and the SD site, he went to a new page and let JAWS read (including the overview) until he heard the searched-for information. In other words, he made a transition from actively searching for information to passively listening for it, usually by letting JAWS read.

Participant #24 commented frequently about content or functionality that deviated from his expectations. For example, after choosing a link to the search page and not finding a form where he could input his search term, he commented, "So I'm on a search page that doesn't have an input field?" (Appendix E, line 559). When in a Links List dialog box, he mentioned that, "There's some things not showing up in this dialog that I was expecting to find." These comments show specific expectations, some of which are based on prior experience with other Web sites.

Participant #31

Participant #31 tended to stick with a task until it was done, resulting in relatively long average times searching for the information goals. Although he did not use nearly as many unique searching commands as #24, he used more unique searching commands than either participants #6 or #20. He showed a preference for using scrolling commands rather than searching commands. He commonly changed navigation technique mid-page, as evidenced both by the number of within-page impasses he encountered and his comments from the think-aloud protocol. He was very willing to spend time exploring a Web site, as demonstrated by the navigation maps, which show he had the most laborious navigation technique of any of these four users.

Participant #31 was adept at producing the think-aloud protocol while navigating a Web site, which provides a great deal of insight into his information-finding processes.

On almost every site he explored, he made a comment about looking around or getting familiar with the site; for example on the TMM site, he said, “I don’t know how this works so I will start reading over things just to have an idea about it.” (Appendix E, line 899). In fact, this initial exploratory phase, where he listened to JAWS read the page before making a navigation decision, was considered a key navigation sequence for him, and can also be observed in the action transcripts (Appendix F, Tables 54 through 58).

This user often had an idea of what information or link he was seeking on a page. For example, when he first encountered the UEX site after hearing the observer read the scenario, he said, “…those instructions sound like there’s already something set up under continuing education, so I’m going to look for a link that might say something like that” (Appendix E, line 967). When browsing links on the home page of the LENG site, he talked through his options, saying, “Custom courses might be one… Short courses might be another one. Software, no. I’m also looking for something that might say continuing education” (Appendix E, line 1104). However, he also made navigation decisions based on information he had found on the page. For example, on the TMM site, he said, “That might be one, the first one [visiting museum] but if I don’t find one more relevant I’ll go back. I’ll go to that one [visiting museum info]. The ‘visiting’ makes me think it might have some info” (Appendix E, line 902). On the LENG site, when browsing through links, he commented, “OK, this sounds… like something I want” (Appendix E, line 1133) and followed the link he had identified.

Based on his comments, user #31 usually knew what he was looking for, but he preferred to listen until he heard something that matched what he had in mind instead of using searching commands to find it. Thus, listening until he found something that matched what he had in mind was a key navigation strategy for this user. He revealed that he employed this technique because he was concerned he might miss key content or information; for example, when searching through a list of classes on the UEX site, he stated, “I think this will probably start with C but I don’t want to miss anything so I don’t want to go too fast. OK, that might be one, CS… elements of databases. I’m going back to see if I missed any CS or if there was only one” (Appendix E, line 993).

When participant #31 did not find what he was looking using his initial navigation tactic, he had alternative navigation options in mind. For example, when first browsing the home page on the LBJ site, he said, “I’m hoping there’s some kind of a link that says LBJ’s biography or something biography so I’ll look for something like that first… if I don’t find anything quickly I might go to the links” (Appendix E, line 1045). On the SD site, when he couldn’t access the search box by using a keyboard command, he tried another tactic, “But it didn’t work, so what I would do is I will search for a link called search” (Appendix E, line 773). When his second option didn’t work, he tried a third, saying, “…I guess I’ll tab hopefully until I can find it [the search box]” (Appendix E, line 780). His ability and willingness to change navigation tactics mid-page has a strong relationship to the relatively high number of within-page impasses.

Participant #31 provided several suggestions on how to improve Web pages that did not meet his expectations. Like users #6 and #24, some of his expectations clearly were based on previous experiences on specific Web sites, such as The University of Texas at Austin home page (www.utexas.edu). For example, when talking about finding courses on the LENG site, he suggested, “I think they could make it much easier if you just put a link that says courses! Like the main [UT Austin] web site” (Appendix E, line 1159). He also expressed frustration about not coming across information that he expected to find on the LENG site, saying, “… it read everything I think and I didn’t find what I want” (Appendix E, line 1126).

Although user #31 made a number of comments related to code and site structure, these comments were different in nature than the comments made by users #20 and #24. Participant #31 expressed confusion with HTML rather than giving specific suggestions for improving it. For example, on the LBJ site, JAWS began saying ‘block quotes.’ At that point he asked the observer, “What is block quotes?” When the observer asked him whether he knew what block quotes were, he responded, “No I have never heard this. So you think it’s reading code? That it’s not this text?” (Appendix E, line 1060). He also commented on something JAWS read at the top of the UEX page, saying, “There is something here I’ve never heard before, Alt+6, those sound like shortcuts to the links, I’ve never seen that before” (Appendix E, line 972). Also, on the LENG site, he mentioned that, “Some of these web sites, they say weird things, like they read symbols and things like that, and I didn’t notice that on the UT web site, on the main utexas.edu, and I remember on this one it said ‘level’ where it was reading this title here, contact us? It said ‘level 1’ [user lets JAWS read] … heading level 1” (Appendix E, line 1183). In this case, JAWS was reading heading tags, but the user was not familiar with headings and therefore didn’t know what they were. After the observer explained heading markup to him, he said, “The problem that I find with that is that for a normal user who doesn’t know any HTML or anything like this, it doesn’t make any sense” (Appendix E, line 1201). The lack of familiarity with shortcuts to links and heading levels is in line with the Disability Rights Commission study (2004), which reported that individuals were often unaware of accessibility features in browsers.

Although user #31 was apparently not very familiar with HTML, he was familiar with skip navigation, and commented when it was missing. On the SD pages, he mentioned that he had to “read all of those links that I don’t really care about” (Appendix E, line 801), because he did “not have a link that would take me directly to the content" (Appendix E, line 842). On the LBJ site, he commented that, "[I] guess once you get to the content, it's OK, but you have to go through 45 links before you get to that … for every page, exactly, that takes a lot of time" (Appendix E, line 1095). On the LENG site, another site that did not have skip links, he specified, "usually in my case what makes it easy or difficult to navigate is having to go through all of those links or not" (Appendix E, line 1180). So despite his lack of HTML knowledge, it was evident that he was familiar with some accessibility features, specifically skip navigation.

Summary of Hypothesis III

The goal of the analysis related to Hypothesis III was to combine the quantitative measures from Hypotheses I and II and the qualitative data extracted from the think-aloud transcripts using grounded theory in order to create a more complete picture of these screen-reader users' navigation techniques. If we consider in more detail the users' comments related to the four most common categories we extracted using grounded theory, as we have discussed on a per-user basis, we find the core category to be different ways of searching for information: either users have something specific in mind that they are looking for, or they do not. Closely related to this core category is the concept of a mismatch of expectations; that is, if users can't find what they are looking for, or if the site, page, or assistive technology behaves in an unexpected way, then a mismatch has occurred. In the face of a mismatch of expectations, the user may change navigation tactics, but if the user's knowledge of navigation tactics is too narrow, the mismatch may lead the user to give up before finding the information goal. Users may also suggest specific improvements to the Web site to address the mismatch of expectations.

Although there were not enough instances of users confirming the information-finding goal to include it as part of the core categories, it is important to note that several participants did ask the observer to clarify the information goal a number of times. This may indicate a relatively high cognitive load, where the user was unable to keep the details of the scenario in mind while looking for the information goal. In addition, users commented about the relevance of the scenario, or about how well they did or did not identify with it. Several users also mentioned that prior Web experience or prior knowledge of the subject was beneficial in completing the information-finding task. Users also had a number of problems with JAWS and made 15 separate comments about JAWS misbehaving during the scenarios. User #31 even rebooted the computer when JAWS was not functioning as he expected.

In summary, we used grounded theory to analyze the think-aloud transcripts. We found the core category for this study was different ways of searching for information. This is the first time grounded theory has been applied to data from screen-reader users, and we now have an emerging theory that can be empirically tested in future studies. We also used the action transcripts to identify a key navigation sequence for each participant, which provides a short description of how each individual prefers to navigate. These descriptions will help those who are not intimately familiar with how screen-reader users navigate through online information to better understand these users' navigation tactics.

DISCUSSION OF HYPOTHESIS IV

> *When screen-reader users use a Web site that is Section 508 compliant, the overall success rate will be higher, the time spent searching for the information goal will be lower, fewer impasses will occur, fewer actions will be needed to find the information goal, and users will report a more satisfying user experience than when navigating a Web site that is not.*

Hypothesis IV indicates that, in addition to the role that individual characteristics and the user's navigation techniques play in overall success, the Web site itself, especially whether the site is Section 508 compliant, also plays a role in the user's success. For this hypothesis, we evaluated five metrics to compare the Web sites in this study, three of which were Section 508 compliant and three of which were not.

The average task completion rate of the three Web sites that were Section 508 compliant was 88.7%, compared to 72% for the three Web sites that were not compliant. Although this finding was not significant for p=0.10, participants in this study were still more likely to successfully find their information goal when navigating the Web sites that were Section 508 compliant. These results are similar to those found by the Disability Rights Commission study (2004), which reported that screen-reader users completed 67% of tasks on sites with low accessibility ratings, while they completed “almost all” of the tasks on sites with high accessibility ratings.

It took users in this study an average of five minutes longer to complete information-finding tasks on the non-compliant Web sites than on the Section 508 compliant sites. In other words, participants in this study completed information-finding tasks over twice as quickly on the Section 508 compliant Web sites than they did on non-compliant sites, as shown in Figure 12. This difference was found to be significant at p=0.10.

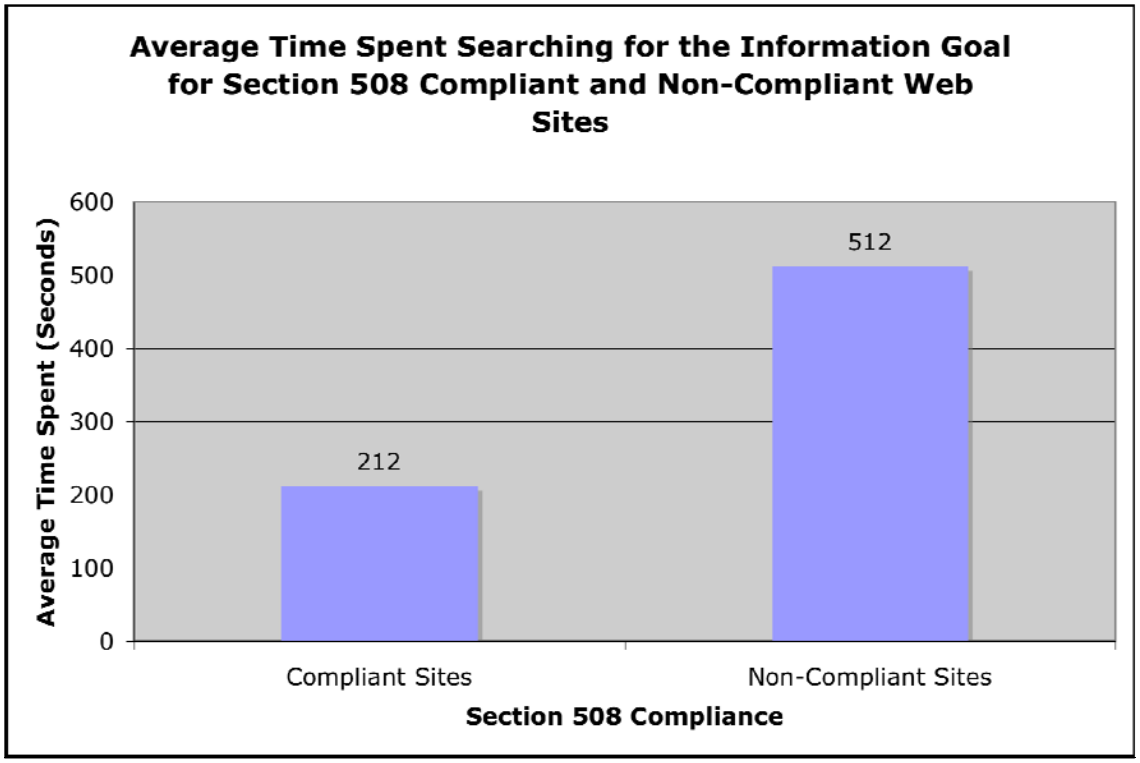


Figure 12: Average Time Spent Searching for the Information Goal for Section 508 Compliant and Non-Compliant Web Sites

Screen-reader users in this study encountered nearly five times more impasses on non-compliant Web sites than on compliant sites; however, the difference was not significant at p=0.10. Participants also performed nearly four times as many actions when using non-compliant sites than when using Section 508 compliant Web sites, as shown in Figure 13. This difference was shown to be significant for p=0.10.

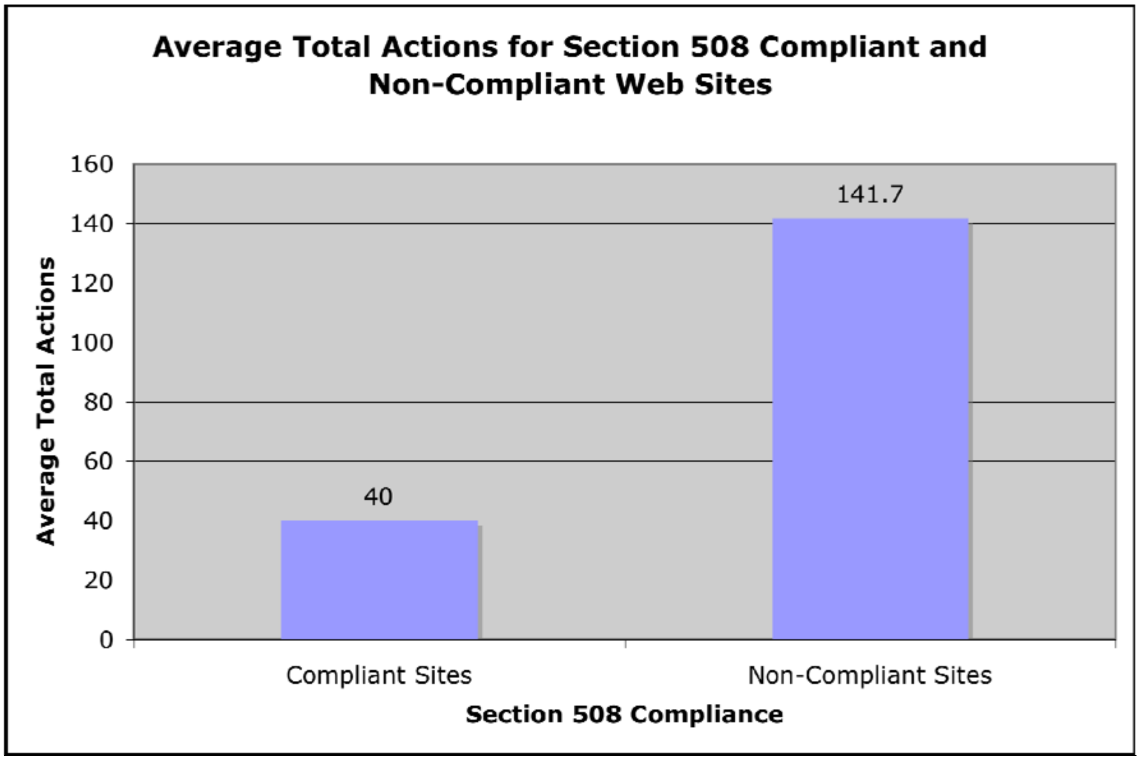


Figure 13: Average Total Actions for Section 508 Compliant and Non-Compliant Web Sites

The screen-reader users in this study used about 10% more scrolling actions on Section 508 compliant sites then they did on non-compliant sites, where they used about 10% more searching actions. This difference in the type of action used to locate information on these sites may indicate that users were not able to get all the information they needed to from scrolling through the page, and were therefore attempting to overcome within-page impasses by using more searching actions.

After each information-finding session, users were asked to answer seven questions designed to rate user satisfaction (see Appendix B for a list of all the questions). Question 5, “This is the type of site I would visit on my own,” was removed from the calculation of the average user satisfaction rating, because it did not have any bearing on overall user satisfaction. The comparison of user satisfaction and Section 508 compliance is shown in Figure 14.

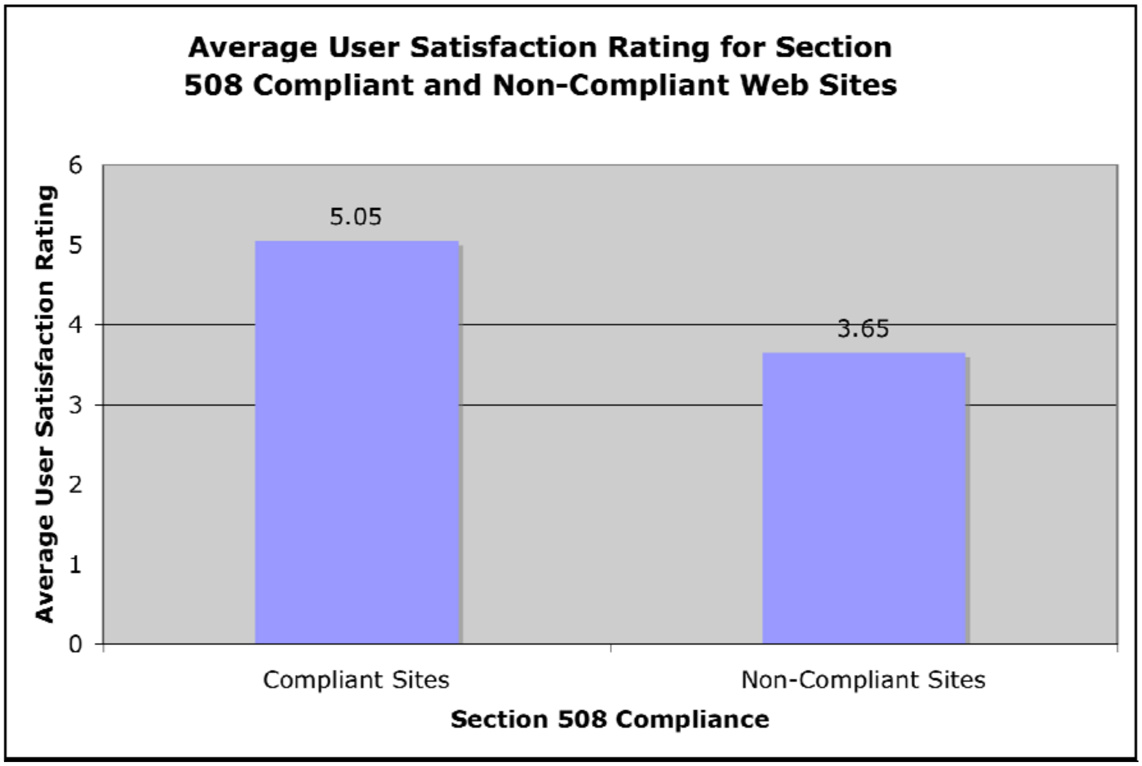


Figure 14: Average User Satisfaction Rating for Section 508 Compliant and Non-Compliant Web Sites

Participants gave Section 508 compliant sites an overall satisfaction rating of 84%, while non-compliant sites only received a 61% satisfaction rating. This difference was shown to be significant at p=0.10.

Summary of Hypothesis IV

In summary, this is the first study to compare how compliance with Section 508 guidelines affects screen-reader users. [12] We found that the three Web sites with Section 508 compliant home pages outranked the non-compliant Web sites on each of the five metrics. These differences were found to be significant at p=0.10, in favor of the Section 508 compliant sites, for user satisfaction rating, number of actions performed, and average time spent searching for the information goal. Although these results indicate the importance of Section 508 compliance, there may be other factors not discussed in the context of this study that also play a role in successful information finding, such as the task, the complexity of the site, and how deep the information goal is located within the site. Therefore, we recommend that strict Section 508 compliance should not be the sole indicator of user success with a site.

[12] Other studies, such as the report by the Disability Rights Commission (2004), focused on evaluating sites that were compliant with the WCAG 1.0 guidelines, which are similar but not identical to the Section 508 guidelines.

8. Conclusions

In this dissertation, we have presented data from a study of four screen-reader users navigating the Web. We have used both quantitative and qualitative techniques to explore the following research questions:

- What navigation techniques do screen-reader users use to navigate the Web, and how can we define them?
- Does user experience affect navigation techniques or success, and if so, how?
- Are information-seeking techniques similar to those used by sighted individuals?
- Does compliance with Section 508 guidelines improve the overall success in an information-finding task?

Our data has addressed these questions and has provided insights into some specific Web navigation techniques of screen-reader users. The study has also been a milestone in accessibility research for several reasons. It is the first to compare Section 508 compliant and non-compliant sites for screen-reader users. It marks the first time grounded theory has been applied to data from screen-reader users. It is also the first time Web navigation models of sighted individuals have been applied to screen-reader users.

Key contributions of this study include quantified definitions of user experience, success, and navigation technique. We defined overall user experience as the combination of years of computer experience, years of Web experience, and number of hours spent per day using a computer. We defined a successful Web experience as one where the information-finding task is completed relatively quickly with few impasses. We defined navigation technique as a combination of the types of actions used (scrolling or searching), the number of impasses encountered, the time spent searching for the information goal, and whether or not the task was successfully completed. We compared both overall experience and overall success to the navigation techniques of the individuals in this study.

The four screen-reader users in this study displayed a surprising variety of Web navigation techniques, supporting the findings of both Malone (2004) and the WebAIM (2009) survey. Based on Gerber (2002) and Murphy et al. (2008), we hypothesized that more experienced users would use more searching actions, such as Links List, Headings List, and JAWS Virtual Find, than scrolling actions. However, this was not necessarily the case in this study. The second most experienced individual was the only one to use more searching actions than scrolling actions. The other three users, including the most experienced user, preferred scrolling to searching for the majority of their navigation actions. Because of the overwhelming success and efficiency of the most experienced user, who used over 70% scrolling actions, predominant usage of searching actions does not necessarily appear to be a hallmark of an experienced user. However, the most experienced user did use site search (when available) or JAWS Virtual Find to navigate directly to the information goal, so perhaps using these specific search functions is a better indicator of experience than is the use of searching actions in general.

We expected that more experienced individuals would use a greater variety of commands, due to their greater knowledge of the assistive technology (Craven and Brophy, 2003). However, during these sessions, both the most and least experienced participants used a very limited number of commands. In subsequent interviews with the most experienced user (Jobst, 2005), he indicated this was because he had found that many Web pages did not have the proper structure to support the use of more complex JAWS commands, so he used the subset of commands that he could rely upon. In the case of the least experienced user, she may have used a small set of commands because she was not yet familiar with all of the commands that were available, or because as a less experienced individual she preferred to navigate in a linear manner, as reported by Murphy et al. (2008), a strategy that requires very few commands. Both the second and third most experienced individuals both used a wider variety of commands; in the case of the second most experienced user, we believe this is because of his overall knowledge of the assistive technology (Jobst, 2005).

Another metric we explored was the number of impasses, or problems finding the information goal, that the participants encountered. While the most experienced individual encountered the fewest impasses, the second and third most experienced users encountered the greatest number of impasses. We suggest this is because these individuals felt that their repertoire for overcoming impasses had many navigation techniques, as exhibited by the overall larger number of unique scrolling and searching commands they used. The least experienced user encountered a relatively small number of impasses. This may be because she used a slow, methodical navigation technique that reduced her chances of becoming lost, a situation that can be difficult for less experienced users to overcome (Barry, 1998).

We expected that more experienced individuals would be more successful overall; however, this was not necessarily the case. In fact, the least experienced individual was the second most successful. Thus, based on our definition of experience and success, experience does not appear to guarantee a successful outcome, nor does lack of experience predict a less successful outcome. However, the metrics for both experience and success can be improved. The experience metrics should also consider the type of experience, for example, experience with assistive technology, as well as knowledge of accessibility and coding experience. In addition, measuring the time it takes to find the information goal and using that as a metric for success can give a skewed result when participants are asked to use the think-aloud protocol while they are navigating to the information goal, a problem identified by Strain et al. (2007). One of the participants provided a significant amount of feedback via the think-aloud protocol, which we believe negatively affected his time on task and therefore his overall success measure. Using a different think-aloud protocol option could provide better time spent on task metrics, while still providing valuable think-aloud information.

When comparing these results to the navigation metrics reported in studies of sighted users, we found that the two most experienced individuals used about three times as many searches as reported for sighted users, whereas the two least experienced users used approximately the same number of searches as sighted individuals (as reported by Kari (2004)). The screen-reader users in this study tended to follow hyperlinks about 10-20% more than did sighted users. However, their use of the back button was lower than what has been reported for sighted users. Even the least experienced user, who used the back button the most frequently, used it from 10-25% less often than has been reported for sighted users. We also discovered that backtracking, following hyperlinks, and searching account for only 30% of total actions for screen-reader users, compared to an average of 85% for sighted individuals (Catledge and Pitkow, 1995; Kari, 2004). This means that about 70% of screen-reader users' actions are spent on within-page navigation.

Participants in this study exhibited a very linear style of navigation. They spent little to no time exploring the Web sites, except in situations where they explored a page and then returned to the previous page using the back button. Contrary to Herder and Juvina (2004), who reported that more experienced sighted individuals used more laborious navigation styles, the most experienced individual in this study used the most direct, shortest path, which is the “flimsiest” navigation style of all. There are many possible explanations for why this user preferred his style of navigation: (1) perhaps it was the most efficient strategy, (2) perhaps a direct navigation style helped mitigate his disorientation, (3) perhaps this style of navigation was context-related, (4) perhaps the navigation was simpler because the tasks were well-defined, or (5) perhaps the navigation sequences he needed in order to find the information goals in this study were too short or too simple to provide the opportunity for laborious navigation. Although this study's findings regarding the use of a flimsy navigation style supports the hypothesis about navigation style suggested by Petrie and Kheir (2007) and Leuthold et al. (2008), more research is needed to determine whether screen-reader users prefer flimsy navigation, or if this phenomenon was specific to the context of this study and screen-reader users prefer a more laborious navigation style that includes probing, as suggested by Bigham et al. (2007).

In addition to using quantitative metrics to analyze screen-reader users' navigation techniques, we used grounded theory to analyze comments collected via the think-aloud protocol. We discovered that the core category in the context of this study related to different ways of searching for information, that is, whether users have something specific in mind as they search for the information goal. If they do not have something specific in mind, they may use information found on the page to make navigation decisions. If users cannot find what they are looking for, or if the site, page, or assistive technology behaves in an unexpected way, a mismatch of expectations occurs. This sometimes leads the user to change navigation tactics, but if the individual is not familiar with a wide variety of navigation tactics, the mismatch may prevent the user from finding the information goal. During the think-aloud protocols, some participants suggested improvements to address the mismatch of expectations.

We analyzed the action transcripts from each session to look for key navigation sequences that characterize an individual's navigation technique, then combined these key action sequences with quantitative information to create short narrative descriptions of each person's technique. The most experienced participant, #20, usually knew exactly what he was looking for and used JAWS virtual find or the site search feature to access the information he wanted, as demonstrated by his relatively high percentage of actual searches. He consistently navigated directly to the information goal, as can be seen from his navigation maps. Although he used a small set of unique commands that primarily consisted of scrolling actions, he was extremely successful and very quick when locating the information goal. His think-aloud comments demonstrated his knowledge of both accessibility requirements and HTML code.

The least experienced participant, #6, was unique because of her slow use of the down-arrow key to navigate through the entire home page of the site. She would then return to the top of the home page and navigate to the link she wanted to follow. Murphy et al. (2008) also described this navigation technique as being used by less experienced individuals. She used a small set of unique commands, and the majority of her actions were scrolling actions. She also seemed to have difficulty changing navigation techniques, perhaps because of her limited knowledge of the assistive technology. Despite her lack of experience, she was the second most successful individual in this study.

Participant #24 was unique in many ways. He was the only individual who preferred to navigate using searching actions, which is evident by the number of times he used headings lists and links lists in the action transcripts. Murphy et al. (2008) also reported this navigation technique being used by more experienced individuals. He employed a wide variety of navigation techniques, as shown by the large number of unique commands we recorded. However, he was not always successful with these navigation techniques, given that he was the third most successful individual in this study. Although Craven and Brophy (2003) suggested that expertise with assistive technology should positively impact an individual's success when completing an information-finding task, participant #24 mentioned in a subsequent interview (Jobst, 2005) that his knowledge of assistive technology and accessibility might not always be beneficial because he could spend a lot of time trying to work around an impasse; instead he might be better off using a few commands that work more reliably. His think-aloud comments indicated a clear understanding of accessibility features, such as use of headings, that support his navigation style.

To navigate, participant #31 preferred to listen as JAWS read much of a page's content before making a navigation decision, a navigation technique that was also reported by respondents in the WebAIM (2009) survey. He knew and used a variety of searching commands, but even so would often use scrolling commands to listen to much of the page, and the majority of the commands he used were scrolling commands. He was the only participant to exhibit a laborious navigation style, and his navigation maps show use of the probing technique suggested by Bigham et al. (2007). Although participant #31 was the least successful individual in this study, this may be due to the metrics we used to define success and the experimental set-up rather than because he used an inefficient navigation technique. For example, he provided a significant amount of verbal feedback during testing, which Strain et al. (2007) noted could contribute to spending a longer amount of time on task, especially for screen-reader users. Participant #31 tended to explore sites extensively in an (often tenacious) effort to find the information goal, again increasing his time spent searching for the information goal and decreasing his overall success ranking.

When considering how Section 508 compliance affects the use of Web sites, for every metric we analyzed, the three Web sites with Section 508 compliant home pages outranked the non-compliant Web sites. Average task completion rate was 16% higher, users required an average of five minutes less to find the information goal (significant at p=0.10), and users encountered one-fifth as many impasses on the Section 508 compliant sites. In addition, users performed nearly one-quarter as many actions on the compliant sites (significant at p=0.10) and had a satisfaction rating 20% higher on the Section 508 compliant sites (significant at p=0.10). These findings were similar to those reported by the Disability Rights Commission study (2004), and clearly demonstrate the importance of Section 508 compliance for screen-reader users. Other factors not discussed in the context of this study that may also influence successful information finding include the complexity of the site, how deep the information goal is located within the site, and the overall usability of the site. Therefore, strict Section 508 compliance should not be the only metric used to evaluate a Web site.

The practical implications of this research are myriad and affect many. Our improved understanding of the most effective navigation techniques could be used to develop training for screen-reader users, thereby improving their navigation techniques and success when accessing information online. Web developers should take special note of this research, especially the descriptions of each participant's navigation style and key navigation sequences. Understanding screen-reader users on a more personal level will enable Web developers to progress from developing sites that are merely technically accessible to developing sites that not only comply with accessibility guidelines but that truly support screen-reader users' navigation styles. On-line businesses would do well to note the mounting evidence, supported by this study, that screen-reader users are more likely to be successful when using a Web site that is Section 508 compliant. Even the companies that develop screen readers, such as Freedom Scientific, should consider how this research can be used to improve future versions of screen readers such as JAWS so that these products better support the end user's navigation techniques.

FUTURE WORK

In many ways, this study has generated as many questions as it has addressed, and we have developed several ideas for future studies:

- We did investigate how user experience affected navigation tactics and overall success, but in future studies we recommend exploring other individual differences. For example, it would be interesting to study whether cognitive/learning style and spatial skills affect Web usage among screen-reader users, and whether diagnostic tests appropriate for these users could be developed. Other individual differences, such as personaliy, experience with different types of computer use (recreational or work-related), and whether the individual is congenitally or adventitiously blind, might be easier to study since special diagnostic tests are not needed to define these differences.
- We now have a greater understanding of the different navigation tactics of screen-reader users. We recommend conducting detailed analysis of within-page navigation tactics and perhaps even developing a model of within-page tactics similar to the one created for sighted individuals by Katajima et al. (2000).
- Participants in this study appear to use a flimsy navigation style, and we suggested several reasons why this might be. To understand whether flimsy navigation styles are actually the preferred navigation style of screen-reader users, we suggest designing an in-situ study with no pre-set scenarios, so that paths to various information goals are not artificially short.

- One of the core concepts of the emerging theory developed in this study was the concept of a mismatch of expectations, where the page, site, or assistive technology behaved in an unexpected way. We suggest using critical incidence analysis to examine these mismatches in more detail, since encountering such a situation can lead a user to change navigation tactics. We expect that understanding these mismatches of expectation can lead to empirically-based guidelines that could prevent these types of mismatches from occurring in the first place.
- Comparing how users performed on Section 508 compliant Web sites compared to sites that were not compliant led us to further questions about how accessibility features affect navigation. We recommend a study to explore whether the availability of defined levels of accessibility compliance, such as the levels defined in WCAG 2.0, affect the navigation techniques of screen-reader users. We would also like to explore whether different genres of Web sites, for example e-commerce or news sites, lead to different navigation strategies.

Experiences during this study have also led us to several recommendations for future studies involving screen-reader users. These recommendations include:

- Gather more granular individual keystroke data, with time stamps. Such data could then be analyzed quantitatively to show the difference between a slow, deliberate navigation style (such as that shown by participants #6 and #31) and a faster, more direct navigation style (such as that shown by participant #20).

- Collect other types of user demographic data, including knowledge of the assistive technology, familiarity with accessibility guidelines, and coding experience. These may be important factors for defining user experience.
- Use the modified stimulated retrospective think-aloud protocol (Strain et al., 2007) so that metrics such as time searching for the information goal are not adversely affected.

SUMMARY

We discovered that among the four individuals in this study, user experience was not necessarily indicative of a successful information-finding experience. As individuals, their navigation techniques varied widely; as a group, they generally searched more frequently and used the back button less frequently than has been reported for sighted individuals. Screen-reader users in this study followed a more flimsy, linear navigation style and generally used scrolling actions rather than searching actions. When using a Web site that has a Section 508 compliant home page, we found that the screen-reader users in this study were able to complete information-finding tasks significantly more quickly, use significantly fewer actions, and report a more significantly more satisfying information-finding experience (significant for p=0.10). They are also more successful and encounter fewer impasses (not significant for p=0.10). Using both quantitative and qualitative measures was critical in this study: the quantitative metrics allowed us to compare values and the qualitative data provided additional insight into individual differences as well as allowing a deeper understanding of the quantitative data.

The information from this study contributes to the growing body of knowledge about screen-reader users. It will benefit the research community as well as the worldwide community of Web developers, designers, and users.

9. Appendices

Appendix A – Demographic Data

At the beginning of each testing session, participants were asked to complete a short demographic survey. For screen-reader users, the survey was read aloud and the observer recorded the participant’s responses, as shown in Table 30. The survey questions appear in the leftmost column in the table.

Question	Participant #6	Participant #20	Participant #24	Participant #31
Age	21 yrs.	32 yrs.	50 yrs.	29 yrs.
Sex	F	M	M	M
Hand preference	R	L	R	R
Visual impairment	Blind	Blind	Retinitis pigmentosa. No useful image in right eye, left eye 2 degrees of vision. 20/100 corrected but blurry and broken up.	3 degrees of vision in left eye, hand motion in right eye.
University education	4 yrs.	14 yrs. / ABD	8 yrs. / Ph.D.	6 yrs. / Masters
Area of study	Psychology	Anthropology	American literature	Accounting
How many years have you used a computer?	3 yrs.	15 yrs.	9 yrs	8 yrs
How long do you use the computer for each day, and what do you use it for?	use up to 4 hrs. day to get info	8-12 hrs/day for academic, personal, finance, shopping prof'l research	often all day for everything, email, research administrative to teaching	95% of time for many things, email, research, pictures, work, communicating, databases
PC or Mac?	PC	Both	Both	PC
OS used	Windows 98	Windows XP	Windows XP	All since Windows 95
Assistive technology used	JAWS, Braille Lite	JAW, Kurzweil 1000	Jaws since 1996, Kurzweil 1000 since 1989	JAWS 3.71, Kurzweil 1000
Browser family used	IE	IE, Netscape Navigator, Lynx	IE, Netscape Navigator, Opera	IE, Netscape Navigator, Opera
Browsers used in the past	IE	IE, Netscape Navigator, Lynx	IE, Netscape Navigator, Opera	IE
Browser version currently in use	IE 5.0	IE 6.0	IE 6.0	IE 5.5
How long have you used this browser?	3 yrs.	10 yrs +	10 yrs.	7-8 yrs

Table 30: User Demographics

APPENDIX B – USER SATISFACTION RATINGS

After each participant finished navigating each Web site, he or she was asked to rate a series of statements on a Likert scale from one to seven, with one being "strongly disagree" and seven being "strongly agree," as shown in Table 31. Q5 was removed from calculations since it had no bearing on this study.

Questions:
Q1. This site was easy to navigate.
Q2. I could effectively complete all the tasks.
Q3. The general layout of the site was easy to learn.
Q4. My overall experience with the site was positive.
Q5. This is the kind of website I would have visited on my own.
Q6. The site was aesthetically pleasing.
Rating Scale:
1- Strongly disagree
7-Strongly agree

Table 31: User satisfaction questionnaire

Tables 32-35 show the responses for each question for each participant. Web sites are denoted using the following abbreviations (also shown in Table 2):

- University Extension Evening Credit Courses – UEX
- Texas Memorial Museum – TMM
- LBJ Library and Museum – LBJ
- Center for Lifelong Engineering Education – LENG
- StarDate – SD
- Department of French and Italian – F&I

#6	Q1	Q2	Q3	Q4	Q5	Q6
UEX	3	2	4	4	5	6
TMM	5	2	6	6	2	6
LBJ	3	1	1	2	1	3

Table 32: Participant #6: Responses to user satisfaction questionnaire

#20	Q1	Q2	Q3	Q4	Q5	Q6
UEX	6	7	6	5	6	4
LENG	2	3	2	2	1	2
SD	3	4	4	6	6	6
F&I	6	7	5	6	6	4
LBJ	5	6	3	5	5	5

Table 34: Participant #20: Responses to user satisfaction questionnaire

#24	Q1	Q2	Q3	Q4	Q5	Q6
LENG	3	3	2	3	1	3
SD	4	5	5	4	5.5	4
F&I	4	4	4	4	4	2.5
LBJ	1	2	4	2	7	1

Table 35: Participant #24: Responses to user satisfaction questionnaire

#31	Q1	Q2	Q3	Q4	Q5	Q6
UEX	6	5	6	6	5	5
LENG	4	4	4	4	3	2
SD	5	5	6	5	3	6
TMM	6	6	6	6	3	6
LBJ	4	3	5	3	3	6

Table 36: Participant #31: Responses to user satisfaction questionnaire

APPENDIX C – SECTION 508 RATINGS

The six Web sites used in this study were chosen from a group of 407 Web sites from the University of Texas at Austin. Of the six sites, three had Section 508 compliant home pages and three did not. Table 37 shows how each site's home page was rated on each of the 17 Section 508 criteria. P indicates that the page passed the criteria, X indicates that the page did not pass the criteria, and N indicates that the criteria was not applicable to the page. If a page passed all criteria, it received an overall rating of "Compliant", and if the page did not pass one criterion or more, it received an overall rating of "Non-complaint."

508 criteria

URL	a a	a m	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	Overall
Section 508 Compliant Home Pages Texas Memorial Museum (TMM)																		
www.tmm.utexas.edu	P	N	N	P	P	N	N	N	N	N	N	N	N	N	P	P	N	Compliant
Department of French and Italian (F&I)																		
www.utexas.edu/cola/depts/frenchitalian	P	N	N	P	P	N	N	N	N	N	N	N	P	N	N	P	N	Compliant
University Extension Evening Credit Courses (UEX)																		
www.utexas.edu/cee/uex	P	N	N	P	N	N	P	N	N	N	N	N	N	N	N	P	N	Compliant
Non-compliant Home Pages Center for Lifelong Engineering Education (LENG)																		
lifelong.engr.utexas.edu	X	N	N	P	P	N	N	N	N	N	P	N	P	N	X	X	N	Non-compliant
StarDate (SD)																		
www.stardate.org	X	N	N	P	N	N	N	N	N	N	N	N	N	N	X	X	N	Non-compliant
LBJ Library and Museum (LBJ)																		
www.lbjlib.utexas.edu	X	N	N	P	N	N	N	N	N	N	N	N	N	X	X	X	N	Non-compliant

Table 37: Section 508 ratings

APPENDIX D – SCENARIO SCRIPTS

Participants in this study were asked to complete information-finding tasks on each of six University of Texas Web sites. This appendix includes the scripts that the observer read aloud to each screen-reader user to describe the first information-finding scenario for each Web site. Participants were asked to complete as many scenarios as possible during the testing session; however, not every participant encountered every Web site.

Script for LBJ Web Site (LBJ) Scenario

"You think that Lyndon Banes Johnson was a great leader and people have told you neat things about the library and museum here at UT. You decide to take a look at the museum's Web site to learn more about it. When did LBJ get married?"

Script for Star Date Web Site (SD) Scenario

"Outer space has always sparked your interest and you like keeping yourself up-to-date on anything new and exciting in the world of astronomy. Find a radio program about Skylab."

Script for Center for Lifelong Engineering Education Web Site (LENG) Scenario

"You're an engineer and in these tough economic times you want to be sure you can set yourself apart from others in your field. The Center for Lifelong Engineering Education offers continuing education opportunities for engineers as well as engineering students and faculty. You are always looking for new and interesting courses to take to make sure you get experiences that others do not. In order to expand your skills, you decide to enroll in a class on software programming. Find a class you can take that is less than $500."

Script for University Extension Evening Credit Courses Web Site (UEX) Scenario

"You are a recent graduate of UT with a bachelor of science in mathematics and are working for the next couple of years to earn money for graduate school. You're interested in computers and programming and want to take some continuing education classes to prepare for graduate school. You have heard that UT's continuing education department offers a specialized program in computer programming."

Script for French & Italian Web Site (F&I) Scenario

"You are proficient in Italian as well as French and are considering a graduate program in either of those fields. You decide to look at the University of Texas at Austin to see what options for graduate work you have there. Find out if an Italian graduate program is available."

Script for Texas Memorial Museum Web Site (TMM) Scenario

"You have always been interested in the natural sciences since you were young. Every now and then you satisfy your curiosity by visiting the Texas Memorial Museum. You're due for another visit soon. If you want to visit the museum this weekend, and you're going by car, how much will it cost to park?"

Appendix E – Transcript of Think-Aloud Protocol

During the testing sessions, participants were asked to "think aloud," or talk about the navigation choices they were making and their thought processes as they navigated through the Web site. This appendix is a transcript of each of the participant's comments for each Web site that he or she encountered, as well as any observer comments. The transcripts also include the responses and comments made by participants during the post-task user satisfaction survey, which was read aloud for screen-reader users. Due to time constraints, not all participants encountered all of the Web sites. Web sites were presented in random order to each participant.

The transcripts were analyzed using grounded theory techniques. In this appendix, memos are indicated by underlined text, and footnotes are used to denote our memos. Then, concepts within the memos were grouped together to form minor categories. Each underlined section of text was organized into these categories, and then we searched for overarching themes that denoted a key category.

For ease of reference, each line of the transcript is numbered.

Transcript of Participant #6

Texas Memorial Museum (TMM)

Observer: (reads scenario from Appendix D)

#6: OK. (stops JAWS)

Observer: So what would be your answer to that question, how much does it cost to park?

#6: My answer would be free because I would take the bus[13]! (laughs)

Observer: OK, but if you were driving…

#6: If I was driving I wouldn't make it! I guess I … (listens to JAWS). Basically it sounds like it's saying that… it doesn't sound like it costs on the weekends.

User satisfaction survey questions:

Observer: So that's going to complete our tasks for the Texas Memorial Museum. I have a couple of questions I would like to ask you. This questionnaire gives you an opportunity to tell us your reactions to the Web site. Please think about all the tasks you just performed as you answer these questions. I'll read each statement to you and you can indicate how strongly you agree or disagree. On a scale from one to 7, with 1 being strongly disagree and 7 being strongly agree, please rate the following.

This site was easy to navigate. 1 is strongly disagree, 7 is strongly agree.

#6: 5

Observer: Do you have additional comments about what could have been better or what was bad?

[13] Scenario doesn't have much to do with this user's real-life situation

#6: I think the only thing with the site is if you wanted to that online thing it would have been hard to find it but maybe, me not finding the other things wasn't really the site it was just…

Observer: Right, so it was hard to find the donation form?

#6: Yeah.

Observer: So any other reasons as to why it was hard to find the donation form or other feedback at all?

#6: Not really, just the search function wasn't working too well[14].

Observer: Ok, the search function wasn't working for you. Alrighty. How about this one:

I could effectively complete all the tasks. 1 is strongly disagree, 7 is strongly agree. (long pause) In your opinion?

#6: 2

Observer: Do you have any additional feedback, what things that could have made it easier? Could have helped you complete the task better? Anything you can think of?

#6: Well there's the fact with all Web sites but I really wish it wouldn't do that when you click on something everything else comes back up and you have to go get past it all again[15].

Observer: So you'd like a skip nav or something to skip to the navigation links or…?

#6: Yeah. Well, I don't know, because I'm not real experienced with using it but that might make it less frustrating when using the site[16].

[14] Search did not match expectations

[15] User has no way to skip navigation

Observer: If you just had a way to easily navigate through all the various links. Ok, good.

Ok, how about this one: the general layout of the site was easy to learn. 7 is strongly agree.

#6: I think, 6.

Observer: Any additional feedback there?

Ok. My overall experience with the site was positive. 7 is strongly agree.

#6: 6.

Observer: OK. Any other feedback about the site at all? Oh wait, I've got two more for you.

This is the kind of Web site I would visit on my own.

#6. Ummm… 2.

Observer: Ok, and any comments as to why you would not generally go to this sort of Web site? Is visiting a museum not your forte?

#6: Yeah, no, not really.

Observer: And how about one more… The site was aesthetically pleasing, as far as, I mean, we know you can't see the screen, but was the layout pleasing to you.

#6. Yes, 6.

Observer: Ok, good deal.

University Extension Evening Credit Courses (UEX)

Observer: (reads scenario from Appendix D)

#6: Am I looking for a specific thing[17]?

Observer: No you're just looking for something in fall 2003.

---

[16] User is not familiar with skip nav but knows she would like to be able to skip repeated content

[17] Clarifying task

#6: Let me go to the top and try something else[18].

Observer: OK.

#6: Ok I found one.

User satisfaction survey questions:

Ok, same scale, 1 to 7.

This site was easy to navigate.

#6: 3

Observer: Ok, Any comments or things that could have made it better?

#6: It was clear. If the, if the… um… I don't know how to say it… I guess, if the links had been clearer[19].

Observer: More descriptive?

#6: Umm-hmm.

Observer: Anything else you can think of? Or something that could help you effectively complete the tasks, do the tasks better?

#6: I think I'm just too used to the UT web site and I would have expected that another site that had classes to be similar to that one since both are UT so it just frustrated me that it wasn't like… um, it wasn't set up the same[20].

Observer: Right, right, OK.

Well, from 1-7, I could effectively complete all the tasks

#6: 2

Observer: Ok. The general layout of the site was easy to learn?

#6: 4

---

[18] Trying another navigation technique
[19] Links were confusing
[20] Expectations based on previous experience

Observer: Ok, kinda goes back to the more descriptive links thing? Is there anything else that could be done to make it more easier?

#6: I think it's mostly just the links.

Observer: Ok. How about, my overall experience with this site was positive. 1-7.

#6: 4

Observer: Ok. Again, if you have any extra comments, just let me know!

This is the kind of web site I would visit on my own. 1-7

#6: I wouldn't have before but it gave me an idea. Like if, I wouldn't have before but it gave me an idea, cause I didn't even know about it.

Observer: Could be something you use in the future? Right, OK, so from 1 to 7 what would you say to this is the kind of site I would use.

#6: Um, 5

Observer: How about, aesthetically pleasing? Did you like the way the site was set up basically? 1-7.

#6: 6

Observer: Any other comments you can think of? Anything else you can add that you'd like to see different? Changes that could make this just a little better surfing experience for you?

#6: Um, I think one thing that it would be neat if they could do it is like when you click on a course that you're wanting to look at or when you pulled up a list of courses, if they have links to the courses to be able to directly register[21]?

Observer: Right, OK.

[21] Suggestion based on expectations

#6: Instead of having to write down and remember all the course stuff[22] and then...

Observer: Right OK.

LBJ Library and Museum (LBJ)

Observer: (reads scenario from Appendix D)

#6. Hm. (goes back to top of page)

Observer: Let's stop real quick. I'm not sure what happened but we got off onto another Web site, we're not even on the LBJ Web site any more. I don't know what happened but at some point we got swapped over. So if you could, let's just go back to that original URL (reads URL).

Yeah, I know, it's frustrating… so we're looking for, when did LBJ get married.

#6: Yeah, I though I'd find the archive and then I was gonna just look at the site index[23] and see what all...

Observer: You know it might be possible to find it there there's a ton of information there. But we're trying to find that on the LBJ site.

#6: But this is what I meant, the site index (listening to Site Index link), right there, and that is the LBJ site[24].

Observer: OK this is not where we were a second ago. I don't know how we got there.

#6: Heh (laughs).

Hm. (listening to the site index).

You'd have to know what year you want[25]!

[22] Writing things down is not practical for a blind user. This could be a lot of information to remember.
[23] User had an idea of what she was going to do
[24] User was on the wrong site before, but that's not clear to her. User was lost.
[25] User is listening to all the years but doesn't know what year is the right one

Observer: If you came across something like this at home is there anything you would try? I mean, you're trying to find out when LBJ got married.

#6: See none of these sound like it would BE under that because… see that's what I thought, when I found the biographical chronology thing I thought that would be a good site because, or a good link[26] because…

Observer: But when you got to the chronology page what did you find? What made you change your mind?

#6: All the years.

Observer: I'm sorry, what?

#6: I found the different years and you would have to know what year you were looking for to be able to click on that to find it and that would take too long[27].

Observer: So there was just too much information right?

#6: Mmm-hmmm.

Observer: I'll tell you what, let's go on to the next task.

User satisfaction survey questions:

Observer: 1-7, this site was easy to navigate.

#6: 3

Observer: Ok, you've given me some information about why it was hard to navigate, do you have anything you would like to add.

#6: I think I told you most of it.

Observer: Ok, how about I could effectively complete the tasks, 1-7.

#6: 4

[26] User had something in mind that she was looking for and was expecting something else

[27] User does not know how to access the information, to her it would take too long to read through all that info

Observer: The general layout of the site was easy to learn.

#6: 1

Observer: Ok, my overall experience with the site was positive.

#6: 2

Observer: Alright. This is the kind of web site I would visit on my own.

#6: No. 1

Observer: And that goes back to not a museum type of person.

The site was aesthetically pleasing.

#6: 2.

Transcript of Participant #20

LBJ Library and Museum (LBJ) Web Site

Observer: (reads scenario from Appendix D)

#20:OK.

Now you didn't actually tell me to … usually they say to peruse the site for a minute first. OK

When did LBJ get married, is that what I'm supposed to be looking for[28]?

Observer: Right.

#20: Ok, so we're looking for when did LBJ get married.

Well right, let's see. (listening to links)

First I have to see what the site is[29].

Well that didn't help[30]. (referring to the Site Index page)

Ok. (hits enter)

November – whatever - 17th 1934.

User satisfaction survey questions:

Observer: This site was easy to navigate. 7 is strongly agree.

#20: I'd say about a 4 or a 5. Maybe a 5. It's not bad once you get to the site map[31], I don't know how you would do it other than that. I might have been cheating but (laughs). I don't usually go to site maps until I get frustrated with everything else but I didn't actually see what I wanted[32]. Um, the fact that I didn't see anything in the tabs or whatever you want to call it, um, I didn't see a meaningful tag for what I was looking

[28] Confirming task
[29] Getting overview of site
[30] Something didn't work
[31] User likes the site map
[32] Had something in mind but couldn't find it.

for[33] so I went to the site map[34]. It was probably under exhibits or something but, like, bio, or something like that[35], but it didn't seem to pop out at me there.

Observer: OK.

#20: But once you got to the site map it was very easy[36].

Observer: Ok. So, I could effectively complete all the tasks. 7 is strongly agree.

#20: Um, I'd say 6.

Observer: Ok. Any other comments on that?

#20: Just that what I said about structural tags like the headings[37] and uh… again, I might have had some more comments on the home page if I'd had used it differently but I just basically used the site map so...

Observer: Ok. The general layout of this site was easy to learn. Seven is strongly agree.

#20: Let me just look at the home page again… (listens to the home page read). I'd say about a 4. Except for… this is interesting, they've got Main page on one page and Home on another page[38]. Yeah, research, I dunno what's under these… there's education, research… museum… how do I know which is which[39]?

Observer: Right.

#20: Um, so, it's actually not very intuitive[40] until you get to the site map which doesn't really require any intuition at all, it's, it's gotta all be on the site map[41]. No, it's

[33] Had something in mind but couldn't find it.
[34] Changed navigation tactics
[35] What he had in mind
[36] What worked
[37] Site structure
[38] Links are inconsistent
[39] Can't tell which one is the right one… information scent? Doesn't match his idea of what he wants?
[40] Not intuitive
[41] What worked

not particularly easy to navigate but I'd say it's about a 4. Maybe even a… let's call it a 3.

Observer: OK. And how about, My overall experience on this site was positive.

#20: Um, 5.

Observer: And… this is the kind of Web site I would have visited on my own.

#20: If I was doing something about LBJ… is this a 1 to 7 thing?

Observer: Yes

#20: Um, 5.

Observer: Ok. Um, this site was aesthetically pleasing. Which in your case, I guess that refers to the layout and navigability.

#20: Again, I'm going to have to say 5, because I did think the biographical page was very nicely done[42].

Observer: Any other comments about this page at all?

#20: Uh-uh.

Star Date Web Site (SD)

Observer: (reads scenario from Appendix D)

#20: Just listening to this[43]… could be under Radio[44].

Oh OK. (goes back to radio link.)

Oh OK.

Don't know if it's going to be one word or two[45]… (doing the search)

---

[42] He liked it but doesn't explain why

[43] Context-gathering? Getting to know the site?

[44] Going by information on the page

[45] Uncertain of spelling

So I mean it could be any of these, should I just um… you know, the next thing I would have to do is just, there's 34 things[46] and hit skylab… except that it's sky space lab[47] and there… (listens a bit more) there we go, that's definitely one.

User satisfaction survey questions:

Observer: I've got some questions for you.

#20: Can I just say that this is a more technical site than Nasa's site.

Observer: Really? More technical?

#20: It might also benefit from headings. Yeah it needs to have headings too, I'm just big on headings. I'm just really learning how valuable headings are when jumping over skip to nav[48]. This does not have a skip to content and I never use it anyway because JAWS will put you just damn near anywhere on the page it wants to when you click them[49], but ah, it needs some structure on the page, like the skip to content links and the headings links[50].

Observer: From 1-7 with 7 being strongly agree, this site was easy to navigate.

#20: I'd have to say 3 on that one.

Observer: OK, any comments?

#20: Just the ones that I've already said. It's mainly cause… I say 3 but I don't have strong critique of it because if I was a stargazer, I would be into this site, I would explore it, and I would know it. You don't come to this site and look for the next eclipse of the sun generally as a random person that's not interested in stargazing[51], you're gonna want to tour this site, I think, I mean I would.

[46] Lot of information
[47] Confirming spelling
[48] Uses headings to jump around the page
[49] But doesn't use them b/c they're not reliable and you lose your place
[50] Needs structure!
[51] Site is not really his interest

Observer: Alright, how about, I could effectively complete all tasks.

#20: Uh, 4… 4.

Observer: You were saying, you'd just like some more background, more time to check out the site?

#20: Yeah, that's basically it, so the numbers may be low as I actually respond here but I actually liked the site a lot.

Observer: The general layout of this site was easy to learn.

#20. 4. Actually, I still don't know what the layout of this site is[52].

Observer: My overall experience with this site was positive.

#20: Well that I'd have to say 6, because it's good information that's here, it's a site that you can actually use, that makes it complicated. You can use this as a tool, like any tool there's a learning curve. If they had the structural stuff, I think that the next time I came back and spent some time seeing what's here, I would be able to complete all the tasks very effectively, you know, if they had the structural stuff all through the site[53]. It was very easy to find the radio programs, the search, the searchability of the site was excellent[54]. I might have, you know, tried eclipses and then seen, looked at what came up that way too.

Observer: Alright. This is the kind of Web site I would have visited on my own.

#20: Yeah, yeah, I'd say 6

Observer: This site was aesthetically pleasing.

#20: I'd say 6 on that one too.

Observer: Any other comments?

---

[52] Does not know structure or layout of site
[53] More structure
[54] Good searchability

#20: No, I’ve talked a lot about this site.

Center for Lifelong Engineering Education (LENG) Web Site

Observer: (reads scenario from Appendix D)

#20: OK.

There’s custom courses. (after doing a find)

Well excuse me, I mean there’s 5 different kinds of classes[55]. (listening to options)

I’ll look under short courses. Any of these varieties of classes[56]?

Observer: We’re looking for a course on software programming that’s under $500.

#20: OK.

What did you say we’re looking for[57]? (listening to a long list of links)

Observer: Software programming.

#20: OK, well there’s software. I assume that’s…

Uh… something’s wrong[58]. (JAWS has stopped talking) (JAWS is back again)

Ah that’s fine. (has found an option that has “software” in it)

Bring it back where it’s… OK

I do that a lot I read web pages backwards I’m not sure why[59].

Ah, the software quality institute.

There’s software quality.

I’m gonna open a new window

---

[55] Indicating that there’s a lot of information on the page.
[56] Confirming task
[57] Confirming task
[58] JAWS not working
[59] Navigation technique

I don't know how many people know that, you can hit ctrl-enter and make sure… it forces it to open a new window so you don't lose your place in the other one[60].

Observer: Oh OK.

#20: Doesn't always work, depends on how they write their program. If it's a JAVA window dot open thing it won't work[61]. (still listening to links)

There's programming…

Let's see if these things list prices… (listening to lots of courses)

Ooops. (hits a wrong key)

Alrighty…

So there's one. (JAWS reads a course)

User satisfaction survey questions:

Observer: This site was easy to navigate.

#20: No. Ah, 2.

Observer: I could effectively complete all the tasks.

#20: 3.

Observer: The general layout of this site was easy to learn.

#20: 2.

Observer: My overall experience with this site was positive:

#20: 2.

Observer: This is the kind of Web site I would have visited on my own.

#20: 1.

Observer: This site was aesthetically pleasing.

#20: 2.

---

[60] Important to know where you are

[61] Understands how this works, code-wise

Observer: Is there anything else you'd like to add?

#20: Um. This really just feels like an engineering site, um, it's just so convoluted[62]. But I don't, again, here again, you're not going to go here unless you belong here… it's not a public… so, I mean… (listens to JAWS)… in this very short period of time, I don't know what this site is, I don't know who these people are, um, I don't know what I'm doing here[63]… (laughs). I don't know what kind of information I'd expect them to have, I don't know this genre of… it's some sort of center of engineering people, it presumably helps people after they're… in their, through their professional, through their career, so they teach all the classes, but I don't know what else they do. I mean I can register for classes.

Observer: Alright, good feedback, is there anything else you'd like to add?

#20: No.

University Extension Evening Credit Courses (UEX) Web Site

Observer: (reads scenario from Appendix D)

#20: You know the problem with these scenarios is they just go on. You need to… I think you need to stop every couple of sentences. I mean, you're just reading reading reading and it's like I don't remember word one of what you're saying, actually, I can't put myself there in this huge stream so[64]…

Observer: Right, its' a lot of information.

#20: Just as sort of a, I mean, number one, minimize it to whatever information you actually need to remember[65].

Observer: right.

[62] Structure not clear
[63] Difficulty putting himself into the scenario, lack of pre-task knowledge
[64] Problems with scenario
[65] A lot of information to remember

#20: Number two, just as sort of a dramaturgical step, I mean I would probably pause and add… elicit sort of OK, you got that, or something.

Observer: OK.

#20: Just like, a pause for processing. I don't know if other people have as much trouble as me but I'm not being very attentive here.

Observer: My problem is that I think faster than I read so… let me slow it down a little. I was really trying to be slow.

You are a recent graduate of UT with a bachelor of science in mathematics and are working for the next couple of years to earn money for graduate school. You're interested in computers and programming and want to take some continuing education classes to prepare for graduate school. You have heard that UT's continuing education department offers a specialized program in computer programming. And that's the info.

#20: Okey-doke.

Observer: And the first is: find a class in computer programming that you want to take in the fall of 2003.

#20: OK.

I could just go there[66]… (as he hears fall 2003 registration link)

Just seeing what's here[67]. (reading links backwards)

Courses… Probably I would tend to go to registration first, because I just, might as well just go to the ones that are…

And the thing is that these days I would expect there to be links to the descriptions from the registration pages[68], we'll see if that's going to be the case.

---

[66] Finds something he likes on the page
[67] Getting an overview of the site
[68] User expectation

Oh, we're just gonna… that's just going to take me back there. (listening to a link to courses to register for)

Well there's one. (hears a link that fits the description). See there's one.

Elements of computers in programming. I probably wouldn't take that since I have a bachelor's already.

User satisfaction survey questions:

Observer: This site was easy to navigate.

#20: Oh, um, didn't have any problems, so…

Observer: That form…

#20: No, I didn't have any problems with the form, I mean, that's an average form, um…

Observer: Seems a little heavy to me. It's a lot of information, they expect you to know a lot of stuff just to fill it out.

#20: Well that's not navigation. Um, I'd say 6 for navigation. And here again, I just want to point out, I'm a graduate student, you know, this is the kind of site that I know how to access[69]. There's a certain literacy that I think that's an issue between a site like this and Star Date and Engineering.

Observer: Alrighty. I could effectively complete all the tasks.

#20: Yup. 7.

Observer: The general layout of this site was easy to learn.

#20: Um, let me see (listens to JAWS). They've got link to home page, by the way, it's unnecessary. They've got these alt tags that say link to home page[70]. Um, yeah, I'd say… what was the question again?

[69] Indicates familiarity with task
[70] Bad coding

Observer: The general layout of this site was easy to learn.

#20: I'd say… yeah, it's got headings and stuff[71], I'd say about a 6 on that. (listens to JAWS) Except that they're using the headings inappropriately… right here… University Extension offers evening courses blah blah blah, this is all Heading level 3… it's also a block quote which is also inappropriate[72].

Observer: So about a 6 you think?

#20: Sure, yeah.

Observer: My overall experience with this site was positive:

#20: Um, 5.

Observer: This is the kind of Web site I would have visited on my own.

#20: Uh, 6. Since I've used courses before.

Observer: This site was aesthetically pleasing.

#20: Um, 4.

Observer: any other comments at all? About this site?

#20: No.

French and Italian (F&I) Web Site

Observer: (reads scenario from Appendix D)

#20: OK

That's a WEIRD combination! (referring to French and Italian)

… graduate classes… that's undergrad…

Uh...

Yup. (hears "courses dash gradute")

---

[71] Has headings

[72] Bad coding

You're wanting to know if a degree program[73]? Or…

Observer: You're looking for a graduate program for Italian.

#20: Well… they have graduate courses

At this point… I would say no they don't… I'm gonna look… because they have B.A. requirements but they don't have M.A. or Ph.D. requirements. But hang on. (keeps listening)

(JAWS reads "no advanced degrees in Italian") There you go.

OK. Yup, no advanced degrees in Italian.

User satisfaction survey questions:

(Observer reads instructions)

Observer: This site was easy to navigate.

#20: Uh, 6. Mostly.

Observer: Alrighty. I could effectively complete all the tasks.

#20: 7.

Observer: The general layout of this site was easy to learn.

#20: Um, 5, at most. The whole French and Italian thing was odd[74].

Observer: Just the combination?

#20: Well some of the links are for both, some of them are for each, you know. Which, a clear hierarchical structure to really KNOW if you're clicking on a link that's going to be for Italian, French, or both[75]… it's one department I guess.

Observer: My overall experience with this site was positive:

#20: Um, 6.

[73] Confirming task
[74] Does not match user expectations
[75] Unclear structure

Observer: This is the kind of Web site I would have visited on my own.

#20: Well I'm a graduate student, so 6 I guess. I don't know how you rate that, 1 to 7, that's a strange… it's a yes/no question actually.

Observer: Right. This site was aesthetically pleasing.

#20: Um, 4, it was a little bit confusing.

Observer: Can you expand on that any, just the arrow keys or hierarchy?

#20: I don't know why there are some things in quotes, <u>some of these links are in quotes, um maybe it's because they're image links, um, yeah, like link graphic quote, they've got quotes, quotation marks inside their alt tags for whatever reason</u>[76]… it's redundant. (listens to JAWS) Um, <u>that was one that's not alt tagged right there</u>[77]…

Observer: anything else they could have done to make it less confusing?

#20: Um… it wasn't that confusing, 4 is average.

---

[76] Bad code

[77] Bad code

Transcript for Participant #24

Center for Lifelong Engineering Education (LENG) Web Site

Observer: (reads scenario from Appendix D)

#24: Hello[78]? (pressing keys but JAWS is not speaking)

Yes? (JAWS starts talking)

Ok…

Observer: What's alt M do?

#24: Should move you to the place on the page where the link is.

I'm in a links list, right[79]?

Observer: Yeah.

#24: But there's… (still in links list, seems to be expecting to hear something but is not)

There's some things not showing up in this dialog that I was expecting to find[80].

I'll go with that there. (leaves dialog box)

Oh, OK. This is JAWS…

Observer: 4.51

#24: I was looking for the thing that was showing up in the links list view[81]. (referring to looking for something on the page)

That's weird, now it's not.

Observer: yeah I don't understand what's going on either.

Unless it's a heading.

---

[78] JAWS problem

[79] Confirming what's happening on the screen

[80] Does not match user expectations

[81] Trying to find information, not matching expectations

B/c I don’t see that link that you found either.

#24: Ah.

Observer: No, I do see it, I lied.

#24: Is that it?

Alright, so anyway we’re going to go to the software quality institute. (chooses link)

Surely those are the same thing[82] (referring to a link on the page)

Let’s see if I can find out about project hot start… (chooses a link)

Ok, so I was looking for a heading on project hot start so I could jump straight to[83] that (he’s in links list)

Skip to main content link… (as he’s scrolling thru links list)

So I did project find…

First I thought hot and start were two separate words[84]…

Observer: oh OK.

#24: Sounds great.

I keep getting the wrong thing because of the keyboard difference.

Hello[85]? (pressing keys but JAWS not responding)

I don’t understand.

That was a little quick. (not clear what he’s referring to)

They should “quote quote” that graphic divider[86].

That doesn’t meet my things anyway (course was too expensive)

---

[82] Not clear if two links are the same thing
[83] User has something in mind that he’s looking for
[84] Spelling issue
[85] JAWS problem
[86] Bad code

So I gotta go somewhere else…

I knew these guys are expensive so… (goes back)

I want to find out about that… (short courses link)

See if I can find out about that… see if it's got…

Thank you JAWS[87] (JAWS quit talking)

Got it. OK, I'm going to take Extreme Programming.

User satisfaction survey questions:

Observer: This site was easy to navigate.

#24: 3

Observer: What are you thinking about there?

#24: Um, I'm really thinking it was hard to find things and it was hard to hard to know what the link names meant[88]. That may be because I don't know enough about engineering to know but it felt like there were multiple links where the link text was close enough that it was hard to differentiate[89]. Or things like the last task where the name you gave me is close to something that was actually on the site but isn't the same thing, and there is no link, no evident link to it at all. It was on the other hand very easy to find the contact information so that stuff is easy. Also there's no skip to main content link, um, so it was annoying to have to listen to all the links[90].

Observer: It looked like you employed a strategy of pulling up a links list to get you into the content to navigate.

[87] JAWS problem
[88] Trouble with link names and locating information
[89] Link problems
[90] Bad code

#24: I was trying to, and that's, that's why I was sort of stalwart and the Alt-M thing didn't work, and I think there's something, there's a way to configure the links list so that would be available[91]. Cause I know it's there on mine.

Observer: So it's a JAWS problem

#24: Yeah, it's a setting somewhere but I don't know where[92], some option somewhere. So yeah, I was doing that also because there were relatively few headings and on the pages I was most concerned about where for example on the course information and stuff the headings weren't particularly useful, so that, you know, they have search under headings which is fine, but sort of critical information wasn't set off with headings so I couldn't use the headings list to jump to it. But that wasn't really available as a meaningful way to bypass the navigation[93].

Observer: OK, how about I could effectively complete all the tasks on this site?

#24: 3 again. I was able to effectively find the mailing address and phone number b/c they were right there under the contact info and that was nice[94]. Finding a course was difficult, and it felt weird to be adding things to the… there was something about the sequence that felt strange[95]… press the Register Now button or select the Register Now link and instantly it's in your shopping cart and then you're going from there to… then there's another Register Now link, and that was disconcerting, and the… then it turned out you had to have an account set up, it asked you for your name and e-mail or something like that…

---

[91] JAWS is not functioning as expected; user describes trying to use links list to navigate
[92] JAWS issue
[93] Poor information structure due to poorly written code
[94] Information that was easy to find
[95] Didn't match user expectations

Observer: And then once you submit it, you don’t actually get to the part where it asks you for the classes.

#24: Yeah I figured that part, but it just seemed disconcerting, like I said register now and instead of asking, it didn’t go directly to asking me for the typical kind of registration information, which is like who are you and all that kind of stuff, and it did that shopping cart thing and I had to hit register now again, so that felt, it was disconcerting to have come to the shopping cart from register now, and it was annoying to then discover that I had registered. It felt like it was asking for information in the wrong order[96], I had to enter my name and e-mail address and then it said, is this your first time, so there could have been a radio button thing where, sort of like one of the Amazon sites, Amazon access[97], where it takes you to a page where it’s got your e-mail address or what it thinks your email address is and there’s a default think with a radio button, so if you haven’t, if you don’t already have and account with them, you can set it up and give the details there.

Observer: How about, the general layout of the site was easy to learn?

#24: No.

Observer: From 1-7 how much do you disagree with that statement?

#24: Um, 2.

Observer: My overall experience was positive, from 1-7.

#24: 3.

Observer: Anything to add?

#24: Pretty much the same thing.

Observer: This is the kind of site I would visit on my own.

---

[96] Did not match user expectation and made the user feel lost

[97] User is comparing it to previous experiences

#24: No.1.

Observer: The site was aesthetically pleasing.

#24: The auditory experience wasn't particularly good[98].

Observer: On a scale from 1-7?

#24: Um, 3.

Observer: Any other comments?

#24: It just didn't feel clear to me. Like it was sort of a hodgepodge instead of a… it didn't feel like it was offering a coherent approach to lifelong education[99]. If you already knew what you wanted and knew the right terms you could probably get to it[100], some of the time anyway. The search feature was really weird, cause it didn't, it sounded like it was trying to be a site search but in fact it only looked for courses[101]. Or at least that's what the search results page… so if it is in fact a search for courses then it should give you a lot more fields so that you can tell it to get more information, more criteria about what you're looking for[102]. If it's not a search for courses and it's really meant to be a site search then it should be a site search.

LBJ Library and Museum (LBJ) Web Site

Observer: (reads scenario from Appendix D)

#24: What is the Age of Augustine doing at the LBJ[103]? (laughs)

I swear I chose a link called Search[104] (JAWS says "input field not found")

So I'm on a search page that doesn't have an input field[105]?

[98] Different kind of aesthetics
[99] Unclear
[100] User thinks prior knowledge would be helpful
[101] Did not match user expectations
[102] Content does not match user expectations
[103] Content does not match user expectations
[104] Search is behaving in an unexpected way

(JAWS says “no heading found”) No headings… and there wasn’t a skip nav link I don’t think[106]… (looks for a skip nav using links list)

I’m curious how we get to a search…

Bio page… I’m trying to decide if that’s something that might have a biography[107]…

Oh not again (is back on the search page)

Do I have to listen to all this again[108]?

Let’s try link full search of our Web site! (chooses link)

Excuse me… (interrupts JAWS)

I think that was actually a JAWS thing[109].

Uh…

Observer: You’re looking for when LBJ got married.

#24: (types in search term)

Well that’s not real helpful. (there are only 3 headings and they’re somewhat cryptic)

I’m searching for telephones[110]. (descriptions)

Didn’t I do that already? I guess not. (on search button)

Wait… (laughs)

Thank you[111] (JAWS announces search results)

(makes exasperated noise, then goes back)

---

[105] Search is behaving in an unexpected way
[106] Site does not have expected content, especially not expected accessibility features
[107] Lack of accessibility features
[108] Frustrated
[109] JAWS problem
[110] User knows what he’s looking for
[111] JAWS problem

Jeez, it's a PDF (JAWS is reading a ridiculously long useless link).

Oh no… (adobe wants to check for updates)

Observer: It told you it didn't have it?

#24: What? It said the buttons didn't have MSAA (in the PDF)

Yeah, it's a scanned document, I suspect anyway[112].

I give up.

User satisfaction survey questions:

Observer: This site is easy to navigate.

#24: 1.

Observer: I'm kind of scared to ask you to explain that, but maybe you could give the highlights about why it's a 1?

#24: (laughs) Um, cause I couldn't FIND… well, I found certain things, like the page where the gifts are, so I guess that was… it was mostly the search thing, that just made me crazy[113]. It made it hard to navigate because I was looking for… if you're looking for really specific information of the sort that you ought to be able to find in a library, it's really difficult because it's organized, it's organized to their understanding of where they got their stuff rather than to mine, in ways that would help someone who doesn't already know what's there and where it is, find it[114].

Observer: I could effectively complete all the tasks

#24: No! ah,

Observer: from 1-7 how much do you disagree with that statement?

---

[112] Inaccessible PDF
[113] Search did not match user expectations
[114] Prior knowledge is needed

#24: I think it's a 2, I was able to complete… I was able to complete, find the museum directions, and the location, and I was able to find the page with the gifts on it, um, but I wasn't able to effectively complete those tasks because in both cases, a) I had to listen to all the navigation… there is no skip nav link, there are no headings[115], so I had to listen to all the navigation stuff in order to get to the part of the page where the information I wanted might be. In the case of the contacts, er, the directions, and the address, that was there, although it said "graphic" for a reason that I don't understand[116]. In the case of the museum, of the gifts, the state gifts, I was able to really complete the task effectively because I was guessing on the basis my experience interpreting file names rather than getting real information in the form of alt text or onscreen text to identify the items[117].

Observer: OK. The general layout of the site was easy to learn.

#24: 4. I'm not sure that layout rather than organization in the sense that… no, that's not even right. But for example when you asked me about gifts, I remember somewhere along the way hearing, somewhere I heard the word gifts go by[118], maybe in the, it might have been on that big search page that had the list of all the different kinds of searches you could perform, I might have heard something there about gifts and I thought, ah, gifts, and I just looked for a link, that began with G,

Observer: and you were able to find it again.

#24: well, it wasn't..

Observer: it's one thing to hear it, it's another thing to go back and get to that.

---

[115] Lack of accessibility features

[116] Bad code? Lack of alt text?

[117] Found info based on previous experiences rather than what was on the page

[118] Navigating by finding content on the page

#24: Well, but I wasn't going to that page, I was going to… but I heard it on page X, and that wasn't the page I went back to, I just, but I was able to bring it up, it turned out there was something in the… I guess I heard something about it… somewhere I heard something that museum had stuff about gifts in it so I went to the museum page and then I went from there, on that page I looked for a link to gifts. So, that was doable, the search stuff was impossible[119].

Observer: My overall experience with the site was positive.

#24: 2.

Observer: this is the kind of web site I would have visited on my own.

#24. Um, 7.

Observer: Are you saying it was REALLY a kind of web site you would visit?

#24: I'm not saying… the emphasis was on the KIND, not that this site is what I would go to, but I do go to, I am interested in things like museum sites and library sites and stuff like that, I go on my own.

Observer: This site was aesthetically pleasing

#24: 1. It was abysmal. It was confusing and there was nothing interesting to listen to and when there was actual text, there were mistakes in it, it was badly written[120]. For example in the objects, the objects aren't given to each other.

Observer: Any other comments?

#24: Ah, I need to talk to [webmaster of this site]

French and Italian (F&I) Web Site

Observer: (reads scenario from Appendix D)

[119] Bad search feature
[120] Aesthetics

#24: Wasn't expecting that![121] (JAWS reads something that starts with a "g" in the links list dialog box)

All right, let's try 'departments"[122] (starts pressing "d" in links list)

Doesn't sound like…

It says courses but there's BA degree requirements. (in Links list)

No. (JAWS reads "there is no graduate degree program…")

User satisfaction survey questions:

Observer: The site was easy to navigate.

#24: I'll give it a 4. It was relatively easy to find most of the stuff but it felt like in getting to the fact if I followed the link to the faculty page it felt like too many more steps to actually get to the faculty[123]. The… I dunno

Observer: I could effectively complete all the tasks

#24: 4. I think I found everything I was looking for but… it just felt a little tougher than, like, for example on the last task, looking for Biezer's stuff, first it was a little bit, that page was a little confusing because there were those links at the top that sounded like I might have to go somewhere else in order to get different sections of the page or something, and then only, because I just decided to let it go because that didn't sound quite right either, and I started hearing the stuff[124] but it wasn't … it would have been nicer if the different categories in the CV like education and publications were actually marked as headings[125]. Because I know what a CV looks like I know what the headings are supposed to be, ah, I was able to search for it and do a find, but it would

[121] Content does not match user's expectations
[122] User tried one thing but did not find it, so tried another
[123] Site structure not direct
[124] Structure not matching user expectations
[125] Lack of accessible structure

have been easier if there were headings. Because then if you didn't know how it was organized, pulling up the headings list would be the way to get to the information[126].

Observer: Ok, how about, the general layout of the site was easy to learn.

#24: It was pretty… 4 again. Nothing jumps out at me as being particularly heinous or particularly great.

Observer: My overall experience with this site was positive.

#24: 4 again.

Observer: This is the kind of web site I would visit on my own.

#24: 4 again. In the sense that I often go to departmental sites because I need to

Observer: This site was aesthetically pleasing

#24: 2 or 3, it's just… I dunno whether it's nice to look at or not, it was ok, I found the stuff I needed but I didn't get any pleasure out of it[127].

Star Date (SD) Web Site

Observer: (reads scenario from Appendix D)

#24: OK. (user found a program)

User satisfaction survey questions:

Observer: The site was easy to navigate.

#24: I would have said 5 or 6 until the last one, but… 4. I was, it's annoying that there's no skip to main link, it got increasingly annoying[128]. And um, I got confused about what kinds of searches I could conduct b/c if I thought I was looking… I went for a link that said keyword search and then I didn't find an input field on that page and then there was a whole list of things which was not quite what I was looking for[129].

[126] Needs headings for structure
[127] Functional but not interesting
[128] Lack of accessible structure
[129] Does not match user expectations

Observer: I could effectively complete all the tasks

#24: Say 5, because it was all but the last one, but that was the… (laughs).

Observer: and that might not be a fair question for their site, that's not what their purpose is, but…

#24: Well but, but for example, you asked me about meteor showers and stuff like that…

Observer: I asked you about events in the middle of this month

#24: Oh, hm, I forgot that part (laughs).

Observer: and you were on the right page and didn't know it and left it and went to find meteor showers.

#24: Because didn't you say something about meteor showers?

Observer: That was the example of an event.

#24: Oh, I didn't know it because it sounded like events…

Observer: That and the keyword you used to jump to the content of almanac was actually listed at the bottom of the page so it took you past all the content… because it didn't have a heading, like almanac…

Observer: Ok, how about, the general layout of the site was easy to learn.

#24: Yeah, um, 5.

Observer: Do you think that's because you've been to it before?

#24: No. Because it seemed like, well, things like, I do know what star date is, I hear it every day, or many days[130]. So for example when you asked me, well two things, one is, I listened to enough of the home page when I first landed on it[131] so I thought I

[130] User has prior knowledge about the subject matter
[131] Getting a feel for the site

heard a link to radio and then and then you asked me about finding a radio program. Well my first instinct was just to go to the search which is not usually the way I would do things – that's because I'm in this kind of weird task situation so that slightly alters my behavior[132]. And I decided I wouldn't do that, I would go to radio and then I was happy when I did that because it, there was specifically a program search there and that's what I was looking for[133]. But that then turned out to be misleading because I then thought there would be sort of constrained searches elsewhere[134], like that there would be an events search

Observer: Right, because actually that program search is on every page.

#24: Right. But it doesn't say program search on the home page I don't think, it just says search[135].

Observer: Uh, I'm confusing my sites, so yeah, maybe.

#24: (user goes back to home page with JAWS, which reads "program search"). Oh, yup, never mind.

Observer: But you're right, altogether it has Program search and then the go button, next to keywords and then it has a site search.

#24: And somehow… see, and then site search and keywords aren't, you can't do that on this page.

Observer: Why not?

#24: Because you have an input field for the go button, but if you want a keyword or site search it's another page[136].

[132] User acknowledges that this setup is not his normal behavior
[133] Experience matched expectations
[134] Does not match user expectations
[135] User is confused about types of search
[136] Search not matching expectations

Observer: I see what you're saying.

#24: That's where I got confused because I went to the keyword one[137] and that was confusing. And I'd forgotten about site search. And that's really badly labeled[138].

Observer: My overall experience with this site was positive.

#24: Uh, say 4. I could find most of the stuff I was looking for so… I thought the program search was really good and the finding affiliates was well done[139] although I must say that I think that only worked for me b/c I listen to NPR so much that I know what affiliates means[140].

Observer: Yeah but I didn't ask you affiliates.

#24: I know, but you asked me to find a station where I could

Observer: You're right, because people don't always recognize that

#24: Right. That's what I mean, it's like, if … I started to look for it under, and maybe I even did go to radio, I can't remember…

Observer: This is the kind of web site I would visit on my own.

#24: Yeah, 5, 6.

Observer: This site was aesthetically pleasing

#24: Give it a 5. It seemed mostly pretty clear except in that last search and, uh, well, I have to say that I'd kick it back to a 4 because not having consistent headings and/or skip nav really gets old. I just don't wanna be on it, I don't wanna have to listen to very many pages. It just takes so long to find out whether you're where you want to be or not[141].

---

[137] User was confused
[138] Bad code
[139] Matched expectations
[140] Using prior experience to complete task
[141] User wants things to be direct and quick

Observer: Right, like it took a long time to figure out whether there were events or something different.

#24: Right

Observer: A common path you could take though. Um, any other comments?

#24: No.

Participant #31

Star Date (SD) Web Site

Observer: (reads scenario from Appendix D)

#31: About sky lab?

Observer: Yeah, it was a satellite that was also sort of a space laboratory for astronauts.

#31: And it would be spelled s-k-y-l-a-b[142]?

Observer: That's right.

#31: So you want me to find information on that, skylab[143].

I think what I will do is try to find a search box, for to search[144], but I see one here but JAWS is not finding it[145]. Usually with ctrl insert and this one… what is this one, I can't remember… this is called home?

Observer: Yeah, home. That's home.

#31: Ctrl inst Home it will take me to a box, but it's not taking me so…

Observer: I wonder if it's a difference with the version, it probably isn't.

#31: I don't… I wouldn't think so, I don't think it would be… but if that doesn't work, this didn't work, my idea would be to do this and that it would take me to this box, so then I could type something and find it, but it didn't work, so what I would do is I will search for a link called search[146]. (opens links list)

Site search… (finds site search in LL)

OK.

---

[142] Checking spelling
[143] Confirming task
[144] User points out a navigation technique based on previous experience and expects one to be there
[145] JAWS problem
[146] Tries another navigation method since his first choice didn't work

Observer: Did you say ctrl inst home?

#31: Ctrl inst… Yeah, that's the keystroke. So, now, it doesn't find it either. So what I would do is, I know that here I should have a box somewhere where I can enter a search term but the command is not finding it. So I guess I'll tab (uses tab key) hopefully until I can find it[147].

Ok, that edit I think will be where I can type it. (JAWS says "edit blank") No… it's not doing what I want. OK, I try to get into that box that I found there that said, that said edit[148]. I think we'll try something else… (goes to another page). I try to get into that box but I wasn't able to get into it. So one thing I would do here, if I were at home I would get the mouse and go to the box here, click, and I would type…[149]

Something's weird (JAWS keeps saying "edit search") because it doesn't let me type there.

(JAWS says "edit, blank") Uh-oh. I don't know what it did there[150].

[After reboot]

#31: Nope, the command doesn't want to work. Ok, that's where I need to be (referring to the search box). Ok, that's… I think if the command works, it would put me there. Oh, now it… now it's on. I wonder if now, maybe now you don't have to do this thing to search for it. Maybe once the cursor is in it, as soon as you do enter, it starts them all[151]. We will see.

Observer: So you're trying to get there without having to tab over to it?

#31: Right. Let's see, OK, so Skylab?

[147] Uses yet another method to access the search box

[148] JAWS is not behaving ase expected

[149] User is changing navigation tactics because JAWS is not behaving as expected

[150] Still having JAWS problems

[151] JAWS is behaving differently than expected.

And here you wanted me to find whatever I could find about Skylab[152]?

Observer: Well actually a radio program.

#31: A radio program? OK. Radio… let's see[153]. (follows link) I guess I'll just let it talk until I find something[154]. (lets JAWS read). So it had to read all of those links that I don't really care about[155]. Ok, I think I will just move the cursor down to see if I can get there faster[156]. I think what it was doing that, probably here I had a long menu of things, but I want to be here[157].

Observer: So in the main content?

#31: Right. I know some of the Web sites, and I think the UT web site, has a link where it says go to main content? And those are useful. Because I think, JAWS has a feature that you can use for that too but it's not very exact[158].

Hopefully, this will tell me where they play the show. (listening to JAWS)

Hm, program schedule might have some information but… there, find an affiliate is probably the one that will give me a radio station[159].

Yeah, I think this version you don't have to activate forms mode. When you get to a box you press enter and it works[160].

Observer: So it's working for you now?

#31: It works.

---

[152] Confirming task again
[153] User has found a link that is interesting
[154] User doesn't have a plan
[155] No way to skip nav
[156] Trying to navigate to the main content.
[157] User knows where he wants to be on the page and is trying to get there
[158] Does not trust it
[159] User is making decisions based on what he finds on the page
[160] Good JAWS feature

Here for example I can see where it says radio affiliate so what I will do is try to move the cursor to that point. Link listen? Oh, ok. (keeps going). I also found Austin somewhere here, see if I can get to that point it will probably tell me the stations I can listen to[161].

Observer: Let me stop you for a minute and just ask you if you are, are you looking for a radio program on this site or a radio station you can listen to.

#31: I was looking for a radio station. Are you looking for online?

Observer: Yes

#31: I think one thing I would do here, if this is the main web site where, the place where I was talking about the show, I will go to the list of links and look for one that says, um, what is that called, streaming audio or something like that[162].

Oh! Ah. (hears the Listen link). I see now, I picked Listen. Ok, so here… I will click on one of these, yesterday's program, I'm assuming that if I click on that one it will play[163].

Observer: Right, but you're looking for one about skylab.

#31: Oh, so if I'm looking for one about skylab, it will probably… I think I saw something that said archive[164]. (finds link) Archive, OK, I'm going to go to archive…hmmm. Search by topic… I was hoping that when I clicked on search by topic it would help me and allow me to do the search[165]… OK, find programs about, so hopefully that's where I am now[166], and I can find about the program I want to find. Ok,

---

[161] Content the user found on the page
[162] User has a plan on what to look for
[163] User expectations
[164] Content the user found on the page
[165] Not meeting user expectations
[166] User is not certain of location

found something. Ok, this is just a table I guess[167]. If I click here, it would um, it will play. I dunno, we want anything related to skylab, so rescuing skylab would be OK?

Observer: Right.

#31: Here it should play… OK, I think this is it.

User satisfaction survey questions:

Observer: This site was easy to navigate.

#31: 5. The only comment is, yeah, well, not having a link that would take me directly to the content, and having to go through all the links on every page[168]…

Observer: That takes a lot of time.

#31: Right. Exactly.

Observer: And one of the things they did on that last page is they had a lot of links on the um, on the right side, and it went all the way down the page and you had to go through all of those before you could get back…

#31: Like on this end? (points to screen)

Observer: Yeah.

#31: I'm glad we didn't need any of those! (laughs)

Observer: yeah they were on most of the pages.

#31: Yeah, and I know, just as a feature I think that, ok, I think they have a feature that these are different frames, if this one is one and this one is one[169],

Observer: I think it's just a single page.

#31: OK, because if they are different frames then JAWS has a command to go to different frames[170], but um, still it's not very useful because if you, unless you know that

[167] Object on the page
[168] Lack of accessible features
[169] User knows about frames
[170] More on frames

the link is all the way on the right, you cannot really go directly there because you don't know what you are missing in the middle[171] if you don't know the web site. So yeah, the main problem I found was having to go through all the links every time you went to a different page[172].

Observer: Question two: I could effectively complete all the tasks.

#31: Um, 5. I think, yeah, I could have done it faster, so yeah, 5.

Observer: The general layout of the site was easy to learn.

#31: I would say 6. I think after I went through a few pages everything was in the same place so that made it easier[173].

Observer: My overall experience with this site was positive.

#31: It's 5.

Observer: This is the kind of web site i would visit on my own.

#31: No. Not because of the formatting but because of the content, I'm not interested in these things. I'd say 3.

Observer: The site was aesthetically pleasing.

#31: I'm not sure what you mean by that.

Observer: I guess it's sort of like your experience of the site. Like, you mentioned lack of skip nav, so that's sort of, but also, this question seems more geared toward the visual experience, but if you want to comment on your experience, like if it was disorganized, from your point of view.

#31: oh, oh yeah. I misunderstood the word, I thought it meant static, like web sites, some of them are static, and some of them are not… but um, about the appearance,

[171] Concern about missing out on important information
[172] No skip nav
[173] Consistency is good

I think, 6. I kind of like how they have, when I have contrast I can see things better so I like having this thing one color and this thing another color, it makes it easier for me to see[174].

Observer: So the contrast?

#31: Yeah.

Observer: And that’s not necessarily the background but like the segmentation of things?

#31: Yeah, actually, both things, because here, these letters are too small if I had to read it, but the contrast is good, I like this, these are very… I like the white color and the background is darker[175].

Observer: I noticed you were reading some of the stuff there before we started…

#31: A little, but if the contrast had been any different I would not have been able to see it. Like these ones here, I might have missed those because they are very small and the contrast is not as good as here, and it’s not as good as the one down here. So I think for the visual appearance it’s a 6.

Observer: Do you have any other comments about this site?

#31: No, I think… no.

Texas Memorial Museum (TMM) Web Site

Observer: (reads scenario from Appendix D)

#31: Ok, I don’t know how this works so I will start reading over things just to have an idea about it, and hopefully in the middle I’ll hear something about parking[176]. (lets JAWS read).

---

[174] Contrast is important for someone with very minimal vision
[175] Contrast
[176] Has an idea of what he’s looking for

Ok, I think I'll go to the list of links and look at the links there. That might be one, the first one (visiting museum) but if I don't find one more relevant I'll go back. I'll go to that one (visiting museum info). The visiting makes me think it might have some info[177]. Ok, I heard a link there (referring to the Parking link, goes back to it)[178]. I'm just tabbing around to find the parking link, tabbing makes it easier to find something[179]. Let me read that… parking… bus parking… free bus parking. We are not going by bus?

Observer: No.

#31: That's kind of unclear to me, I guess, are they talking about capital metro or are they talking about you going with a bus, because if it's capital metro then they're not going to park there and I'd say it's unlikely that you would drive there with your big bus, with your big motor home[180]. (listens more to JAWS) Car parking, that's probably what we want. Ok, so the first 30 minutes are free, after that there is an hourly fee. But they don't give me the hourly rate. Ok, I found out that I have to pay, they don't want to tell me how much, so I guess I'll keep reading, it might say something[181]. We are not coming with a handicapped license right?

Observer: Um, no.

#31: I think this is what we want now…30 dash 59, I don't know what it's saying there[182]. Let's see (uses the right/left arrow keys). Oh, ok, well, I see there so I guess… from 30 to 59 minutes, three bucks. From 60 to 119 min, five bucks. This is I guess the answer of the question.

User satisfaction survey questions:

---

[177] Information scent

[178] User has heard something that matches what he's looking for

[179] Tabbing for navigation technique

[180] Meaning of content not clear

[181] User is finding the information he wants on the page

[182] What JAWS is reading doesn't make sense, so user uses different keys to read it character by character

Observer: This site was easy to navigate.

#31: 6

Observer: how come?

#31: The main thing I saw was that it didn't have too many links in comparison with the other one or in comparison to some other web sites, and I think most of the time it was taking me right to where I wanted to go, to the results of the search or um, to the content of the page, it wasn't taking me through the links[183]. There was one time when I think it took me through the links.

Observer: But that really saves a lot of time and it's not as repetitive.

#31: Exactly.

Observer: I could effectively complete all the tasks.

#31: Uh, 6. And I think it was, filling out the form was OK, yeah, 6 is fine.

Observer: The layout of the site was easy to learn.

#31: Also 6.

Observer: My overall experience with the site was positive.

#31: Yeah 6.

Observer: This is the kind of web site I would visit on my own.

#31: 3.

Observer: The site was aesthetically pleasing.

#31: Um, I don't remember seeing much but I didn't see anything that I disliked, yeah 6, because I think it's simple, it doesn't have too many fancy things[184], yeah, 6 is fine.

Observer: Ok, do you have any other comments about this web site?

[183] Direct nav
[184] Good feature of site

#31: The only thing that got me confused was the thing about memberships and donations[185]. But I don't know if um, do you see memberships and donations as being the same thing?

Observer: Well not exactly but… I guess, kinda like you did, if I didn't see donations anywhere else I would probably think that this is what they mean.

#31: Yeah, ok, and that… I think the information for the donation, I think this is actually a table, I thought that was clear, I thought that was good[186], but I was a little confused to understand if the membership was a donation or if the donation was something else, so.

Observer: Yeah, I think they probably do this to make donating more, you know if they give benefits away with donating then they make it more attractive.

#31: so yeah, so it's more membership like than donation.

Observer: Yeah, and I guess also, maybe other people do that as well, like if you donate to PBS then you have a membership as well

#31: Oh that's true, right, like they have on TV where they play the specials of whatever, and if you give us a $200 donation, we'll give you whatever, a video of the show

Observer: Yeah, so maybe that's what they were saying.

#31: Yeah, OK.

University Extension Evening Credit Courses (UEX) Web Site

Observer: (reads scenario from Appendix D)

#31: Ok, those instructions sound like there's already something set up under continuing education, so I'm going to look for a link that might say something like

[185] Trouble with word choice

[186] Table has clear layout of information

that[187]. Ok, I think that's the one probably. And I'm sorry, they were computer classes[188]?

Observer: Yeah, they were a class in computer programming that you can take this fall.

#31: Computer programming? OK. (starts listening) There is something here I've never heard before, alt+6, those sound like shortcuts to the links, I've never seen that before[189]. Ok…I think… (listening). Ok, I think I will go to professional enrichment[190]. (goes back to that link). And I think, let's see if that one has it. These computer programs are not part of a certificate are they? It doesn't say anything so…

Observer: Yeah the task doesn't see anything about that.

#31: Ok, let's see what we've got there, in professional[191]…

Observer: I'm gonna stop you here because we got off the site. There's something in the task about the continuing education department but we wanted to test the site called University Extension. So you need to go back a few pages.

#31: OK. So this is the one right (on UEX home page)?[192] So can I still go to the continuing education link that I found, or that one was the one that took me off?

Observer: That was the one that took you off.

#31: Ok, so I just look for it here… Ok. (listens to JAWS read) That was the one I clicked on before, so I will skip that one. Link to courses, I'll look for it there and see if I can find… ok, I um, this sounds like because it's not part of a program and it said there that I have don't have to be admitted to this, UEX I guess, so it sounds like I can take an

[187] User has in mind what he's looking for
[188] Confirming task
[189] New feature, user is guessing what they are
[190] User chooses his navigation option from a link he found on the page
[191] Exploring the contents of that page
[192] User confirming his position

independent course without having to worry about any other courses, so I'll give this a try[193]. This was, um, this semester, um, where are we, October? Fall 03?[194]

Observer: Yeah, do it for Fall 2003, even though they would have been past but…

#31: Right. Ok, view classes. Ok, let's see what the table has. (scrolls through table) I'm trying to… I think this will probably start with C but I don't want to miss anything so I don't want to go too fast. Ok, that might be one, CS… elements of databases. I'm going back to see if I missed any CS or if there was only one[195]… (moves up and down in the table) Ok, I think what I will do here is do a search for computer and, no, I'll do a search for program, that should find programming too, and see if I can, if the description of the class supposedly should say something programming or program related, let's see what they have[196]. Ok, search string not found, but JAWS didn't read that. Ok, I guess I'll go, I'll have to go through everything.[197] (scrolls down through table). Let's see… if it finds something under language[198]. Oh, that's not what I wanted (language and culture). Um, I think I will go to the M's and see if I find something for MIS[199]. Ok, I'm still looking for something that… (still scrolling in table). Ok, so that's not it… sounds like a computer one but doesn't sound like programming, and now jump to marketing. Ok, MIS, it went from MIS to ??? so it sounds to me like there aren't any MIS classes, I though it might be, might list some of the, um, some of the programming classes. Um, I didn't find them where I thought I would find them, under MIS or under

[193] User will try this link because it sounds good
[194] Confirming the time of the course
[195] Concern that he might have missed information
[196] Search is based on scenario terms
[197] User comments on the amount of information he'll have to go through to find what he's looking for
[198] User has something in mind that he's looking for
[199] User knows what he's looking for and a navigation tactic for finding it

CS, let's see if I can… if "computer" helps any. That didn't find anything either, so… it would sound to me that it's not here[200].

Observer: Ok, well how about we go with one of the ones that were kind of close [for the next scenario].

User satisfaction survey questions:

Observer: This site was easy to navigate.

#31: 6

Observer: I could effectively complete all the tasks.

#31: 5

Observer: The general layout of this site was easy to learn.

#31: 6

Observer: My overall experience on this site was positive.

#31: 6

Observer: I would visit this kind of site on my own.

#31: 5, just because of being a student.

Observer: and you probably would have realized by now if you've ever been there before

#31: No, I don't think so, I don't remember any of those things. I never dropped any classes so I don't have to worry about that part. And the schedule, I remember looking at a schedule, some things I know about but not exactly this.

Observer: The site was aesthetically pleasing.

[200] User is not finding information where he expected it

#31: Um, didn't really look at it much but I think, I'd say 5. I noticed that it's not full of colors and weird things which makes it good. The text there is all clear, no fancy things[201], so… yeah, 5.

Observer: OK, do you have any other comments?

#31: Well I like the link on top that takes you to the main content, that's what we always talk about so that's a good thing[202], and I think everything else was OK.

LBJ Library and Museum (LBJ) Web Site

Observer: (reads scenario)

#31: I think I've been here, a long time ago, probably 3 years ago.

Observer: Why did you go to the site?

#31: I think I was doing some research about some illness or something medical, I don't remember why, but I remember it wasn't school related.

Observer: Well since it was a long time ago, let's go ahead and do it.

#31: Ok, I'll let you know if things start sounding really familiar, but I don't remember much at all.

#31: Let's take a general look around[203] (starts listening to JAWS). I think, let me tell you what I'm thinking of doing. I'm hoping there's some kind of a link that says LBJ's biography or something biography so I'll look for something like that first… if I don't find anything quickly I might go to the links[204]. (listens for a while) Let's do the links. I don't want to deal with the images[205] (referring to the images on the page). I thought I was going to find something there but nothing… it's all the same.

---

[201] Simplicity is good

[202] Likes accessibility feature

[203] Getting an overview of the site

[204] User has a plan of what he is looking for

[205] User changes tactics

Um, I think I'll go to research[206]. (new page) Ok, I'll go to the links again. Hm, education maybe… ok, let's try that one (biographical chronology link)[207]. Well, I'll make this read and see if at some point it gets to it…JAWS got wacky! (JAWS is saying "block quote start" over and over again). Do we have more to read on the page? According to JAWS I'm at the end of the page. But I remember on top I had a bunch of links to the page… do you see anything visually that is relevant to what JAWS is saying??? [208]

Observer: It looks like they used block quotes, but I can't imagine why they'd have a whole bunch of block quotes together like that. Has JAWS done something like this before?

#31: No I have never heard this. So you think its reading code? That it's not this text[209]?

Observer: Well, yeah, there's the possibility it's doing that but I don't know.

#31: Ok, I'll keep looking (pulls up JVF). I'll see if it finds something about married[210]. Ok, there it is. November 17, 1934. That was the question, right? The date?

Observer: Yes.

#31: Ok. I don't know what the other thing was!

Observer: You know they've got bits of text, but actually, the paragraphs of text don't look like block quotes, and they're left justified.

#31: Block quotes meaning? What is block quotes[211]?

---

[206] User didn't find what he was looking for so he followed a link he found on the page
[207] User is making decisions based on what he's finding on the page
[208] JAWS problem
[209] JAWS problem
[210] User changes navigation tactics to work around JAWS problem

[211] User does not know about HTML code

Observer: Oh, a block quote is a formatting thing, if you quote someone…

#31: Oh it's a quote? More than 4 lines or something?

Observer: Exactly, it's something you use for the text, and it's… the margins are straight on both sides, so it could be formatting, but also, it should be used for quotations

#31: But nothing looks like it here, right?

Observer: yeah but if you notice the right margin is jagged

#31: On this?

Observer: yeah, and for a block quote it would be straight.

#31: right, and also, the contents didn't have anything that would be quoted.

Observer: Right, this is all just, these things happen, this is all…

#31: Yeah, hm, I dunno, I wonder if this, this is an image here, I wonder if that had anything to do with it, getting everything confused. Let's see if it keeps reading (lets JAWS read). Sounds OK now.

Observer: Maybe it was just a JAWS thing. Let's go on to the next text.

User satisfaction survey questions:

Observer: This site was easy to navigate.

#31: 4, mostly because of all those links and not having a way to skip them[212].

Observer: I could effectively complete all the tasks.

#31: No, 4 or 3. Let's say 3.

Observer: The general layout of this site was easy to learn.

#31: Um, say 5. After I got through all the links 4 times[213]! (laughs)

Observer: My overall experience on this site was positive.

[212] Lots of links, no accessibility feature

[213] User got frustrated with trying to get through all the links

#31: Uh, 3. I think this is the worst one we've seen so far. A lot of things there and no way to avoid some of the things I was not interested in[214].

Observer: So, very frustrating?

#31: Well, I guess once you get to the content, it's OK, but you have to go through 45 links before you get to that[215].

Observer: For every page.

#31: For every page, exactly, that takes a lot of time[216]. And then when it takes you to web sites that are worse than the web site you're on, that's not good!

[the video quit at this point and moved on to the next one]

Center for Lifelong Engineering Education (LENG) Web Site

Observer: (reads scenario)

#31: Ok, software programming. Let's look around the links[217] (brings up links list). Custom courses might be one… Short courses might be another one. Software, no. I'm also looking for something that might say continuing education[218]. Ok, I think I'll go to the… where was that one… I'm going to start with custom courses. From everything you read it doesn't give me the impression that it's a short course, so if, if it were I might have gone to that one[219]. Let's see what I can find here.

(JAWS will not read) Ok, let's see if it wants to read. Did I kick the speaker? No? I'm not on the Web site. Let's see.[220] (JAWS starts reading again) Well, um, what I want to take is not a custom course, it's just a regular course isn't it?[221]

---

[214] User would like more navigation options that let him skip around
[215] Lots to get through before getting to the useful information
[216] User would like for things to be faster
[217] Links list navigation technique
[218] Has an idea of what he wants but is mentally marking other possibilities.
[219] Making decisions based on the scenario
[220] Problems with JAWS

Observer: Yeah you want to find a course they already have.

#31: So this is not the right place then (goes back). Certificate programs, no… I think I'll try short courses. It also sounds to me that this course is an independent course, not part of a certificate program or a degree I'm trying to get so I guess short courses might have something[222].

(Listens to JAWS on new page) No, I don't like this one either. (goes back)

I guess I'll go to one of the other ones I said I wouldn't go to… let's do e-training[223]. (JAWS won't read) Again, it doesn't want to read. Is it still loading? Loading the web site[224]?

Observer: I think it's finished. What does F5 do?

#31: Refresh. This is what I did earlier (presses some buttons) and it made it read. (JAWS starts reading again) What was the course again[225]?

Observer: It was a course on software programming for less than $500.

#31: Here I would like to find a link but it gives me a list of courses. So far nothing. (listens to more links) Software, software sounds like different pieces of software but nothing that I would want. Ok, it read everything I think and I didn't find what I want[226]. I don't know… I don't want that one… I'll go up to that one and see (chooses certificate programs). Again, it doesn't want to read[227].

#31: I don't know if we've seen this before, if this is JAWS.

---

221 Confirming task

222 Thinking through what would be the best option – looking for something that matches what he's thinking of

223 User is making decisions based on what he finds on the page

224 More JAWS problems

225 Confirming the task

226 Nothing on this page is matching what the user is looking for

227 JAWS problem

I dunno, but JAWS was reading everything fine before. It looks like it gets stuck and then when you open something else it's OK. (lets JAWS read). Ok, this sounds… like something I want. No, that's not what I want[228]. Oh, I guess I need, it sounds like I need to go there to learn more about this. Do we want to go there?

Observer: If that's what you want to do…

#31: Because it will take me to a different web site it sounds like[229]. What it said on that page looked kind of like what I wanted, where it said that you can take one class, or the classes you want only, or complete the certificate in three years, that sounds kind of like what I want, just one class[230]. But then it said if you want to learn more about this, go to this other Web site, and this is the other web site… uh-oh (IE has disappeared from the screen). Ok (gets it back up, then disappears again). Why is it doing this?

Observer: What are you doing?

#31: I'm pressing the, I'm minimizing everything, I'm getting confused[231]. Ok, now I wanted to see the address… I guess… um, I guess I… I'm not really sure where I am but I'm looking for certificates[232]. Let's see if this is what I want. Link programming. I think this is within certificates, I'll go there and see if it gives me any classes. Um, it didn't give me what I wanted there[233] (goes back). Ok, this is where I left off.

Ok, it sounds like this ones are the classes, because you have to complete the 6 classes, and I think these are the classes, but it doesn't talk about pricing, and I know the

228 User can't decide which link to follow
229 Is concerned about going off site
230 Is trying to match the scenario to what he's hearing on the page
231 Confused
232 User is not certain where he is but knows what he's looking for
233 Is not sure he heard all the relevant information

class had to be less than $500[234]. Ok, I'll keep looking… does this have prices? No. I'll go to payment information and see what it says.

Ok, that's not one (read a class that was $1800). No… no… (all courses are $1800), no…

Well, um, I think I'm, well, they are too expensive, but also the class I wanted was a programming class, and this said something about a programming certificate I thought, I don't know if these are about programming[235].

Observer: So these course titles don't sound like what you'd expect?

#31: Right, exactly. And this was under certificates and I thought I'd looked under the other links… I didn't find anything. I think they could make it much easier if you just put a link that says courses![236] (laughs) Like the main web site does. I dunno, maybe, I might have gone through some of them and they might have been there but nothing was clear enough to tell me that that's where I was so I might have skipped it[237]. Um, I can go back and review all of them again if you want

Observer: Well, I just want you to do what you would do if you were at home, including say I would stop here and give them a phone call.

#31: I think at this point I would try to find a phone number and call them. Well… I will go again to e-training. Ok, that's, I think that's where I started…no, I don't think this is the one that has what I want[238] (goes back). Let's see short courses, is the last thing I can check. This is the same thing I saw earlier. Ok, this doesn't say anything about software programming. Some of these are… there's no information about payment[239]. I'll

[234] Doesn't have the information he needs
[235] Is trying to match scenario with what's on the page
[236] Not matching what expects, which is courses.
[237] Is not sure he heard all the relevant information
[238] Decided that this page does not have what he needs
[239] Information he expects is not there

look toward the bottom and see if there's anything about payment like there was on the other one. Let me go to the end and go back[240]. Ok, that's one, and that's a link, let's see if it gives me price information.

Um, programming is where I went last time, I don't think I found anything there. I'm looking for money here… (listening to JAWS) Oh I guess… they are that expensive, they are hiding the cost![241] (laughs) No, I think this is similar to what I saw earlier, but it's too expensive.

User satisfaction survey questions:

Observer: This site was easy to navigate.

#31: 4. And usually in my case what makes it easy or difficult to navigate is having to go through all of those links or not[242].

Observer: Yeah, and there were a lot of links.

#31: And another thing is that, some of these web sites, they say weird things, like they read symbols and things like that, and I didn't notice that on the UT web site, on the main utexas.edu, and I remember on this one it said "level" where it was reading this title here, contact us? It said "level 1"? (lets JAWS read) Heading level 1[243].

Observer: Well, that's actually hypertext markup

#31: Oh is it?

Observer: Yeah

#31: I dunno… so that's the Web site?

Observer: Well, it's part of the HTML…

---

[240] Using a different nav technique
[241] Still not finding cost information
[242] No way to skip links
[243] User is not familiar with this HTML code

#31: but I didn't hear any HTML on the other web sites[244].

Observer: Yeah, well, people have different ways of making the text, um, have different visual characteristics, and sometimes it's not going to be picked up by the screen readers because they may just change the font size and make it bold, but one way of changing the visual characteristics is also a way of organizing information, which is using these heading levels, and there are six different levels that people can use, like level 1 is the biggest, level 2 is slightly smaller, so you could use it to like, mark up a paper or something like that. So here they said, contact us, we want this to be bigger because there's information that fits underneath it.

#31: The problem that I find with that is that for a normal user who doesn't know any HTML or anything like this, it doesn't make any sense[245]. But I noticed that on this one it has these things and on some other ones they didn't have it, on some other web sites.

Observer: I think on the main UT page they specify the size of the text, I think it may be in pixels, so you're not going to hear anything like that.

#31: Can they do this same thing, have this coded as exactly the same way it looks, but in a different way so that it won't say that?[246]

Observer: Oh yeah sure. Most people don't use, well, I think it's pretty common not to use that type of markup, but there is another site we were looking at today that had that, and I can't remember what it was right now…

[244] User is not familiar with heading tags in HTML
[245] Users shouldn't have to know HTML to navigate
[246] Not meeting his expectations, he should not have to hear confusing stuff

#31: I don't remember… I know some of the ones we did earlier that had a lot of links they also had a lot of things in the middle that didn't really make much sense, like a lot of symbols[247].

Observer: University Extension I think had that kind of markup, but yeah, I'm not surprised you wouldn't hear it too often.

#31: Yeah.

Observer: Um, I could effectively complete all the tasks.

#31: Um, say, 4, to that. I'm being kind.

Observer: The general layout of this site was easy to learn.

#31: 4.

[the video cut off after this point]

[247] Hearing JAWS read code is apparently nothing new

Tables of Grounded Theory Codes

After creating memos in the transcripts, as indicated by the footnotes, we looked for categories within the memos and created the following list of categories (in alphabetical order)

- Changed navigation tactics
- Comments about code, markup, or accessible features, or lack thereof
- Confirming Task
- Content or functionality did not match user's expectations
- Getting familiar with the Web site
- JAWS is misbehaving
- Overall experience
- The user liked something
- Unable to differentiate between links
- User comments on how long something takes
- User comments on identifying/ not identifying with current scenario
- User comments on lack of site structure
- User comments on the quantity or quality of information
- User has something in mind that he's looking for
- User is making decisions based on the information found on the page
- User is uncertain of spelling
- User is worried about losing their place, missing information, or has lost their place
- User points out a navigation technique
- Using or lacking prior knowledge

After creating the list of categories, we reviewed each of the underlined user comments and organized these comments into categories. We then identified overarching themes to define a small number of core categories that described the user's navigation tactics. This process is discussed in more detail within the body of the dissertation document; Tables 38-41 show the steps of organizing comments into categories.

Participant #6

Web Site	Line number	User comment	Grounded theory category
Texas Memorial Museum (TMM)	7	My answer would be free because I would take the bus!	• User comments on identifying/ not identifying with current scenario
	29	the search function wasn't working too well	• Content or functionality did not match user's expectations
	38	I really wish it wouldn't do that when you click on something everything else comes back up and you have to go get past it all again.	• Comments about code, markup, or accessible features, or lack thereof
	43	I don't know, because I'm not real experienced with using it but that might make it less frustrating when using the site.	• Overall experience • Comments about code, markup, or accessible features, or lack thereof
University Extension Evening Credit Courses (UEX)	66	Am I looking for a specific thing?	• Confirming task
	68	Let me go to the top and try something else.	• Changed navigation tactics
	76	I guess, if the links had been clearer.	• Unable to differentiate between links

	82	I'm just too used to the UT web site and I would have expected that another site that had classes to be similar to that one since both are UT so it just frustrated me that it wasn't like… um, it wasn't set up the same.	• Content or functionality did not match user's expectations
	108	I think one thing that it would be neat if they could do it is like when you click on a course that you're wanting to look at or when you pulled up a list of courses, if they have links to the courses to be able to directly register?	• Content or functionality did not match user's expectations
	112	Instead of having to write down and remember all the course stuff	• User comments on the quantity or quality of information
LBJ Library and Museum (LBJ)	123	I though I'd find the archive and then I was gonna just look at the site index	• User has something in mind that he's looking for • Content or functionality did not match user's expectations
	127	But this is what I meant, the site index (listening to Site Index link), right there, and that is the LBJ site.	• User is worried about losing their place, missing information, or has lost their place • Content or functionality did not match user's expectations
	133	You'd have to know what year you want!	• User comments on the quantity or quality of information
	136	See that's what I thought, when I found the biographical chronology thing I thought that would be a good site because, or a good link	• User has something in mind that he's looking for • Content or functionality did not match user's expectations

	143	I found the different years and you would have to know what year you were looking for to be able to click on that to find it and that would take too long.	• User comments on the quantity or quality of information • Content or functionality did not match user's expectations

Table 38: Participant #6: Grounded theory categories

Participant #20

Web Site	Line number	User comment	Grounded theory category
LBJ Library and Museum (LBJ)	171	When did LBJ get married, is that what I'm supposed to be looking for	• Confirming Task
	175	First I have to see what the site is.	• Getting familiar with the Web site
	176	Well that didn't help.	• Content or functionality did not match user's expectations
	183	I didn't actually see what I wanted.	• Content or functionality did not match user's expectations
	181	It's not bad once you get to the site map	• The user liked something
	185	I didn't see a meaningful tag for what I was looking for so I went to the site map.	• User has something in mind that he's looking for • Comments about code, markup, or accessible features, or lack thereof • Changed navigation tactics
	187	like, bio, or something like that	• User has something in mind that he's looking for
	189	site map it was very easy	• The user liked something
	193	structural tags like the headings	• Comments about code, markup, or accessible features, or lack thereof

	200	I dunno what's under these… there's education, research… museum… how do I know which is which	• Unable to differentiate between links
	199	they've got Main page on one page and Home on another page.	• Unable to differentiate between links
	215	I did think the biographical page was very nicely done.	• The user liked something
Star Date (SD)	221	Just listening to this	• Getting familiar with the Web site
	222	could be under Radio [link]	• User is making decisions based on the information found on the page
	224	Don't know if it's going to be one word or two	• User is uncertain of spelling
	226	except that it's sky space lab	• User is uncertain of spelling
	226	there's 34 things [on the page]	• User comments on the quantity or quality of information
	232	It might also benefit from headings. Yeah it needs to have headings too, I'm just big on headings. I'm just really learning how valuable headings are when jumping over skip to nav.	• User comments on lack of site structure; Comments about code, markup, or accessible features, or lack thereof
	234	This does not have a skip to content and I never use it anyway because JAWS will put you just damn near anywhere on the page it wants to	• Comments about code, markup, or accessible features, or lack thereof
	236	needs some structure on the page, like the skip to content links and the headings links	• User comments on lack of site structure • Comments about code, markup, or accessible features, or lack thereof
	244	as a random person that's not interested in stargazing	• User comments on identifying/ not identifying with current scenario
	253	I still don't know what the layout of this site is.	• User comments on lack of site structure

	257	If they had the structural stuff, I think that the next time I came back and spent some time seeing what's here, I would be able to complete all the tasks very effectively, you know, if they had the structural stuff all through the site.	• User comments on lack of site structure
	260	the searchability of the site was excellent	• The user liked something
Center for Lifelong Engineering Education (LENG)	273	I mean there's 5 different kinds of classes	• User comments on the quantity or quality of information
	275	Any of these varieties of classes?	• Confirming Task
	279	What did you say we're looking for?	• Confirming Task
	282	Uh… something's wrong.	• JAWS is misbehaving
	285	I do that a lot I read web pages backwards I'm not sure why	• User points out a navigation technique
	289	I don't know how many people know that, you can hit ctrl-enter and make sure… it forces it to open a new window so you don't lose your place in the other one	• User is worried about losing their place, missing information, or has lost their place
	292	If it's a JAVA window dot open thing it won't work.	• Comments about code, markup, or accessible features, or lack thereof
	313	This really just feels like an engineering site, um, it's just so convoluted	• User comments on identifying/ not identifying with current scenario
	316	I don't know what this site is, I don't know who these people are, um, I don't know what I'm doing here	• User comments on identifying/ not identifying with current scenario
University Extension Evening Credit Courses (UEX)	328	I can't put myself there in this huge stream	• User comments on identifying/ not identifying with current scenario
	331	minimize it to whatever information you actually need to remember.	• Confirming Task • User comments on the quantity or quality of information

	350	I could just go there	• User is making decisions based on the information found on the page
	351	Just seeing what's here	• Getting familiar with the Web site
	354	I would expect there to be links to the descriptions from the registration pages	• Content or functionality did not match user's expectations
	370	this is the kind of site that I know how to access . There's a certain literacy that I think that's an issue between a site like this and Star Date and Engineering.	• User comments on identifying/ not identifying with current scenario
	376	They've got link to home page, by the way, it's unnecessary. They've got these alt tags that say link to home page.	• Comments about code, markup, or accessible features, or lack thereof
	381	Except that they're using the headings inappropriately … right here… University Extension offers evening courses blah blah blah, this is all Heading level 3… it's also a block quote which is also inappropriate.	• Comments about code, markup, or accessible features, or lack thereof
French and Italian (F&I)	401	You're wanting to know if a degree program?	• Confirming Task
	416	The whole French and Italian thing was odd	• User comments on identifying/ not identifying with current scenario
	419	clear hierarchical structure to really KNOW if you're clicking on a link that's going to be for Italian, French, or both	• User comments on lack of site structure
	429	some of these links are in quotes, um maybe it's because they're image links, um, yeah, like link graphic quote, they've got quotes, quotation marks inside their alt tags for whatever reason…	• Comments about code, markup, or accessible features, or lack thereof
	432	that was one that's not alt tagged right there	• Comments about code, markup, or accessible features, or lack thereof

Table 39: Participant #20: Grounded theory categories

Participant #24

Web Site	Line number	User comment	Grounded theory category
University Extension Evening Credit Courses (UEX)	438	Hello?	• JAWS is misbehaving
	443	I'm in a links list, right?	• User is worried about losing their place, missing information, or has lost their place
	447	There's some things not showing up in this dialog that I was expecting to find	• User has something in mind that he's looking for • Content or functionality did not match user's expectations
	451	I was looking for the thing that was showing up in the links list view	• User has something in mind that he's looking for
	462	Surely those are the same thing	• Unable to differentiate between links
	464	so I was looking for a heading on project hot start so I could jump straight to	• Changed navigation tactics; User has something in mind that he's looking for
	468	First I thought hot and start were two separate words	• User is uncertain of spelling
	472	Hello?	• JAWS is misbehaving
	475	They should "quote quote" that graphic divider	• Comments about code, markup, or accessible features, or lack thereof
	481	Thank you JAWS	• JAWS is misbehaving

	487	it was hard to find things and it was hard to hard to know what the link names meant	• Unable to differentiate between links • Content or functionality did not match user's expectations
	489	there were multiple links where the link text was close enough that it was hard to differentiate	• Unable to differentiate between links
	493	there's no skip to main content link , um, so it was annoying to have to listen to all the links.	• Comments about code, markup, or accessible features, or lack thereof
	497	I was trying to, and that's, that's why I was sort of stalwart and the Alt-M thing didn't work, and I think there's something, there's a way to configure the links list so that would be availalbe	• JAWS is misbehaving • Content or functionality did not match user's expectations • Changed navigation tactics
	501	it's a setting somewhere but I don't know where , some option somewhere	• JAWS is misbehaving
	502	there were relatively few headings and on the pages I was most concerned about where for example on the course information and stuff the headings weren't particularly useful, so that, you know, they have search under headings which is fine, but sort of critical information wasn't set off with headings so I couldn't use the headings list to jump to it. But that wasn't really available as a meaningful way to bypass the navigation.	• User comments on lack of site structure; Comments about code, markup, or accessible features, or lack thereof
	509	I was able to effectively find the mailing address and phone number b/c they were right there under the contact info and that was nice.	• The user liked something
	511	there was something about the sequence that felt strange	• Content or functionality did not match user's expectations

	519	It just seemed disconcerting, like I said register now and instead of asking, it didn't go directly to asking me for the typical kind of registration information, which is like who are you and all that kind of stuff, and it did that shopping cart thing and I had to hit register now again, and it was annoying to then discover that I had registered. It felt like it was asking for information in the wrong order	• Content or functionality did not match user's expectations
	526	sort of like one of the amazon sites, amazon access	• Content or functionality did not match user's expectations
	542	The auditory experience wasn't particularly good	• Overall experience
	546	it was sort of a hodgepodge instead of a… it didn't feel like it was offering a coherent approach to lifelong education	• User comments on lack of site structure
	547	If you already knew what you wanted and knew the right terms you could probably get to it	• Using or lacking prior knowledge
	549	The search feature was really weird, cause it didn't, it sounded like it was trying to be a site search but in fact it only looked for courses	• Content or functionality did not match user's expectations
	551	if it is in fact a search for courses then it should give you a lot more fields so that you can tell it to get more information , more criteria about what you're looking for.	• Content or functionality did not match user's expectations
LBJ Library and Museum (LBJ)	557	What is the Age of Augustine doing at the LBJ?	• Content or functionality did not match user's expectations
	558	I swear I chose a link called Search	• User is worried about losing their place, missing information, or has lost their place • Content or functionality did not match user's expectations

	559	So I'm on a search page that doesn't have an input field?	• User has something in mind that he's looking for • Content or functionality did not match user's expectations
	560	No headings… and there wasn't a skip nav link I don't think	• Comments about code, markup, or accessible features, or lack thereof
	563	Bio page… I'm trying to decide if that's something that might have a biography	• User has something in mind that he's looking for
	566	Do I have to listen to all this again?	• Comments about code, markup, or accessible features, or lack thereof • User comments on the quantity or quality of information
	569	I think that was actually a JAWS thing	• JAWS is misbehaving
	575	I'm searching for telephones	• User has something in mind that he's looking for
	584	Yeah, it's a scanned document, I suspect anyway	• Comments about code, markup, or accessible features, or lack thereof
	592	it was mostly the search thing, that just made me crazy.	• Content or functionality did not match user's expectations
	595	it's organized to their understanding of where they got their stuff rather than to mine , in ways that would help someone who doesn't already know what's there and where it is, find it.	• Using or lacking prior knowledge • Content or functionality did not match user's expectations

	603	I had to listen to all the navigation… there is no skip nav link, there are no headings, so I had to listen to all the navigation stuff in order to get to the part of the page where the information I wanted might be.	• Comments about code, markup, or accessible features, or lack thereof
	607	although it said “graphic” for a reason that I don’t understand	• Comments about code, markup, or accessible features, or lack thereof
	608	I was able to really complete the task effectively because I was guessing on the basis my experience interpreting file names rather than getting real information in the form of alt text or onscreen text to identify the items	• Using or lacking prior knowledge
	615	I remember somewhere along the way hearing, somewhere I heard the word gifts go by	• User is making decisions based on the information found on the page
	626	the search stuff was impossible.	• Content or functionality did not match user's expectations
	637	It was abysmal. It was confusing and there was nothing interesting to listen to and when there was actual text, there were mistakes in it, it was badly written.	• Overall experience; User comments on the quantity or quality of information • Content or functionality did not match user's expectations
French and Italian (F&I)	644	Wasn’t expecting that!	• Content or functionality did not match user's expectations
	646	All right, let’s try ‘departments”	• Changed navigation tactics • User has something in mind that he's looking for

	652	it felt like in getting to the fact if I followed the link to the faculty page it felt like too many more steps to actually get to the faculty .	• User comments on lack of site structure • Content or functionality did not match user's expectations
	658	that page was a little confusing because there were those links at the top that sounded like I might have to go somewhere else in order to get different sections of the page or something , and then only, because I just decided to let it go because that didn't sound quite right either, and I started hearing the stuff	• User comments on lack of site structure • Content or functionality did not match user's expectations
	661	it would have been nicer if the different categories in the cv like education and publications were actually marked as headings	• User comments on lack of site structure; Comments about code, markup, or accessible features, or lack thereof
	663	I know what a CV looks like I know what the headings are supposed to be, ah, I was able to search for it and do a find, but it would have been easier if there were headings. Because then if you didn't know how it was organized, pulling up the headings list would be the way to get to the information .	• Using or lacking prior knowledge; • User comments on lack of site structure; Comments about code, markup, or accessible features, or lack thereof
	675	I found the stuff I needed but I didn't get any pleasure out of it	• Overall experience
			•
Star Date (SD)	682	it's annoying that there's no skip to main link, it got increasingly annoying	• Comments about code, markup, or accessible features, or lack thereof
	686	I got confused about what kinds of searches I could conduct b/c if I thought I was looking… I went for a link that said keyword search and then I didn't find an input field on that page and then there was a whole list of things which was not quite what I was looking for	• Content or functionality did not match user's expectations
	706	I do know what star date is, I hear it every day, or many days.	• Using or lacking prior knowledge

	708	I listened to enough of the home page when I first landed on it	• Getting familiar with the Web site
	711	That's because I'm in this kind of weird task situation so that slightly alters my behavior	• User comments on identifying/ not identifying with current scenario
	712	I was happy when I did that because it, there was specifically a program search there and that's what I was looking for	• The user liked something
	714	Then that turned out to be misleading because I then thought there would be sort of constrained searches elsewhere	• Content or functionality did not match user's expectations
	718	But it doesn't say program search on the home page I don't think, it just says search.	• Content or functionality did not match user's expectations
	728	you have an input field for the go button, but if you want a keyword or site search it's another page	• Content or functionality did not match user's expectations
	731	That's where I got confused because I went to the keyword one	• User is worried about losing their place, missing information, or has lost their place
	732	that's really badly labeled	• Comments about code, markup, or accessible features, or lack thereof
	734	I thought the program search was really good and the finding affiliates was well done	• The user liked something
	736	I think that only worked for me b/c I listen to NPR so much that I know what affiliates means	• Using or lacking prior knowledge
	747	not having consistent headings and/or skip nav really gets old . I just don't wanna be on it, I don't wanna have to listen to very many pages. It just takes so long to find out whether you're where you want to be or not	• User comments on how long something takes • Comments about code, markup, or accessible features, or lack thereof

Table 40: Participant #24: Grounded theory categories

Participant #31

Web Site	Line number	User comment	Grounded theory category
Star Date (SD)	762	And it would be spelled s-k-y-l-a-b?	• User is uncertain of spelling
	764	So you want me to find information on that, skylab	• Confirming Task
	765	I see one here but JAWS is not finding it	• JAWS is misbehaving
	765	I think what I will do is try to find a search box, for to search	• User points out a navigation technique
	773	but it didn't work, so what I would do is I will search for a link called search	• Changed navigation tactics • Content or functionality did not match user's expectations
	780	So I guess I'll tab (uses tab key) hopefully until I can find it.	• Changed navigation tactics
	782	No… it's not doing what I want. OK, I try to get into that box that I found there that said, that said edit.	• JAWS is misbehaving
	784	I think we'll try something else… I try to get into that box but I wasn't able to get into it. So one thing I would do here, if I were at home I could get the mouse and go to the box here, click, and I would type…	• Changed navigation tactics
	787	Something's weird because it doesn't let me type there. Uh-oh, I don't know what it did there.	• JAWS is misbehaving
	793	I wonder if now, maybe now you don't have to do this thing to search for it. Maybe once the cursor is in it, as soon as you do enter, it starts them all. We will see.	• JAWS is misbehaving
	798	And here you wanted me to find whatever I could find about Skylab?	• Confirming the task
	800	OK. Radio… let's see.	• User is making decisions based on the information found on the page
	800	I guess I'll just let it talk until I find something.	• User is making decisions based on the information found on the page

	801	So it had to read all of those links that I don’t really care about.	• Comments about code, markup, or accessible features, or lack thereof
	802	I think I will just move the cursor down to see if I can get there faster.	• User points out a navigation technique; Changed navigation tactics
	803	I think what it was doing that, probably here I had a long menu of things, but I want to be here.	• Comments about code, markup, or accessible features, or lack thereof
	806	I think the UT web site, has a link where it says go to main content? And those are useful. Because I think, JAWS has a feature that you can use for that too but it’s not very exact.	• Comments about code, markup, or accessible features, or lack thereof
	810	program schedule might have some information but… there, find an affiliate is probably the one that will give me a radio station	• User is making decisions based on the information found on the page
	812	I think this version you don’t have to activate forms mode. When you get to a box you press enter and it works.	• JAWS is misbehaving
	817	I also found Austin somewhere here, see if I can get to that point it will probably tell me the stations I can listen to.	• User is making decisions based on the information found on the page
	825	I will go to the list of links and look for one that says, um, what is that called, streaming audio or something like that.	• User points out a navigation technique; User has something in mind that he's looking for
	827	I see now, I picked Listen. Ok, so here… I will click on one of these, yesterday’s program, I’m assuming that if I click on that one it will play.	• User is making decisions based on the information found on the page
	831	I think I saw something that said archive.	• User is making decisions based on the information found on the page
	833	I was hoping that when I clicked on search by topic it would help me and allow me to do the search	• Content or functionality did not match user's expectations
	834	so hopefully that’s where I am now	• User is worried about losing their place, missing information, or has lost their place

	836	This is just a table I guess	• Comments about code, markup, or accessible features, or lack thereof
	842	not having a link that would take me directly to the content, and having to go through all the links on every page	• Comments about code, markup, or accessible features, or lack thereof
	853	I think they have a feature that these are different frames, if this one is one and this one is one	• Comments about code, markup, or accessible features, or lack thereof
	856	if they are different frames then JAWS has a command to go to different frames	• User points out a navigation technique
	857	still it's not very useful because if you, unless you know that the link is all the way on the right, you cannot really go directly there because you don't know what you are missing in the middle	• User is worried about losing their place, missing information, or has lost their place
	859	the main problem I found was having to go through all the links every time you went to a different page .	• Comments about code, markup, or accessible features, or lack thereof
	865	everything was in the same place so that made it easier .	• The user liked something
	880	I kind of like how they have, when I have contrast I can see things better so I like having this thing one color and this thing another color, it makes it easier for me to see.	• The user liked something
	888	I like the white color and the background is darker.	• The user liked something
Texas Memorial Museum (TMM)	899	I don't know how this works so I will start reading over things just to have an idea about it , and hopefully in the middle I'll hear something about parking	• User has something in mind that he's looking for • Getting familiar with the Web site
	902	That might be one, the first one (visiting museum) but if I don't find one more relevant I'll go back. I'll go to that one (visiting museum info). The visiting makes me think it might have some info	• User is making decisions based on the information found on the page
	905	I heard a link there (referring to the Parking link, goes back to it).	• User is making decisions based on the information found on the page

	905	I'm just tabbing around to find the parking link, tabbing makes it easier to find something.	• User has something in mind that he's looking for • User points out a navigation technique
	909	That's kind of unclear to me, I guess, are they talking about capital metro or are they talking about you going with a bus, because if it's capital metro then they're not going to park there and I'd say it's unlikely that you would drive there with your big bus, with your big motor home.	• User comments on the quantity or quality of information
	915	I found out that I have to pay, they don't want to tell me how much, so I guess I'll keep reading, it might say something.	• User is making decisions based on the information found on the page
	918	I don't know what it's saying there.	• User is uncertain of spelling
	926	it didn't have too many links in comparison with the other one or in comparison to some other web sites, and I think most of the time it was taking me right to where I wanted to go , to the results of the search or um, to the content of the page, it wasn't taking me through the links .	• The user liked something
	943	I think it's simple, it doesn't have too many fancy things	• The user liked something
	946	The only thing that got me confused was the thing about memberships and donations	• User is uncertain of spelling or word choice
	951	I think this is actually a table, I thought that was clear, I thought that was good,	• The user liked something
University Extension Evening Credit Classes (UEX)	967	those instructions sound like there's already something set up under continuing education, so I'm going to look for a link that might say something like that	• User has something in mind that he's looking for
	969	And I'm sorry, they were computer classes?	• Confirming Task
	972	There is something here I've never heard before, alt+6, those sound like shortcuts to the links, I've never seen that before	• Comments about code, markup, or accessible features, or lack thereof

	974	Ok, I think I will go to professional enrichment.	• User is making decisions based on the information found on the page
	978	Ok, let's see what we've got there, in professional	• Getting familiar with the Web site
	982	So this is the right one?	• User is worried about losing their place, missing information, or has lost their place
	986	Link to courses, I'll look for it there and see if I can find… ok, I um, this sounds like because it's not part of a program and it said there that I have don't have to be admitted to this, UEX I guess, so it sounds like I can take an independent course without having to worry about any other courses, so I'll give this a try.	• User is making decisions based on the information found on the page
	990	This was, um, this semester, um, where are we, October? Fall 03?	• Confirming Task
	993	I think this will probably start with C but I don't want to miss anything so I don't want to go too fast. Ok, that might be one, CS… elements of databases. I'm going back to see if I missed any CS or if there was only one	• User has something in mind that he's looking for • User points out a navigation technique
	996	I think what I will do here is do a search for computer and, no, I'll do a search for program, that should find programming too, and see if I can, if the description of the class supposedly should say something programming or program related, let's see what they have.	• User points out a navigation technique; User has something in mind that he's looking for
	1000	I guess I'll go, I'll have to go through everything.	• Changed navigation tactics • Content or functionality did not match user's expectations • User comments on the quality or quantity of the information
	1001	Let's see… if it finds something under language.	• User has something in mind that he's looking for

	1002	I think I will go to the M’s and see if I find something for MIS.	• User has something in mind that he's looking for • Changed navigation tactics
	1007	I didn’t find them where I thought I would find them, under MIS or under CS, let’s see if I can… if “computer” helps any. That didn’t find anything either, so… it would sound to me that it’s not here.	• Changed navigation tactics • User has something in mind that he's looking for • Content or functionality did not match user's expectations
	1029	I noticed that it’s not full of colors and weird things which makes it good. The text there is all clear, no fancy things	• The user liked something
	1033	I like the link on top that takes you to the main content, that’s what we always talk about so that’s a good thing	• Comments about code, markup, or accessible features, or lack thereof; The user liked something
LBJ Library and Museum (LBJ)	1044	Let’s take a general look around	• Getting familiar with the Web site
	1045	I’m hoping there’s some kind of a link that says LBJ’s biography or something biography so I’ll look for something like that first… if I don’t find anything quickly I might go to the links.	• User has something in mind that he's looking for
	1047	Let’s do the links. I don’t want to deal with the images	• Changed navigation tactics • Content or functionality did not match user's expectations
	1050	Um, I think I’ll go to research.	• User is making decisions based on the information found on the page
	1051	education maybe… ok, let’s try that one (biographical chronology link) .	• User is making decisions based on the information found on the page

	1052	JAWS got wacky! (JAWS is saying “block quote start” over and over again). Do we have more to read on the page? According to JAWS I’m at the end of the page. But I remember on top I had a bunch of links to the page… do you see anything visually that is relevant to what JAWS is saying???	• JAWS is misbehaving
	1060	No I have never heard this. So you think its reading code? That it’s not this text?	• JAWS is misbehaving; Comments about code, markup, or accessible features, or lack thereof
	1063	Ok, I’ll keep looking (pulls up JVF). I’ll see if it find something about married.	• Changed navigation tactics; User has something in mind that he's looking for
	1069	What is block quotes?	• Comments about code, markup, or accessible features, or lack thereof
	1086	mostly because of all those links and not having a way to skip them	• Comments about code, markup, or accessible features, or lack thereof
	1090	After I got through all the links 4 times!	• Comments about code, markup, or accessible features, or lack thereof
	1092	A lot of things there and no way to avoid some of the things I was not interested in.	• Comments about code, markup, or accessible features, or lack thereof
	1095	I guess once you get to the content, it’s OK, but you have to go through 45 links before you get to that	• Comments about code, markup, or accessible features, or lack thereof
	1098	For every page, exactly, that takes a lot of time.	• User comments on how long something takes
-	1103	Let’s look around the links	• Getting familiar with the Web site
	1104	Custom courses might be one… Short courses might be another one. Software, no. I’m also looking for something that might say continuing education.	• User has something in mind that he's looking for

	1106	From everything you read it doesn't give me the impression that it's a short course, so if, if it were I might have gone to that one	• User has something in mind that he's looking for
	1109	Ok, let's see if it wants to read. Did I kick the speaker? No? I'm not on the Web site. Let's see.	• JAWS is misbehaving
	1110	what I want to take is not a custom course, it's just a regular course isn't it?	• Confirming Task
	1113	Certificate programs, no… I think I'll try short courses. It also sounds to me that this course is an independent course, not part of a certificate program or a degree I'm trying to get so I guess short courses might have something.	• User is making decisions based on the information found on the page • User has something in mind that he's looking for
	1118	I guess I'll go to one of the other ones I said I wouldn't go to… let's do e-training	• User is making decisions based on the information found on the page
	1119	Again, it doesn't want to read. Is it still loading? Loading the web site?	• JAWS is misbehaving
	1123	What was the course again?	• Confirming Task
	1126	Software, software sounds like different pieces of software but nothing that I would want. Ok, it read everything I think and I didn't find what I want.	• User is making decisions based on the information found on the page; • User has something in mind that he's looking for • Content or functionality did not match user's expectations
	1129	Again, it doesn't want to read	• JAWS is misbehaving
	1133	Ok, this sounds… like something I want. No, that's not what I want.	• User is making decisions based on the information found on the page
	1136	Because it will take me to a different web site it sounds like.	• User is worried about losing their place, missing information, or has lost their place

	1136	What it said on that page looked kind of like what I wanted, where it said that you can take one class, or the classes you want only, or complete the certificate in three years, that sounds kind of like what I want, just one class.	• User is making decisions based on the information found on the page; User has something in mind that he's looking for
	1143	I'm getting confused.	• JAWS is misbehaving
	1144	I'm not really sure where I am but I'm looking for certificates.	• User is worried about losing their place, missing information, or has lost their place • User has something in mind that he's looking for
	1145	Let's see if this is what I want. Link programming. I think this is within certificates, I'll go there and see if it gives me any classes. Um, it didn't give me what I wanted there	• User has something in mind that he's looking for • Content or functionality did not match user's expectations
	1149	but it doesn't talk about pricing, and I know the class had to be less than $500.	• User has something in mind that he's looking for • Content or functionality did not match user's expectations
	1154	the class I wanted was a programming class, and this said something about a programming certificate I thought , I don't know if these are about programming	• User has something in mind that he's looking for
	1159	I think they could make it much easier if you just put a link that says courses! Like the main web site.	• Content or functionality did not match user's expectations
	1161	I might have gone through some of them and they might have been there but nothing was clear enough to tell me that that's where I was so I might have skipped it.	• User is worried about losing their place, missing information, or has lost their place

	1167	I think that's where I started…no, I don't think this is the one that has what I want	• User has something in mind that he's looking for • User is worried about losing their place, missing information, or has lost their place
	1169	this doesn't say anything about software programming. Some of these are… there's no information about payment.	• Content or functionality did not match user's expectations
	1172	Let me go to the end and go back.	• Changed navigation tactics
	1175	I'm looking for money here… (listening to JAWS) Oh I guess… they are that expensive, they are hiding the cost!	• User has something in mind that he's looking for
	1180	usually in my case what makes it easy or difficult to navigate is having to go through all of those links or not .	• Comments about code, markup, or accessible features, or lack thereof
	1183	some of these web sites, they say weird things, like they read symbols and things like that , and I didn't notice that on the UT web site, on the main utexas.edu, and I remember on this one it said "level" where it was reading this title here, contact us? It said "level 1"? (lets JAWS read) Heading level 1	• Comments about code, markup, or accessible features, or lack thereof • Content or functionality did not match user's expectations
	1192	I didn't hear any HTML on other web sites	• Using or lacking prior knowledge
	1201	The problem that I find with that is that for a normal user who doesn't know any HTML or anything like this, it doesn't make any sense.	• Using or lacking prior knowledge • Comments about code, markup, or accessible features, or lack thereof
	1207	Can they do this same thing, have this coded as exactly the same way it looks, but in a different way so that it won't say that?	• Comments about code, markup, or accessible features, or lack thereof
	1212	some of the ones we did earlier that had a lot of links they also had a lot of things in the middle that didn't really make much sense, like a lot of symbols.	• Comments about code, markup, or accessible features, or lack thereof

Table 41: Participant #31: Grounded theory categories

APPENDIX F – ACTION TRANSCRIPTS

In addition to creating a transcript of user comments during testing, we also created a transcript of each action he or she took while attempting to complete each information-finding task.

The action transcripts were created by watching and listening to videos of each user, then hand-recording each action based on JAWS utterances, actions occurring on the screen, and user comments. In some cases, recorded actions are composites of multiple actions where we were unable to determine exactly how many times an action occurred. For example, if the user pressed the down-arrow key several times in rapid succession, these multiple key presses were recorded as a single action.

For reference, common JAWS actions are explained below:

- Tab/Shift+Tab – moves the user to the next link within the page, or back to the previous link.
- Up/Down-arrow key – moves the user to the next line of text within the page, or back to the previous line of text.
- JAWS read all (Ctrl+down arrow) – commands JAWS to start reading from the current cursor position to the end of the page (or until the user provides a different command).
- Ctrl+Back arrow – return to the previous page.
- Links list – opens a dialog box with a list of all the links on the page, in the order in which they appear on the page. Up/down arrow keys and letter find (pressing a letter jumps the user to the next link that starts with that letter) can be used to navigate within these dialog boxes.
- Headings list - opens a dialog box with a list of all the headings on the page, in the order in which they appear on the page. Up/down arrow keys

and letter find (pressing a letter jumps the user to the next heading that starts with that letter) can be used to navigate within these dialog boxes.

- JVF (JAWS Virtual Find) – searches for text within the current page.
- Ctrl+Home – moves user to the top of the page.

Participant #6

LBJ Library and Museum (LBJ) Web Site

New page 1. Down arrow through entire page 2. Ctrl-home to return to top of page 3. JVF – ‘archive’ 4. Selected link - NARA
New page – NARA – skipped overview 5. Down arrow through left nav (fast for a few links at top, then slow for left nav, then fast again. Goes between fast & slow several times) 6. Up arrow to return to Site Index link 7. Selected link
New page – Site index – skipped overview 8. Down arrow through top (slow) and left nav (then fast – goes back and forth between the two) 9. Selected link
Revisited page – Home – skipped overview 10. Down arrow through links to site index (slow, but only 2 links) 11. Selected link
New page – Site Index – played overview (but was talking and may not have heard it) 12. Down arrow through nav (fast to get to main content), continue to down arrow through first few links in main content 13. Up arrow to return to link 14. Selected link
Same page – Site Index – skipped overview 15. Down arrow through ‘a’ links for 2-3 links 16. JVF – ‘Johnson’ – success 17. Selected link
New page – LBJ Biography – played overview 18. Down arrow through top nav (fast); down arrow through part of main content (got stuck in block quotes) 19. Alt+back arrow 2 pages

Revisited page – Home – no overview played 20. Down arrow slowly through links 21. Failed – Observer called time

Table 42: Participant #6, LBJ action transcript

Texas Memorial Museum (TMM) Web Site

New page 1. Down arrow through left nav, slowly, and main content 2. Ctrl-home to get to top of page 3. Down arrow through left nav, medium speed
New page – Museum info and overview – played overview 4. Down arrow through left nav slowly
New page – Parking – no overview offered (JAWS went straight to content) 5. Up arrow through content 6. Down arrow through content 7. JAWS read all 8. Down arrow quickly to listen Success

Table 43: Participant #6, TMM action transcript

University Extension Evening Credit Courses (UEX) Web Site

New page 1. Down arrow through top navigation 2. Up arrow back to Courses link quickly 3. Selected link
New page – Courses – no overview offered 4. Down arrow to main content 5. Tab in form 6. Down arrow to move through form elements
New page – No courses found – no overview offered (JAWS reads content automatically) 7. Goes to top navigation (unknown command) 8. Alt back arrow to previous page

Previous page – Courses – no overview offered (JAWS goes to where user left off when she left the page)

9. Up arrow in content
10. Down arrow in content
11. Back to top of page (accidentally, user is upset)
12. Page down
13. Up arrow
14. Down arrow
15. Tab through form
16. Submit the form

New page – Courses list – played overview

17. Down arrow to listen to first few links slow/med; then down arrow through top nav fast; down arrow through content slowly, listening to content

Success

Table 44: Participant #6, UEX action transcript

Participant #20

French and Italian (F&I) Web Site

New page

1. JVF – 'Italian' - (success but in the header)
2. Down arrow through left navigation quickly
3. Select link

New page – Italian program – no overview (JAWS skipped it or it wasn't there; places user in main content)

4. Down arrow though main content to Italian grad classes, passes it
5. Shift-tab back repeatedly to Italian grad link
6. Selected link

New page – Italian Graduate Classes – skipped overview

7. Down arrow through left navigation & main content; down arrow through main content till user hears there answer to task

Success

Table 45: Participant #20, F&I action transcript

Star Date (SD) Web Site

New page

1. Down arrow through a few links at the top of page
2. Tab through links, past Radio
3. Shift-tab back to Radio link
4. Selected link

New page – Radio – skipped overview 5. Down arrow through top nav (fast) and side nav to search box 6. Site search – ‘skylab’, submit search
New page – Results – skipped overview 7. JVF – ‘lab’ – success 8. Tabs through several links for Skylab 9. Down arrow for a few links 10. Tab for a few links 11. Mentions that this link would work, but does not choose it Success

Table 46: Participant #20, SD action transcript

LBJ Library and Museum (LBJ)

New page 1. Lets JAWS read navigation bar 2. Ctrl-Home to top of page 3. Down arrow through navigation bar 4. Up arrow back to link of interest 5. Selected link
New page – Site Index – skipped overview 6. Down arrow fast through top & side navigation fast; 7. Down arrow through content slowly 8. Selected link
New page – LBJ biography – skipped overview 9. Down arrow through main content 10. JVF – ‘marr’ – success 11. Lets JAWS read results of JVF Success

Table 47: Participant #20, LBJ action transcript

University Extension Evening Credit Courses (UEX) Web Site

New page 1. Down arrow through navigation (slower, then fast) 2. Tab (once) 3. Up arrow through links in content 4. Down arrow through links in content 5. Tab through content links 6. Shift-tab back through links (overshot on shift-tab) 7. Down arrow back through links to get to link of interest 8. Tab to get to link 9. Selected link
New page – Fall 2003 Registration – skipped overview 10. Down arrow to content fast, found courses link but kept going 11. Shift-tab back to courses link
New page – Courses – skipped overview 12. Down arrow to content fast; down arrow to combo box 13. Tab to view classes button 14. Shift-tab back to combo box 15. Tab to view classes button, 16. Selected button
New page – Courses Fall 2003 – skipped overview 17. JVF – ‘prog’ – success (had to hit F3 to get to the second instance of it) 18. Down arrow through table 19. Up arrow to class 20. Selected link
New page – Class description – skipped overview 21. Down arrow very fast Success

Table 48: Participant #20, UEX action transcript

Center for Lifelong Engineering Education (LENG) Web Site

New page 1. JVF – Courses – success 2. Down arrow through several links 3. Up arrow through several links 4. Selected link
New page – Short Courses – skipped overview 5. Down arrow through top and side navigation 6. Up arrow to Software link 7. Selected link

New page – Software – skipped overview

8. Down arrow through top & side nave
9. JVF – Software – success (puts user in content)
10. Up arrow through content
11. Down arrow through content
12. Tab through content to links
13. Up arrow through content near link (reading backwards)
14. Has JAWS read all
15. Selected link

New page (in a new window) – SQI – skipped overview

16. Down arrow fast through left navigation to Topic areas, then slows
17. Unidentified action

New page – Programming – skipped overview

18. Down arrow fast through left navigation
19. JVF – Programming – success
20. F3 to get to next instance of Programming through JVF (user in content)
21. Down arrow through content
22. Presses Enter
23. Unknown action
24. Checks for headings (none found)
25. Up arrow slower through navigation
26. Down arrow to main content, then down arrow fast through content
27. JVF - $ - success
28. Down arrow around $

Success

Table 49: Participant #20, LENG action transcript

Participant #24

French and Italian (F&I) Web Site

New page

1. Links list
2. LL letter find – ‘d’
3. Down arrow through LL
4. LL letter find – ‘g’
5. Top of LL
6. Down arrow through list
7. LL letter find – ‘I’ (pressed ‘I’ twice)
8. Selected link from link list (Italian)

New page

9. Links list

10. LL letter find – ‘g’ 11. Up arrow 12. Down arrow 13. Up arrow 14. Selected link from links list (Graduate courses)
New page (Graduate Courses – played overview) 15. JAWS skipped navigation links 16. Lets JAWS read content Success

Table 50: Participant #24, F&I action transcript

Star Date (SD) Web Site

New page 1. Lets JAWS read 2. Links list 3. LL letter find – ‘s’ 4. Exit LL (esc) 5. Links list 6. LL letter find – ‘r’ 7. Alt+m to go to link on page 8. Down arrow to next link (next line?) 9. Up arrow to previous link (next line?) 10. Selected link
New page – Radio – overview 11. Lets JAWS read (but just for 2 or 3 links) 12. F to go to form element - Site search – ‘Skylab’ 13. Site search –enter ‘Skylab’
New page – Results – overview 14. Lets JAWS read Success

Table 51: Participant #24, SD action transcript

LBJ Library and Museum (LBJ) Web Site

New page – played overview 1. Lets JAWS read 2. Links list 3. Down arrow through LL 4. Home button in LL to top of list 5. Down arrow through LL to Search link 6. Selected link

New page – Search – skipped overview 7. Ctrl-shift to read page title 8. F to access form (twice) – failed 9. Headings list – none 10. Links list 11. LL letter find – ‘s’ – not found 12. Exit LL (esc) 13. Has JAWS read all 14. Down arrow through navigation (a few links) 15. Has JAWS read all (for navigation & content) 16. Up arrow to previous paragraph 17. Read all (again) 18. Left arrow to make sure on link 19. Selected link
New page – LBJ Library History Home Page – played overview 20. Ctrl-shift to read page title 21. Ctrl-back arrow (to return to previous page)
Previous page – Search – (no overview) 22. JAWS starts reading where it left off 23. JAWS Virtual Find – ‘oral’ – success 24. Lets JAWS read from JVF 25. Links list (since user stopped JAWS reading on a link, LL pulls up with that link highlighted) 26. Selected link
New page – Full Search – skipped overview 27. F to access form (but JAWS reads past form – user mentions that this is a JAWS problem) 28. F to access form again 29. Search on ‘Wedding anniversary’
New page – Search results – played overview 30. Lets JAWS read 31. Headings list 32. Down arrow 33. Up arrow 34. Down arrow (through HL) 35. Exit HL (esc) 36. Down arrow through content 37. Shift-tab 38. Search again in search form 39. JVF ‘result’ – success 40. Lets JAWS read at JVF spot 41. Read all (to continue when JAWS quits reading after JVF) 42. Up arrow through lines

43. Links list 44. LL letter find – ‘l’ 45. Down arrow in LL 46. Up arrow in LL 47. Selected link
New page – 1st Ladies gallery – played overview 48. Lets JAWS read 49. JVF ‘gallery’ – success in left navigation 50. Lets JAWS read results 51. Down arrow through links 52. Ctrl-back arrow to return to previous page
Previous page – Search Results – no overview (JAWS puts him where he left off) 53. Links list 54. Up arrow through LL 55. Selected link
New page – PDF file – no overview offered 56. Ctrl-? To read title in PDF file 57. Down arrow in PDF – nothing but blank lines (says JAWS) – user comments that this must be a scanned document. 58. Alt-V (View menu in IE) -> Go to -> back User gave up – failed

Table 52: Participant #24, LBJ action transcript

Center for Lifelong Engineering Education (LENG) Web Site

New page – LENG Home 1. Links list 2. LL letter find – ‘c’ – several times 3. LL letter find – ‘s’ – several times
New page – Software courses – played overview 4. Unknown command 5. Ctrl-shift to read page title 6. Unknown command 7. Links list 8. Down arrow in LL 9. Up arrow in LL 10. Down arrow in LL 11. Up arrow in LL 12. Alt+M 13. Ctrl-shift 14. Alt+M 15. Tab

16. Alt-M
17. Esc to close LL
18. Down arrow
19. JAWS read all (to end of page)
20. Ctrl-hom to top of page – lets JAWS read
21. JAWS read all – from top of page
22. Down arrow
23. Links list
24. Home in LL
25. Down arrow in LL
26. Up arrow in LL
27. Esc to close LL
28. JAWS read all
29. Links list
30. LL letter find – ‘s’ – several times
31. Esc to exit LL
32. Unknown command
33. Headings list
34. Esc to close headings lis
35. Unknown command
36. JAWS read all
37. Links list
38. LL letterfind – ‘s’
39. Down arrow in LL
40. Up arrow in LL
41. Down arrow in LL
42. Up arrow in LL

New page – SQI – played overview

43. Headings list
44. Down arrow in HL
45. Up arrow in HL
46. Enter to select heading and jump to heading on page
47. Headings list
48. Down arrow in HL
49. Up arrow in HL
50. Esc to exit HL
51. Links list
52. LL letter find – ‘p’

New page – Program Management Courses – played overview

43. Links list
44. LL letter find – ‘p’

New page – Project Hot Start – played overview

45. Unknown command

46. Headings list
47. Down arrow in HL
48. Up arrow in HL
49. Down arrow in HL
50. Up arrow in HL
51. Esc to exit
52. Links list
53. LL letter find – ‘s’- failed
54. Esc to exit LL
55. JVF – Hotstart – failed
56. JVF – Hot start – success
57. JAWS read all
58. JVF – cost – failed
59. Headings list – user says “mistake”
60. Esc to exit HL
61. Links list
62. LL letter find – ‘r’

New page – Register – played overview

63. F to form (site search)
64. Tab (out of form)
65. Ctrl-shift to read page title
66. Tab
67. F to form
68. JAWS read all
69. Unknown command – user says “I don’t understand”
70. Tab
71. F to form
72. Down arrow
73. Up arrow to Hot Start Link

New page – Hot Start – played overview

74. Links list
75. Down arrow in LL

New page – E-training – skipped overview

76. F for form (search)
77. JAWS read all
78. Alt-back arrow

Revisited page – skipped overview (JAWS reads where he left off)

79. Links list
80. Down arrow in LL
81. LL letter find – ‘l’
82. LL letter find – ‘c’
83. Down arrow in LL
84. Up arrow in LL

85. Down arrow in LL
New page – Short courses – played overview 86. Links list 87. Up arrow in LL 88. Down arrow in LL 89. JVF – ‘fee’ – success 90. JAWS read all Success

Table 53: Participant #24, LENG action transcript

Participant #31

Texas Memorial Museum (TMM) Web Site

New page 53. Read all (ctrl down arrow) 54. Links list 55. Exit links list (esc) 56. Links list 57. Down arrow through LL, 58. Up arrow through LL 59. Selected link
New page – Visiting Museum Info – played overview 60. Lets JAWS read all to Parking link 61. Up arrow a few times (past Parking link) 62. Tab through links to Parking link 63. Selected link
New page – Parking – played overview 64. Read all, JAWS goes to content 65. Down arrow through content 66. Up arrow through content 67. Right/left arrow to read letter by letter Success

Table 54: Participant #31, TMM action transcript

LBJ Library and Museum (LBJ) Web Site

New page 1. Lets JAWS read 2. Links list 3. Down arrow through LL 4. Letter find – r for Research – success

5. Selected link
New page – Research – played overview 6. Lets JAWS read (a little) 7. Links list 8. Down arrow through LL 9. Up arrow through LL 10. Down arrow through LL 11. Selected link
New page – Biography – played overview 12. Lets JAWS read 13. Down arrow through content for a few lines 14. Lets JAWS read 15. Down arrow through content 16. Up arrow through content 17. JVF – Married – success 18. Lets JAWS read a little 19. Down arrow to read around 20. Up arrow to read around Success

Table 55: Participant #31, LBJ action transcript

Star Date (SD) Web Site

New page 1. Lets JAWS read but not very far 2. Ctrl-Ins-Home (to get to search box) – fails 3. Tab to search 4. Shift-tab 5. Tab 6. Shift-tab 7. Forms mode on – site search – Skylab 8. Submit search
New page – Search results – played overview 9. Lets JAWS read 10. Down arrow through links 11. Selected link (Radio)
New page – Radio – played overview 12. Lets JAWS read 1. Down arrow through content 2. Up arrow in form area 13. Down arrow again 14. Tries to use “find an affiliate” text as link (but it’s not)

15. Down arrow to next combo box, presses Enter to edit 16. Enters text 17. Tab to Go button 18. Selected Go button
New page – Star Date Radio Affiliates Search Results– played overview 19. Lets JAWS read 20. Down arrow through links to main content 21. Up arrow through links 22. Down arrow 23. Alt back arrow to previous page
Previous page – Radio – JAWS reads where he left off 24. Down arrow once 25. Unknown command – went to top of page 26. Down arrow at top of page 27. Links list 28. Down arrow through LL 29. Up arrow through LL 30. Down arrow through LL 31. Up arrow through LL 32. Down arrow through LL 33. Up arrow through LL 34. Selected link
New page – Listen – played overview 35. JAWS goes straight to content and starts reading (but user doesn't let it read for long) 36. Down arrow through content 37. Up arrow 38. Down arrow 39. Alt+ back arrow
Previous page – Radio – JAWS puts user where he left off 40. Links List (JAWS puts him on a link since that's where he was on the page) 41. Up arrow in LL 42. Down arrow in LL 43. Letter find – "a" – success (archive) 44. Selected link
New page – Archive – played overview 45. JAWS skipped navigation & starts reading content 46. Up arrow in content 47. Down arrow in content 48. Up arrow in content 49. Tried to use "search by topic" as a link but it's not 50. Down arrow 51. Up arrow

52. Down arrow 53. Site search – Skylab – success 54. Selected site search results
New page – Search Results – JAWS skipped overview & jumps to content but doesn’t read 55. Down arrow 56. Shift-tab 57. Tab 58. Selected link
New page – Play Audio – no overview offered in Real Player Success

Table 56: Participant #31, SD action transcript

University Extension Evening Credit Courses (UEX) Web Site

New page 1. Links List 2. Down arrow through LL 3. Selected link
New page – Continuing Ed – played overview 4. Lets JAWS read 5. Down arrow through content 6. JAWS read all 7. Up arrow to links 8. Down arrow through links 9. Selected link
New page – Professional development – played overview 10. Lets JAWS read 11. Selected link
New page - ??? – played overview 12. Alt + back arrow to previous page
Previous page – Professional development - no overview since JAWS puts him where he left off 13. Lets JAWS read a little 14. Down arrow through nav 15. Up arrow to link user wanted 16. Selected link
New page – Courses – played overview 17. Lets JAWS read 18. Up arrow to skipped navigation link 19. Down arrow through content 20. To form box

21. Selected button
New page – Course listing – played overview 22. Lets JAWS read 23. Down arrow through table headers of classes to CS 24. Up arrow in class list 25. Down arrow in class list 26. JVF- Program – failed 27. Down arrow again 28. JVF – Language 29. Down arrow quickly then slowly 30. JVF – Computer – failed Failed

Table 57: Participant #31, UEX action transcript

Center for Lifelong Engineering Education (LENG) Web Site

New page 1. Links List 2. Down arrow in LL 3. Up arrow in LL 4. Selects link
New page – custom courses – played overview 5. JAWS won't talk but user eventually forces JAWS to read all 6. Selected link?
New page - ??? – played overview 7. (some kind of action?) 8. Alt + back arrow
Previous page – Custom Courses – no overview (JAWS reads where it left off) 9. Links list 10. Down arrow through LL 11. Selected link
New page – Short courses – played overview 12. Lets JAWS read 13. Selected link
New page - ??? – listens to overview 14. Unknown action 15. Alt + back arrow
Previous page – custom courses – no overview read 16. Links list 17. Up arrow through LL 18. Down arrow through LL 19. Selects link

New page – E-training – played overview 20. JAWS not reading, but user forces JAWS to read all 21. Down arrow to read main content 22. Links list 23. Down arrow in LL 24. Up arrow in LL 25. Esc to exit LL 26. Lets JAWS read 27. Down arrow from top of page 28. Selected link
New page – Certification program – played overview 29. JAWS not reading, but user forces JAWS to read all 30. Down arrow to read remaining content 31. Selected SQI link
New page – SQI – stops overview 32. Down arrow through left navigation slowly 33. Up arrow through left navigation 34. Selected link
New page – Certification Program – played overview 35. Lets JAWS read a little 36. Down arrow through left navigation 37. UP arrow through left navigation 38. Selected link
New page – Programming – played overview 39. Lets JAWS read 40. Alt + back arrow
Previous page – Certification Program – no overview (JAWS puts user where he left off) 41. Down arrow through left navigation to content 42. Up arrow 43. Selected link
New page – Payment Info – played overview 44. Lets JAWS read 45. Down arrow in content 46. Alt + back arrow twice to home page (no overviews)
Previous page 47. Links list 48. Up arrow in LL 49. Down arrow in LL 50. Selects link
New page – E-training – played overview 51. Lets JAWS read – JAWS skipped to content when reading 52. Alt + back arrow
Previous page – Home – no overview

53. Links list 54. Up arrow in ll 55. Down arrow in LL 56. Selects link
New page – Short courses – played overview 57. Lets JAWS read – JAWS skipped to content when reading 58. Down arrow through content 59. Up arrow to link 60. Selected link
New page – SQI – played overview 61. Lets JAWS read 62. Down arrow very fast through left nav 63. User stops, says he would call in to ask for info. Failed

Table 58: Participant #31, LENG action transcript

APPENDIX G – ACTION TABLES

Using the action transcripts in Appendix F, we counted the number of each type of action for each participant on each Web site. Actions were categorized into either scrolling actions or searching actions. A "-" in the table means that the participant did not use that particular keyboard command on that Web site.

Participant #6

Participant #6: Scrolling Commands

	LBJ	UEX	TMM
New pages	5	4	3
Revisited pages	2	1	-
Same pages	1	-	-
Overview played	2	1	1
Tab	-	2	-
Shift-tab	-	-	-
Up arrow	2	3	1
Down arrow	8	7	5
Left arrow	-	-	-
Right arrow	-	-	-
Jaws read all	-	-	1
Ctrl-Home	1	1	1
Ctrl back arrow	3	1	-
Total scrolling commands	**24**	**20**	**12**

Participant #6: Searching Commands

	LBJ	UEX	TMM
Skipped overview	3	1	4
Site search	-	-	-
JVF	2	-	2
Links list	-	-	-
Up/down arrow in LL	-	-	-
Letter find in LL	-	-	-
Close LL	-	-	-
Skip Nav	-	-	-
F to go to form control	-	-	-
Headings list	-	-	-
Ctrl-Shift	-	-	-
Page down	-	1	1
Unknown command	-	1	1
New window (Ctrl+Enter)	-	-	-
Total searching commands:	**5**	**3**	**8**

Participant #6: Summary

Total time on task (UEX):	4:31
Total time on task (LBJ):	8:32
Total time on task (TMM):	4:13
Total number of back actions:	4
Total scrolling commands	56
Total searching commands	16
Total number of actions:	72
Average scrolling commands	18.7
Average searching commands	5.3

Table 59: Action count for participant #6

Participant #20

Participant #20: Scrolling Commands

	LBJ	SD	LENG	UEX	F&I
New pages	3	3	6	5	3
Revisited pages	-	-	-	-	-
Same pages	-	-	-	-	-
Overview played	-	-	-	-	-
Tab	-	3	1	5	-
Shift-tab	-	1	-	3	1
Up arrow	1	-	5	2	-
Down arrow	3	3	10	7	3
Left arrow	-	-	-	-	-
Right arrow	-	-	-	-	-
Jaws read all	-	-	1	-	-
Ctrl-Home	1	-	-	-	-
Total scrolling commands:	**8**	**10**	**23**	**22**	**7**

Participant #20: Searching Commands

	LBJ	SD	LENG	UEX	F&I
Skipped overview	2	2	5	4	1
Site search	-	1	-	-	-
JVF	1	1	4	1	1
Links list	-	-	-	-	-
Up/down arrow in LL	-	-	-	-	-
Letter find in LL	-	-	-	-	-
Close LL	-	-	-	-	-
Skip Nav	-	-	-	-	-
F to go to form control	-	-	-	-	-
Headings list	-	-	1	-	-
Ctrl-Shift	-	-	-	-	-
Ctrl back arrow	-	-	-	-	-
Page down	-	-	-	-	-
Unknown command	-	-	-	-	-
New window (Ctrl+Enter)	-	-	1	-	-
Total searching commands:	**3**	**4**	**11**	**5**	**2**

Participant #20: Summary

Total time on task (LBJ):	1:21
Total time on task (SD):	1:11
Total time on task (LENG):	4:19
Total time on task (UEX):	2:00
Total time on task (F&I):	1:17
Total number of Back actions:	0
Total scrolling commands	25
Total searching commands	70
Total number of actions	95
Average scrolling commands	14
Average searching commands	5

Table 60: Action count for participant #20

Participant #24

Participant #24: Scrolling Commands

	LBJ	SD	LENG	F&I
New pages	7	3	10	3
Revisited pages	2	-	1	-
Same pages	-	-	1	-
Overview played	4	3	7	1
Tab	-	-	3	-
Shift-tab	1	-	-	-
Up arrow	2	1	1	-
Down arrow	4	1	3	-
Left arrow	1	-	-	-
Right arrow	-	-	-	-
Jaws read all	4	-	9	1
Ctrl-Home	-	-	2	-
Ctrl back arrow	2	-	1	-
Total scrolling commands:	**27**	**8**	**38**	**5**

Participant #24: Searching Commands

	LBJ	SD	LENG	F&I
Skipped overview	2	-	1	-
Site search	-	1	-	-
JVF	4	-	4	-
Links list	5	2	13	1
Up/down arrow in LL	4	6	3	-
Letter find in LL	2	2	9	4
Close LL	1	1	4	-
Skip Nav	-	-	-	-
F to go to form control	4	1	4	-
Headings list	2	-	5	-
Ctrl-Shift	3	-	3	-
Page down	-	-	-	-
Unknown command	-	-	5	-
New window (Ctrl+Enter)	-	-	-	-
Top of LL (home button)	1	-	1	1
Alt+M	-	2	3	-
Up/down arrow in HL	1	-	3	-
Exit HL	1	-	4	-
PFD	1	-	-	-
Use browser menu	1	-	-	-
Tab in LL	1	-	-	-
Alt+F	-	-	1	-
Total searching commands:	**33**	**15**	**63**	**6**

Participant #24: Summary

Total time on task (LBJ):	10:20
Total time on task (SD):	1:10
Total time on task (LENG):	15:32
Total time on task (F&I):	1:31
Total number of Back actions:	3
Total scrolling commands	78
Total searching commands	117
Total number of actions	195
Average scrolling commands	19.5
Average searching commands	29.25

Table 61: Action count for participant #24

Participant #31

Participant #31: Scrolling Commands

	LBJ	SD	LENG	UEX	TMM
New pages	3	8	15	3	4
Revisited pages	-	3	3	-	-
Same pages	-	-	-	-	1
Played overview	2	6	12	2	3
Tab	-	7	-	-	-
Shift-tab	-	4	-	-	-
Up arrow	2	6	4	1	1
Down arrow	3	14	9	2	2
Left arrow	-	-	-	-	1
Right arrow	-	-	-	-	1
Jaws read all	1	1	1	1	1
Ctrl-Home	-	-	-	-	-
Ctrl back arrow	-	3	5	-	-
Total scrolling commands:	**11**	**52**	**49**	**9**	**14**

Participant #31: Searching Commands

	LBJ	SD	LENG	UEX	TMM
Skipped overview	-	-	-	-	-
Site search	-	2	-	-	-
JVF	1	-	-	3	-
Links list	2	3	6	1	2
Up/down arrow in LL	2	2	6	1	2
Letter find in LL	1	2	-	-	-
Close LL	-	-	1	-	1
Skip Nav	-	-	-	-	-
F to go to form control	-	-	-	-	-
Headings list	-	-	-	-	-
Ctrl-Shift	-	-	-	-	-
Page down	-	-	-	-	-
Unknown command	-	7	-	-	-
New window (Ctrl+Enter)	-	-	-	-	-
Ctrl+Ins+Home	-	4	-	-	-
Total searching commands:	**6**	**20**	**13**	**5**	**5**

Participant #31: Summary	
Total time on task (LBJ):	6:12
Total time on task (SD):	11:31
Total time on task (LENG):	24:40
Total time on task (UEX):	10:53
Total time on task (TMM):	5:25
Total number of Back actions:	8
Total scrolling commands	135
Total searching commands	49
Total number of actions	184
Average scrolling commands	27
Average searching commands	9.8

Table 62: Action count for participant #31

Summary of Actions

In this section, we present the summary of all user actions.

Table 63 shows the *total number of actions* performed by each user for each Web site, including the sum of actions by user and by Web site.

	LBJ	SD	LENG	UEX	TMM	F&I	**SUM**
#6	29	-	-	23	20	-	**72**
#20	11	14	34	27	-	9	**95**
#24	61	23	102	-	-	11	**197**
#31	17	72	62	14	19	-	**184**
SUM	**118**	**109**	**198**	**64**	**39**	**20**	

Table 63: Summary of all actions

Table 64 shows the *total number of scrolling actions* performed by each user for each Web site, including the sum of actions by user and by Web site.

	LBJ	SD	LENG	UEX	TMM	F&I	SUM
#6	24	-	-	20	12	-	**56**
#20	8	10	23	22	-	7	**70**
#24	27	8	38	-	-	5	**78**
#31	11	52	49	9	14	-	**135**
SUM	**70**	**70**	**110**	**51**	**26**	**12**	

Table 64: Summary of scrolling actions

Table 65 shows the *total number of searching actions* performed by each user for each Web site, including the sum of actions by user and by Web site.

	LBJ	SD	LENG	UEX	TMM	F&I	SUM
#6	5	-	-	3	8	-	**16**
#20	3	4	11	5	-	2	**25**
#24	33	15	63	-	-	6	**117**
#31	6	20	13	5	5	-	**49**
SUM	**47**	**39**	**87**	**13**	**13**	**8**	

Table 65: Summary of searching actions

APPENDIX H – SCREEN SHOTS OF WEB SITES' HOME PAGES

The following figures are of the home pages of the Web sites used for this study. These figures were captured using the WayBack Machine (web.archive.org) and as such are representative of the Web sites at a point in time close to when the sessions for this study were held; they may not exactly show how the home page of the Web site rendered on the day of testing. Note that Section 508 compliance is not determinable from the information presented in this appendix.

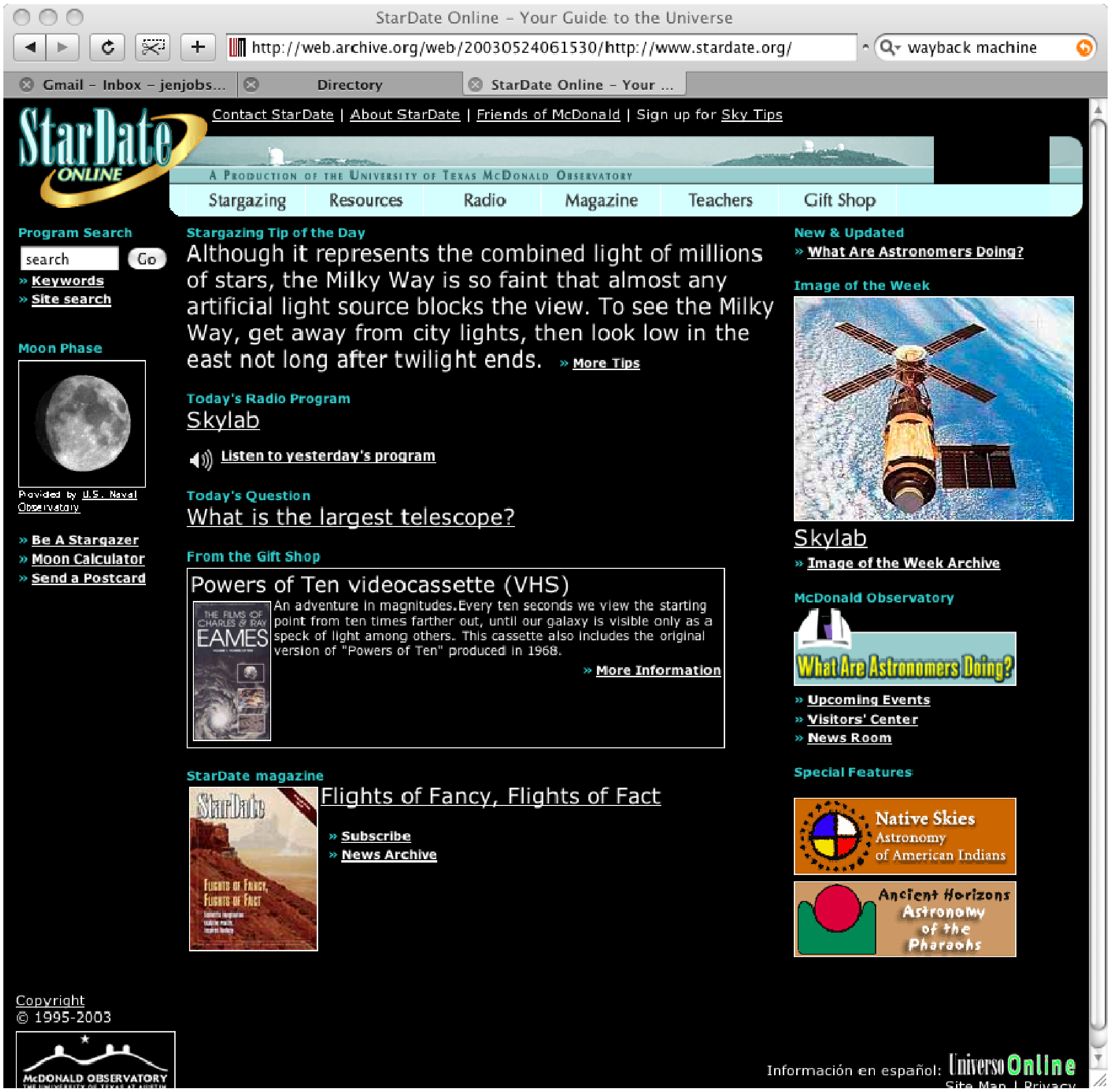


Figure 15: Star Date (SD) Home Page - May 24, 2003

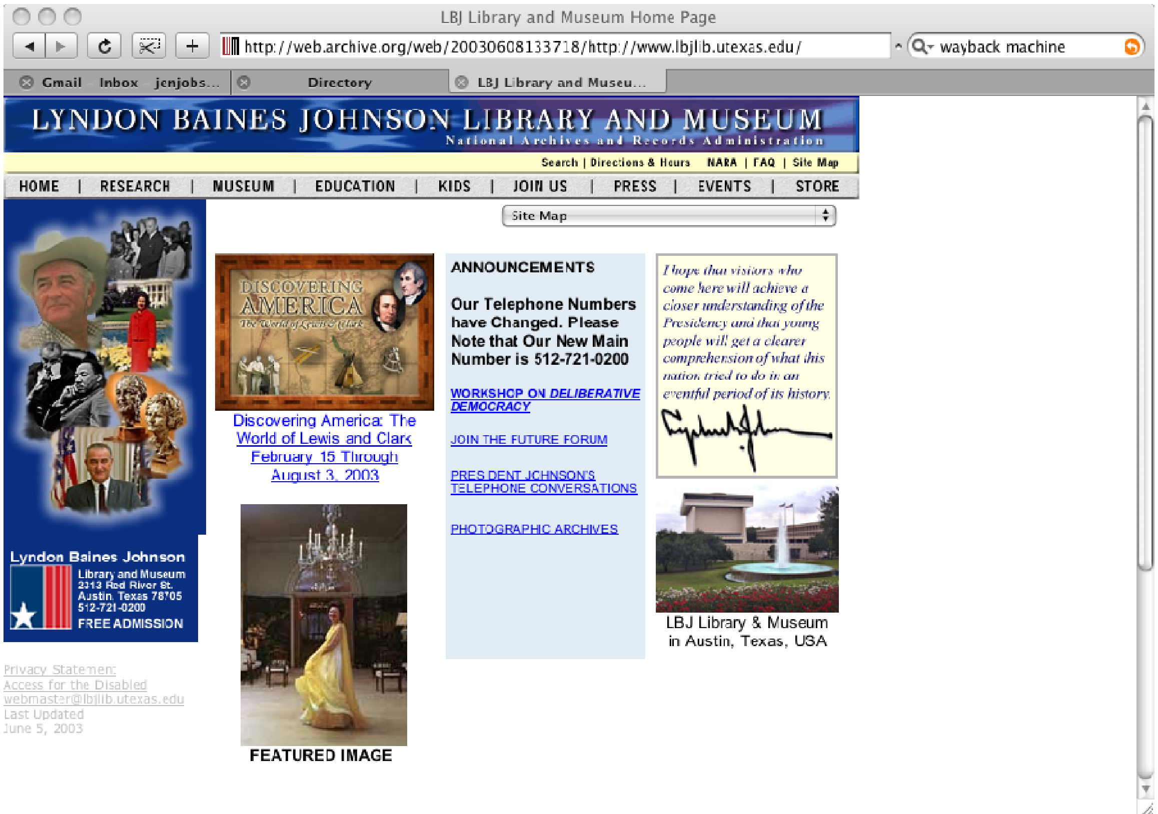


Figure 16: LBJ Library and Museum (LBJ) Home Page - June 8, 2003

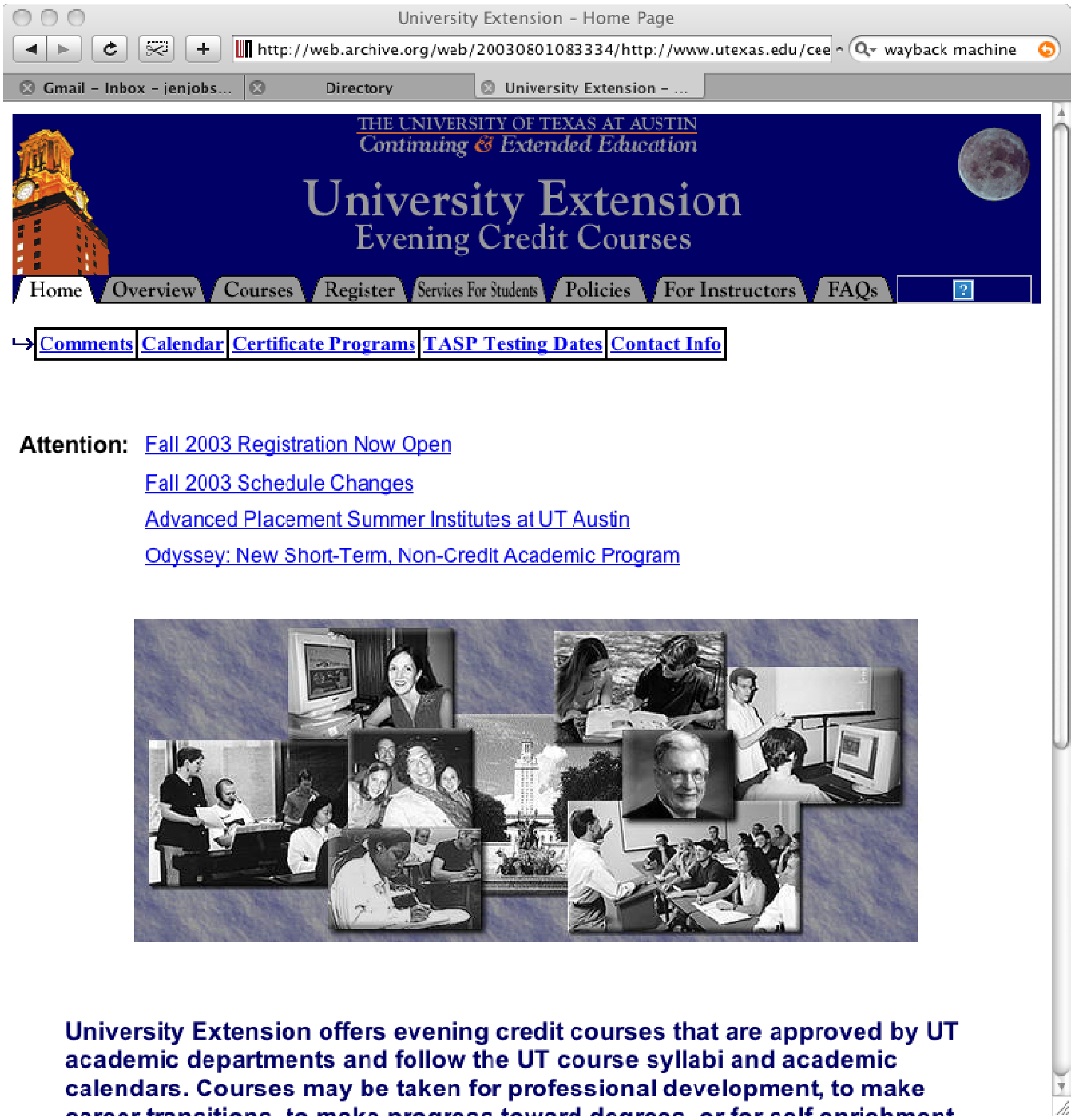


Figure 17: University Extension Evening Credit Courses (UEX) Home Page - August 1, 2003

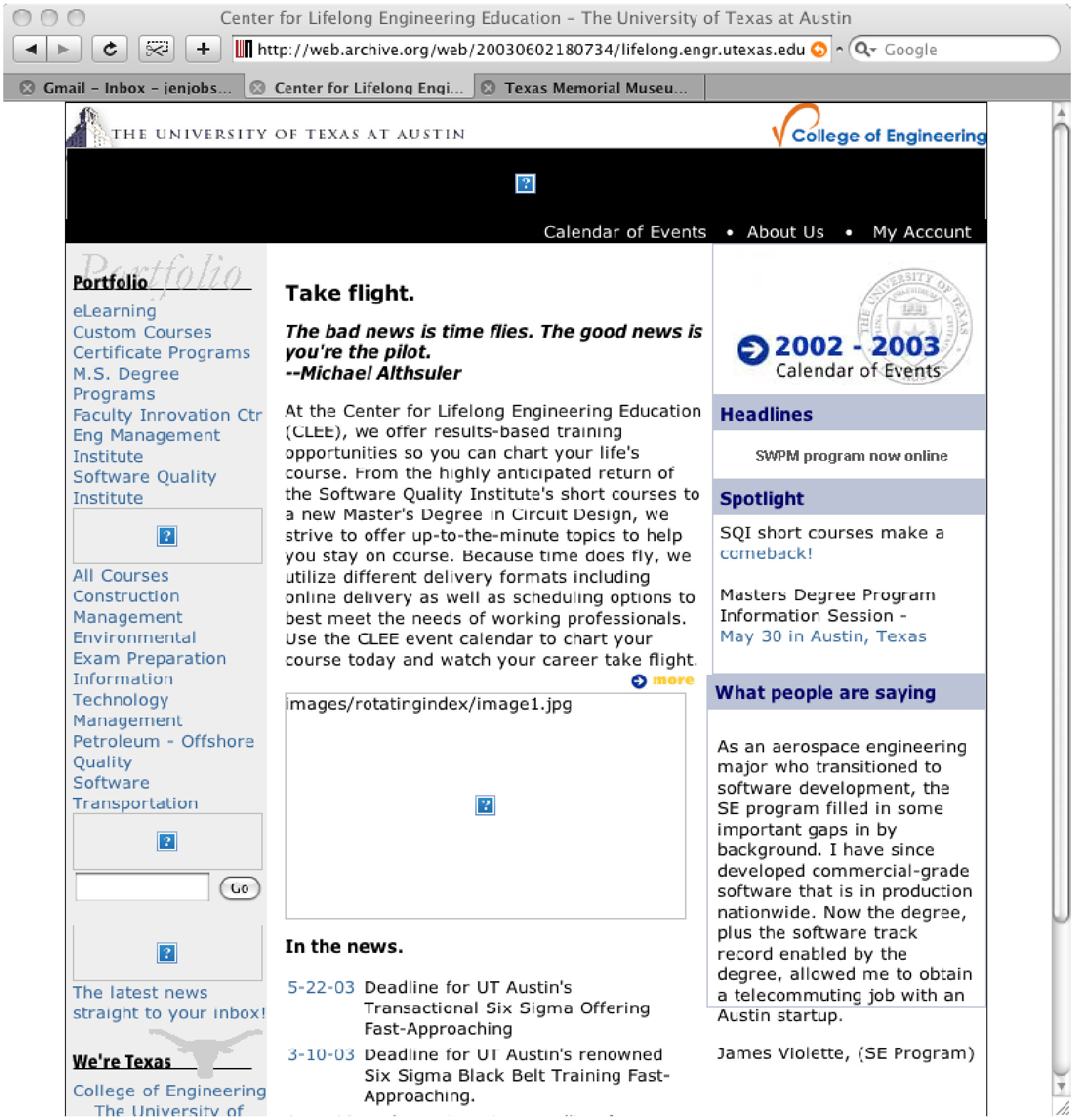


Figure 18: Center for Lifelong Engineering Education (LENG) Home Page - May 23, 2003

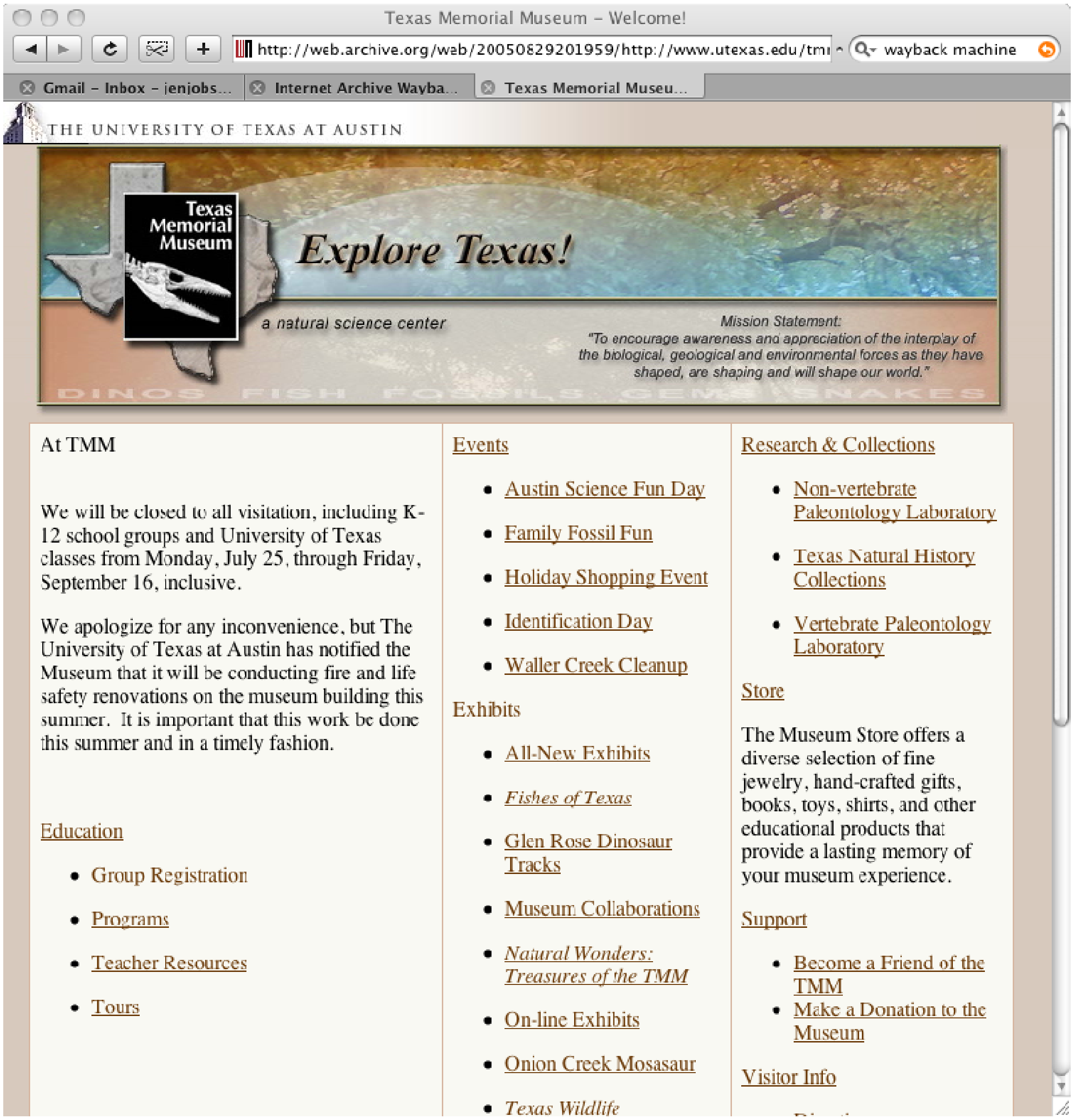
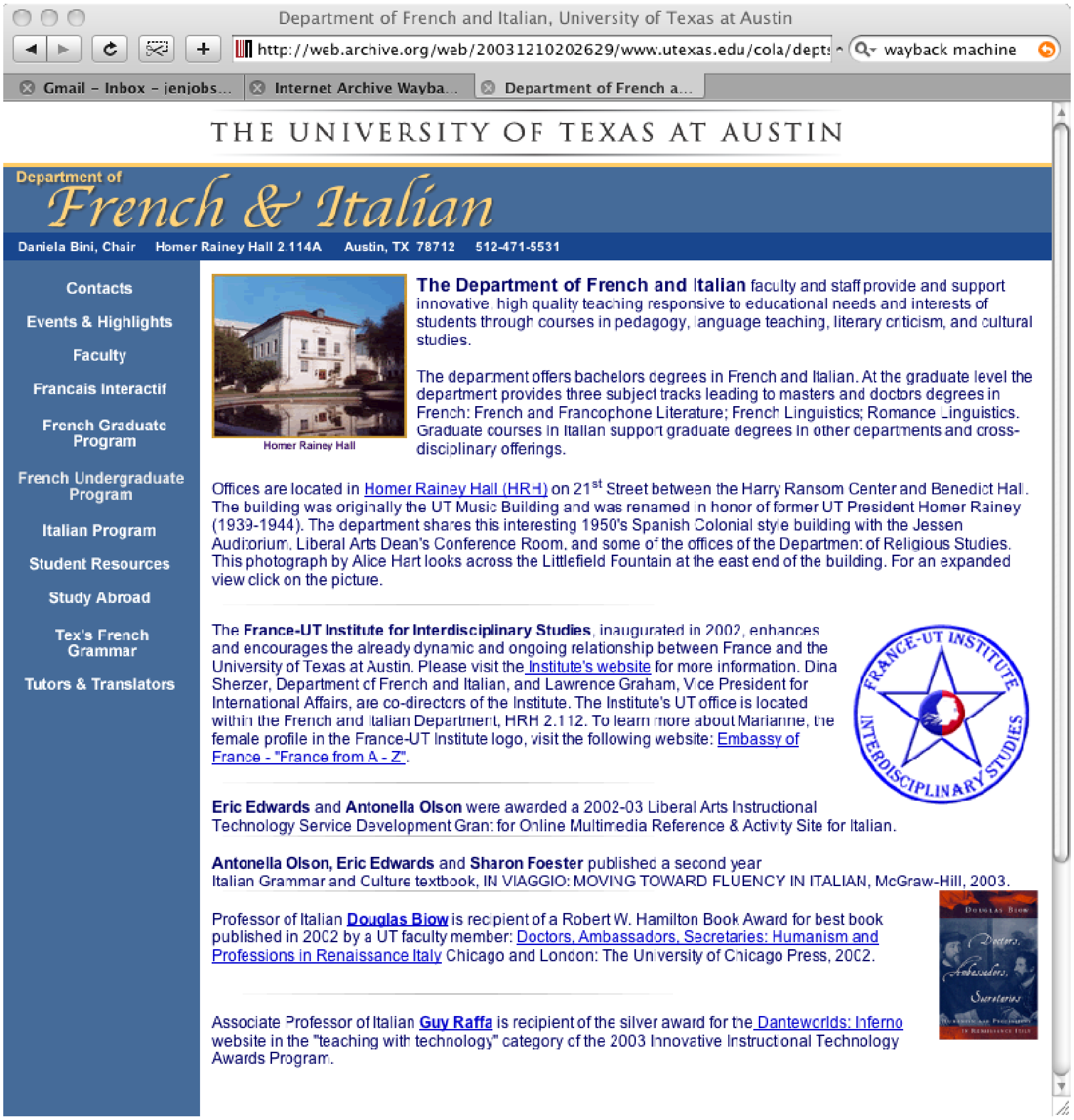


Figure 19: Texas Memorial Museum (TMM) Home Page - August 29, 2005 (no earlier archived version was available)


Department of French and Italian, University of Texas at Austin

http://web.archive.org/web/20031210202629/www.utexas.edu/cola/depts

wayback machine

Gmail - Inbox - jenjobs... | Internet Archive Wayba... | Department of French a...

THE UNIVERSITY OF TEXAS AT AUSTIN

Department of French & Italian

Daniela Bini, Chair Homer Rainey Hall 2.114A Austin, TX 78712 512-471-5531

Contacts
Events & Highlights
Faculty
Francais Interactif
French Graduate Program
French Undergraduate Program
Italian Program
Student Resources
Study Abroad
Tex's French Grammar
Tutors & Translators

Homer Rainey Hall

The Department of French and Italian faculty and staff provide and support innovative, high quality teaching responsive to educational needs and interests of students through courses in pedagogy, language teaching, literary criticism, and cultural studies.

The department offers bachelors degrees in French and Italian. At the graduate level the department provides three subject tracks leading to masters and doctors degrees in French: French and Francophone Literature; French Linguistics; Romance Linguistics. Graduate courses in Italian support graduate degrees in other departments and cross-disciplinary offerings.

Offices are located in Homer Rainey Hall (HRH) on 21st Street between the Harry Ransom Center and Benedict Hall. The building was originally the UT Music Building and was renamed in honor of former UT President Homer Rainey (1939-1944). The department shares this interesting 1950's Spanish Colonial style building with the Jessen Auditorium, Liberal Arts Dean's Conference Room, and some of the offices of the Department of Religious Studies. This photograph by Alice Hart looks across the Littlefield Fountain at the east end of the building. For an expanded view click on the picture.

The **France-UT Institute for Interdisciplinary Studies**, inaugurated in 2002, enhances and encourages the already dynamic and ongoing relationship between France and the University of Texas at Austin. Please visit the Institute's website for more information. Dina Sherzer, Department of French and Italian, and Lawrence Graham, Vice President for International Affairs, are co-directors of the Institute. The Institute's UT office is located within the French and Italian Department, HRH 2.112. To learn more about Marianne, the female profile in the France-UT Institute logo, visit the following website: Embassy of France - "France from A - Z".

FRANCE-UT INSTITUTE INTERDISCIPLINARY STUDIES

Eric Edwards and **Antonella Olson** were awarded a 2002-03 Liberal Arts Instructional Technology Service Development Grant for Online Multimedia Reference & Activity Site for Italian.

Antonella Olson, Eric Edwards and **Sharon Foester** published a second year Italian Grammar and Culture textbook, IN VIAGGIO: MOVING TOWARD FLUENCY IN ITALIAN, McGraw-Hill, 2003.

Professor of Italian **Douglas Biow** is recipient of a Robert W. Hamilton Book Award for best book published in 2002 by a UT faculty member: Doctors, Ambassadors, Secretaries: Humanism and Professions in Renaissance Italy Chicago and London: The University of Chicago Press, 2002.

Associate Professor of Italian **Guy Raffa** is recipient of the silver award for the Danteworlds: Inferno website in the "teaching with technology" category of the 2003 Innovative Instructional Technology Awards Program.

Figure 20: French and Italian (F&I) Home Page - October 14, 2003

10. Bibliography

Aguilar, F. J. (1967). *Scanning the business environment*. New York: Macmillan.

Alexa (2009). Alexa, The Web Information Company. Retrieved May 1, 2006, from www.alexa.com

Allen, B. (1998). *Information space representation in interactive systems: relationship to spatial abilities*. Paper presented at the Third ACM Conference on Digital Libraries, Pittsburgh, PA.

Anderson, J. (1996). ACT: A simple theory of complex cognition. *American Psychologist, 51*, 355-365.

Anderson, J., Bothell, D., Byrne, M. D., Douglass, S., Lebiere, C., & Quin, Y. (2004). An integrated theory of the mind. *Psychological Review, 111*(4), 1036-1060.

Andronico, P., Buzzi, M., Castillo, C., & Leporini, B. (2006). Improving search engine interfaces for blind users: a case study. *Universal Access in the Information Society, 5*, 23-40.

Andronico, P., Buzzi, M., Leporini, B., & Castillo, C. (2006). *Testing Google interfaces modified for the blind.* Paper presented at the WWW 2006, Edinburgh, Scotland.

Arons, B. (1991). *Hyperspeech: Navigating in speech-only hypermedia.* Paper presented at the Hypertext '91.

Baloian, N., Luther, W., & Sanchez, J. (2002). *Modeling eductional software for people with disabilities: Theory and practice.* Paper presented at the ACM Assets 2002, Edinburgh, Scotland.

Barfield, W., & Dingus, T. (1998). *Human factors in intelligent transportation systems*. Mahway, New Jersey: Lawrence Erlbaum Associates, Inc.

Barnicle, K. (2000). *Usability testing with screen reading technology in a Windows environment.* Paper presented at the ACM Conference on Universal Usability, Arlington, VA.

Barry, J. (1998). Apart or a part? Access to the Internet by visually impaired and blind people, with particular emphasis on assistive enabling technology and user perceptions, from www.rit.edu/~easi/itd/itdv06n3/article2.htm

Bates, M. J. (1989). Design of browsing and berrypicking techniques for the online search interface. *Online Review, 13*, 407-424.

Belkin, N. J., Oddy, R. N., & Brooks, H. M. (1982a). ASK for information retrieval: Part 1. *Journal of Documentation, 38*(2), 61-71.

Belkin, N. J., Oddy, R. N., & Brooks, H. M. (1982b). ASK for information retrieval: Part 2. *Journal of Documentation, 38*(3), 145-164.

Bigelow, A. E. (1996). Blind and sighted children's spatial knowledge of their home environments. *International Journal of Behavioral Development*, *19*(4), 797-816.

Bigham, J. P., Cavender, A. C., Brudvik, J. T., Wobbrock, J. O., & Ladner, R. E. (2007). *WebinSitu: a comparative analysis of blind and sighted browsing behavior*. Paper presented at the ASSETS '07, Tempe, Arizona, USA.

Bigham, J. P., Prince, C. M., & Ladner, R. E. (2008). *WebAnywhere: a screen reader on-the-go.* Paper presented at the W4A2008, Beijing, China.

Blackmon, M. H., Polson, P. G., Kitajima, M., & Lewis, C. (2002). *Cognitive Walkthrough for the Web.* Paper presented at the CHI 2002.

Blattner, M., Sumikawa, D., & Greenberg, R. (1989). Earcons and icons: their structure and common design principles. *Human-Computer Interaction*, *4*(1), 11-44.

Boechler, P. M. (2001). How spatial is hyperspace? Interacting with hypertext documents: Cognitive processes and concepts. *CyberPsychology and Behavior, 4*(1), 23-46.

Borgman, C. L. (1984). *The application of human factors to systems design and training.* Paper presented at the 47th American Society for Information Science Annual Meeting, Philadelphia, PA.

Borodin, Y., Bigham, J. P., Stent, A., & Ramakrishnan, I. V. (2008). *Towards one world web with HearSay3.* Paper presented at the W4A 2008, Beijing, China.

Borodin, Y., Mahmud, J., Ramakrishnan, I. V., & Stent, A. (2007). *The HearSay non-visual web browser*. Paper presented at the 2007 International Cross-disciplinary conference on Web Accessibility (W4A).

Bradley, N. A., & Dunlop, M. D. (2002). *Understanding contextual interactions to design navigational context-aware applications.* Paper presented at the 4th International Symposium on Mobile Human-Computer Interaction.

Brennan, S. E. (1990). Conversation as direct manipulation: an iconoclastic view. In B. Laurel (Ed.), *The Art of Human-Computer Interface Design*. Reading: Addison-Wesley.

Brewster, S. A. (1997). *Navigating telephone-based interfaces with earcons.* Paper presented at the HCI on People and Computer XII.

Brewster, S. A. (1998). Using non-speech sounds to provide navigation cues. *ACM Transactions on Computer-Human Interaction*, *5*(3), 224-259.

Brewster, S. A., Capriotti, A., & Hall, C. (1998). Using compound earcons to represent hierarchies. *HCI Letters*, 6-8.

Brewster, S. A., & Pengelly, H. (1998). *Visual impairment, virtual reality and visualization.* Paper presented at the First International Workshop on Usability Evaluation for Virtual Environments, Leicester, UK.

Brewster, S. A., Wright, P. C., & Edwards, A. D. N. (1995). *Experimentally derived guidelines for the creation of earcons.* Paper presented at the BCS HCI '95, Huddersfield, UK.

Brophy, P., & Craven, J. (2007). Web accessibility. *Library Trends, 55*(4), 950-972.

Brudvik, J. T., Bigham, J. P., Cavender, A. C., & Ladner, R. E. (2008). *Hunting for headings: sighted labeling vs. automatic classification of headings.* Paper presented at the ASSETS '08, Halifax, Nova Scotia, Canada.

Burgstahler, S., Jirikowick, T., Kolko, B., & Eliot, M. (2004). Software accessibility, usability testing, and individuals with disabilities. *Information Technology and Disabilities, 10*(2).

Burnett, G. E., & Joyner, S. M. (1997). An assessment of moving map and symbol-based route guidance systems. In Y. I. Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 115-137). London: Lawrence Erlbaum Associates.

Burnett, G. E., & Porter, J. M. (2001). Ubiquitous computing within cars: designing controls for non-visual use. *International Journal of Human-computer Studies, 55*, 521-531.

Byerley, S. L., & Chambers, M. B. (2002). Accessibility and usability of Web-based library databases for non-visual users. *Library Hi-Tech, 20*(2), 169-178.

Catledge, L. D., & Pitkow, J. E. (1995). Characterizing browsing strategies in the World Wide Web. *Computer Networks and ISDN Systems, 27*(6), 1065-1073.

Charmaz, K. (2000). Grounded theory: Objectivist and constructivist methods. In N.K. Denzin and Y.S. Lincoln (Eds.), *Handbook of qualitative research, second edition* (pp. 509-535): Sage Publications.

Chen, S. Y., & Macredie, R. D. (2002). Cognitive styles and hypermedia navigation: development of a learning model. *Journal of the American Society for Information Science and Technology, 53*(1), 3-15.

Chi, E. H., Pirolli, P., Chen, K., & Pitkow, J. (2001). *Using information scent to model user information needs and actions on the Web.* Paper presented at the CHI 2001.

Choo, C. W., Detlor, B., & Turnbull, D. (1998). *A behavioral model of information seeking on the Web - preliminary results of a study of how managers and IT specialists use the Web.* Paper presented at the 61st Annual Meeting of the American Society of Information Science (ASIS), Pittsburg, Pennsylvania, USA.

Choo, C. W., Detlor, B., & Turnbull, D. (2000). *Web Work: information seeking and knowledge work on the World Wide Web*. Dordrecht: Kluwer Academic Publishers.

Chou, C., & Lin, H. (1998). The effect of navigation map types and cognitive styles on learners' performance in a computer-networked hypertext learning system. *Journal of Educational Multimedia and Hypermedia, 7*(2/3), 151-176.

Cockburn, A., & McKenzie, B. (2001). What do Web users do? An empirical Analysis of Web use. *International Journal of Human-Computer Studies, 54*(6), 903-922.

College of Computing, Georgia Institute of Technology, (2001). GVW's WWW User Surveys. Retrieved May 1, 2006, from www.gvu.gatech.edu/user_surveys/

Cove, J. F., & Walsh, B. C. (1988). Online text retrieval via browsing. *Information Processing and Management, 24*(1), 31-37.

Coyne, K., & Nielsen, J. (2001). *Beyond ALT text: making the Web easy to use for users with disabilities*. Fremont: Nilesen Norman Group.

Craik, K. (1943). *The nature of exploration*. Cambridge, England: Cambridge University Press.

Craven, J., & Brophy, P. (2003). *Non-visual access to the digital library: the use of digital library interfaces by blind and visually impaired people* (No. 145). Manchester: Centre for Research in Library and Information Management.

Darken, R. P., & Sibert, J. L. (1996). *Wayfinding strategies and behaviors in large virtual environments.* Paper presented at the CHI '96.

Dauterman, W. L. (1972). *Manual for the Standford multi-modality imagery test*: American Foundation for the Blind.

Dervin, B. (1983). *An overview of sense-making research: concepts, methods, and results to date.* Paper presented at the Annual Meeting of the International Communication Association, Dallas, TX.

Dervin, B., & Nilan, M. (1986). Information needs and uses. *Annual Review of Information Science and Technology (ARIST), 21*, 3-33.

Dillon, A., & Jobst, J. (2005). Multimedia learning with hypermedia. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (pp. 569-588). New York: Cambridge University Press.

Disability Rights Commission (2004). *The web: access and inclusion for disabled people. A formal investigation conducted by the Disability Rights Commission.* London: Disability Rights Commission.

Donker, H., Klante, P., & Gorny, P. (2002). *The design of auditory user interfaces for blind users.* Paper presented at the Second Nordic Conference on Human-Computer Interaction, Arhus, Denmark.

Dunn, R., & Dunn, K. J. (1979). Learning styles/teaching styles: Should they, can they be matched? *Educational Leadership, 36*, 238-244.

Egan, D., & Gomez, M. (1985). *Assaying, isolating, and accomodating individual differences in learning a complex skill*. NY: Academic press.

Ellis, D. (1989). A behavioral model for information retrieval system design. *Journal of Documentation, 45*, 171-212.

Ellis, D. (1993). Modeling the information seeking patterns of academic researchers: the grounded theory approach. *Library Quarterly, 63*(4), 469-486.

Ellis, D., Cox, D., & Hall, K. (1993). A comparison of the information seeking patterns of research scientists in an industrial environment. *Journal of Documentation, 49*(4), 356-369.

Ellis, D., & Haugan, M. (1997). Modeling the information seeking patterns of engineers and research scientists in an industrial environment. *Journal of Documentation, 53*(4), 384-403.

Evans, S., & Douglas, G. (2008). E-learning and blindness: a comparative study of the quality of an e-learning experience. *Journal of Visual Impairment and Blindness*, 77-88.

Freedom Scientific (2009). JAWS for Windows. Retrieved January 15, 2009, from www.freedomscientific.com

Gagnon, D. (1985). Videogames and spatial skills: an exploratory study. *Educational Communication and Technology, 33*(4), 263-275.

Gaver, W. W. (1989). The SonicFinder: An interface that uses auditory icons. *Human-Computer Interaction, 4*(1).

Gerber, E. (2002). Surfing By Ear: Usability Concerns of Computer Users Who Are Blind or Visually Impaired. *AccessWorld*, *3*(1).

Glaser, B., & Strauss, A. (1967). *The discovery of grounded theory: Strategies for qualitative research.* Chicago: Aldine.

Glaser, B. (1992). B*asics of grounded theory analysis: Emergence vs. forcing.* Mill Valley, CA: Sociology Press.

Glaser, B. (1995). A look at grounded theory: 1984-1994. In B. Glaser (Ed.), *Grounded Theory, 1984-1994* (Vol. 1, pp. 3-17). Mill Valley, CA: Sociology Press.

Glaser, B. (1998). *Doing grounded theory: issues and discussions*. Mill Valley, CA.: Sociology Press.

Golledge, R. G. (1999). Wayfinding behavior: cognitive mapping and other spatial processes. *Psycoloquy, 10*(36).

Goose, S., & Moller, C. (1999). *A 3D audio only interactive web browser: Using spatialaizaiton to convey hypermedia document structure.* Paper presented at the ACM Multimedia 1999.

Grice, H. P. (1975). Logic and conversation. In Cole & Morgan (Eds.), *Syntax and Semantics: Speech Acts* (Vol. 3, pp. 41-58): Academic Press.

GW Micro (2009). Windows-Eyes. Retrieved January 15, 2009, from www.gwmicro.com/Window-Eyes/

Hackett, S., Parmanto, B., & Zeng, X. (2003). Accessibility of Internet websites through time. *ACM SIGACCESS Accessibility and Computing* (77-78), 32-29.

Hamilton, A. (2000). Metaphor in theory and practice: the influence of metaphors on expectations. *ACM Journal of Computer Documentation, 24*(4), 237-253.

Hanson, V., & Richards, J. (2004). *A Web accessibility service - update and findings.* Paper presented at the Sixth ACM Conference on Assistive Technologies (ASSETS 2004), Atlanta, GA.

Herder, E., & Juvina, I. (2004). *Discovery of individual user navigation styles.* Paper presented at the Third International Conference on Adaptive Hypermedia and Adaptive Web-based Systems.

HiSoftware (2009). Cynthia Says. Retrieved January 15, 2009, from www.cynthiasays.com

Hoelscher, C. (1998). *How Internet experts search for information on the Web.* Paper presented at the World Conference of the World Wide Web, Internet, and Intranet, Orlando, FL.

Holscher, C., & Strube, G. (2000). *Web search behavior of Internet experts and newbies.* Paper presented at the 9th International World Wide Web Conference.

Hook, K., & Dahlback, N. (1997). *Designing navigational aids for individuals.* Paper presented at the CHI97 Workshop on Navigational Aids in Electronic Environments.

Huberman, B. A., Pirolli, P. L., Pitkow, J. E., & Lukose, R. M. (1998). Strong regularities in World Wide Web surfing. *Science, 280*(5360), 95-97.

Hudson, R., Weakley, R., & Miller, L. (2005). *Source order, skip links, and structural labels.* Paper presented at the OZeWAI Conference, Australia.

Hutchins, E. L. (1986). Direct manipulation interfaces. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: new perspectives on human-computer interaction*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

IBM (2009a). IBM HomePage Reader. Retrieved January 15, 2009, from www-03.ibm.com/able/solution_offerings/hprtrial3.html

IBM (2009b). IBM Web Site Security (Watchfire). Retrieved January 15, 2009, from www-01.ibm.com/software/rational/offerings/websecurity

Ingwersen, P. (1996). Cognitive perspective of information retrieval. *Journal of Documentation, 52*(1), 3-50.

IT Accessibility & Workforce Division (1998). Section 508: the Road to Accessibility. Retrieved January 15, 2009, from www.section508.gov/

Jacobson, R. D. (1998). Cognitive mapping without sight: four preliminary studies of spatial learning. *Journal of Environmental Psychology, 18*, 289-305.

Jansen, B., Spink, A., Bateman, J., & Saracevic, T. (1998). Real life information retrieval: a study of user queries on the Web. *ACM SIGIR Forum, 32*(1), 5-17.

Jobst, J. (2005). How does the web sound? Interviews with screen-reader users. Unpublished Paper, The University of Texas at Austin.

Johnson-Laird, P. N. (1983). *Mental Models*. Cambridge: Cambridge University Press.

Jones, W., & Dumas, S. (1986). The spatial metaphor for user interfaces: experimental tests of reference by location versus name. *ACM Transactions on Information Systems*, *4*(1), 42-63.

Kamel, H. M., Roth, P., & Rashimi, R. S. (2001, July 29-August 1). *Graphics and user's exploration via simple sonics (GUESS): providing interrelational representation of objects in a non-visual environment.* Paper presented at the 2001 International Conference on Auditory Display, Espoo, Finland.

Kari, J. (2004). Web information seeking by pages: an observational study of moving and stopping. *Information Research, 9*(4).

Katajima, M., Blackmon, M. H., & Polson, P. G. (2000). *A comprehension-based model of Web navigation and its application to web usability analysis.* Paper presented at the HCI 2000.

Kelly, B. (2002). An accessibility analysis of UK university entry points. *Ariadne*(33).

Kelly, B., Phipps, L., & Howell, C. (2005). Implementing an holistic approach to e-learning accessibility. In J. Cook & D. Whitelock (Eds.), *Exploring the frontiers of e-learning: borders, outposts and migration*.

Kerka, S. (2000). *Incidental learning*: *Trends and Issues Alert 18.* Center on Education and Training for Employment.

Kim, K. S. (2001). Implications of user characteristics in information seeking in the World Wide Web. *International Journal of Human-Computer Interaction, 13*(3), 323-340.

Kirby, J. R., Moore, P. J., & Schofield, N. J. (1988). Verbal and visual learning styles. *Contemporary Educational Psychology*, *13*, 169-184.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, N.J.: Prentice-Hall, Inc.

Kuhlthau, C. C. (1991). Inside the search process: information seeking from the user's perspective. *Journal of American Society of Information Science*, *42*(5), 361-371.

Landau, S., Russel, M., Gourgey, K., Erin, J. N., & Cowan, J. (2003). Use of the talking tactile tablet in mathematics testing. *Journal of Visual Impairment and Blindness, 97*(2), 85-96.

Lazar, J., Allen, A., Kleinman, J., & Malarkey, C. (2007). What frustrates screen reader users on the web: a study of 100 blind users. *International Journal of Human-Computer Interaction, 22*(3), 247-269.

Lazar, J., Beere, P., Greenridge, K., & Nagappa, Y. (2003). Web accessibility in the mid-Atlantic United States: A study of 50 homepages. *Universal Access in the Information Society, 2*, 331-341.

Leitheiser, B., & Munro, D. (1995, August 25-27). *An experimental study of the relationship between spatial ability and the learning of a graphical user interface.* Paper presented at the Inaugural Americas Conference on Information Systems, Pittsburgh, PA.

Leporini, B., & Paterno, F. (2004). Increasing usability when interacting through screen readers. *Universal Access in the Information Society, 3*(1), 57-70.

Leuthold, S., Bargas-Avila, J. A., & Opwis, K. (2008). Beyond web content accessibility guidelines: design of enhanced text user interfaces for blind Internet users. *International Journal of Human-Computer Studies, 66*, 257-270.

Lewis, C. (1986). *A model of mental model construction.* Paper presented at the SIGCHI Conference on Human Factors in Computing Systems, Boston, Massachusetts, US.

Lewis, K. (2004). *Integrating Accessibility into a User-Centered Design Process: A Case Study*. Paper presented at the 13th Annual Usability Professionals' Association Conference, Minneapolis, Minnesota, USA.

Lewis, K., Bronstad, M. P., Barron, B., & Hays, J. (2004). *Web usage strategies: individuals with learning disabilities and individuals with visual impairments.* Paper presented at the 2004 CSUN Conference, Los Angeles, California.

Lumbreras, M., & Rossi, G. (1995). *A metaphor for the visually impaired: Browsing information in a 3D auditory environment.* Paper presented at the ACM CHI '95.

Lumbreras, M., & Sanchez, J. (1999). *Interactive 3D sound hyperstories for blind children.* Paper presented at the ACM CHI '99.

Mahmud, J., Borodin, Y., & Ramakrishnan, I. V. (2008). *Assistive browser for conducting web transactions*. Paper presented at the IUI 2008. from www.cs.sunysb.edu/~borodin/publications/KBiui2008.pdf

Malone, D. (2003). Testing a Web site for accessibility: part II, 2006, from nnlm.gov/pnr/news/200301/usability2.html

Malone, D. (2004). Testing a Web site for accessibility: part II. *Dragonfly, 34*(1).

Marcus, A. (2004). The next revolution: vehicle user interfaces. *Interactions, 11*(1), 40-47.

Mayer, R. E. (2005). Introduction to multimedia learning. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (pp. 1-16). Cambridge MA: Cambridge University Press.

Mayes, J. T., Draper, S. W., McGregor, M. A., & Oatley, K. (1998). Information flow in a user interface: the effect of experience and context on the recall of MacWrite screens. In D. M. Jones & R. Einder (Eds.), *People and Computers IV*. Cambridge: Cambridge University Press.

Merriam, S. (2002). Grounded theory. In S. Merriam (Ed.), *Qualitative Research in Practice*. Jossey-Bass.

Middlebrooks, J. C., & Green, D. M. (1991). Sound localization by human listeners. *Annual Review of Psychology, 42*, 135-159.

Miller, C. S., & Remington, R. W. (2004). Modeling information navigation: Implications for information architecture. *Human-Computer Interaction, 19*, 225-271.

Mote, L. J. B. (1962). Reasons for the variations in the information needs of scientists. *Journal of Documentation, 18*(4), 169-175.

Murphy, E., Kuber, R., McAllister, G., Strain, P., & Yu, W. (2008). An empirical investigation into the difficulties experienced by visually impaired Internet users. *Universal Access in the Information Society, 7*, 79-91.

Mynatt, E. D. (1994). *Auditory presentation of graphical user interfaces*. Reading, M.A.: Addison-Wesley.

Mynatt, E. D., & Edwards, W. K. (1992). *Mapping GUIs to auditory interfaces.* Paper presented at the ACM UIST '92.

Mynatt, E. D., & Weber, G. (1994). *Nonvisual presentation of graphical user interfaces: Contrasting two approaches.* Paper presented at the ACM CHI '94.

Nielsen, J. (1989). *The matters that really matter for hypertext usability.* Paper presented at the Hypertext '89, Second ACM Conference on Hypertext, Pittsburgh, Pennsylvania.

Nielsen, J. (2005). Severity Ratings for Usability Problems. Retrieved January 15, 2009, from www.useit.com/papers/heuristic/severityrating.html

Nilsson, R. M., & Mayer, R. E. (2002). The effects of graphic organizers giving cues to the structure of a hypertext document on users' navigation strategies and performance. *International Journal of Human-Computer Studies, 57*, 1-26.

Norman, D. A. (1983). Some observations on mental models. In D. A. Gentner & A. A. Stevens (Eds.), *Mental models*. Hillsdale, NJ: Erlbaum.

O'Malley, C., & Draper, S. W. (1992). Are mental models really in the mind? Representation and interaction. In Y. Rogers, A. Rutherford & P. Bibby (Eds.), *Models in the Mind: Perspectives, Theory, and Application* (pp. 73-91). London: Academic Press.

Oddy, R. N. (1977). Information retrieval through man-machine dialogue. *Journal of Documentation, 33*(1), 1-14.

Padovani, S., & Lansdale, M. (2003). Balancing search and retrieval in hypertext: Context-specific trade-offs in navigational tool use. *International Journal of Human-Computer Studies, 58*, 125-149.

Paivio, A. (1986). *Mental representations: A dual coding approach*. Oxford: Oxford Science Publications.

Palmquist, R. A., & Kim, K. S. (2000). Cognitive style and on-line database search experience as predictors of Web search performance. *Journal of the American Society for Information Science, 51*(6), 558-566.

Parkinson, A., & Redmond, J. A. (2002). *Do cognitive styles affect learning performance in different computer media?* Paper presented at the 7th annual conference on innovation and technology in computer science education, Aarhus, Denmark.

Petrie, H., Hamilton, F., & King, N. (2004). *Tension, what tension? Website accessibility and visual design.* Paper presented at the 2004 International Cross-disciplinary Workshop on Web Accessibility (W4A), New York, NY.

Petrie, H., & Kheir, O. (2007). *The relationship between accessibility and usability of websites.* Paper presented at the SIGCHI Conference on Human Factors in Computing Systems, San Jose, California, USA.

Pirolli, P., & Card, S. (1995). *Information foraging in information access environments.* Paper presented at the SIGCHI Conference on Human Factors in Computing Systems, Denver, CO.

Pirolli, P., & Card, S. (1999). Information foraging. *Psychological Review, 106*(4), 643-675.

Pirolli, P. L., & Wu, W. T. (2003). *SNIF-ACT: A model of information foraging on the World Wide Web.* Paper presented at the Ninth International Conference on Users Modeling, Johnstown, PA.

Ramakrishnan, I. V., Stent, A., & Yang, G. (2004). *Hearsay: enabling audio browsing on hypertext content.* Paper presented at the 13th International Conference on the World Wide Web, New York, NY, USA.

Raman, T. V. (1996). *Emacspeak - A Speech Interface.* Paper presented at the ACM CHI 96, Vancouver, BC Canada.

Reinert, H. (1976). Identifying student learning styles. *The Modern Language Journal, 60*(4).

Resnick, P. (1992). *HyperVoice: a phone-based CSCW platform.* Paper presented at the ACM Conference on Computer-supported cooperative work, Toronto, Ontario, Canada.

Riding, R. (1991). Cognitive styles--an overview and integration. *Educational Psychology, 11*(3/4).

Riding, R. (1998). *Cognitive styles and learning strategies: understanding style differences in learning and behaviour*. London: David Fulton Publishers.

Robertson, G. (1997). *Navigation in information spaces.* Paper presented at the CHI Workshop on Navigation in Electronic Worlds.

Romano, N. C. (2002). Customer relationship management for the Web-access challenged: inaccessibility of Fortune 250 business Web sites. *International Journal of Electronic Commerce, 7*(2), 81-117.

Rotard, M., Taras, C., & Ertl, T. (2008). Tactile Web Browsing for Blind People. *Multimedia Tools Applications, 37,* 53-69.

Roth, P., Petrucci, L., Pun, T., & Assimacopoulos, A. (1999). *Auditory browser for blind and visually impaired users.* Paper presented at the Conference on Human Factors in Computing Systems, Pittsburgh, PA.

Savidis, A., & Stephanidis, C. (1995a). *Building non-visual interaction through the development of the Rooms metaphor.* Paper presented at the ACM CHI '95.

Savidis, A., & Stephanidis, C. (1995b). *Developing dual user interfaces for integrating blind and sighted users: The HOMER UIMS.* Paper presented at the ACM CHI '95.

Schmandt, C. (1993). *Phoneshell: The telephone as computer terminal.* Paper presented at the ACM International Multimedia Conference, Anaheim, CA.

Schneider, J., & Strothotte, T. (2000). *Constructive exploration of spatial information by blind users.* Paper presented at the Fourth International ACM Conference on Assistive Technologies, Arlington, Virgina, United States.

Schneiderman, B., & Plaisant, C. (2005). Designing the user interface: strategies for effective human-computer interaction, 4/E: Addison-Wesley.

Slatin, J., Lewis, K., Liaw, L., & Burt, R. (2002). Web site accessibility at UT Austin Retrieved July 18, 2006, from www.utexas.edu/research/accessibility/research/summary/baseline.html

Spink, A., & Jansen, B. (2004). A study of Web search trends. *Webology, 1*(2).

Srinivisan, R. (1999). An overview of some human factors issues for in-vehicle navigation and route guidance systems. *Transportation Research Record*, *1694*, 20-26.

Strain, P., Shaikh, A. D., & Boardman, R. (2007). *Thinking but not seeing: think-aloud for non-sighted users.* Paper presented at the Conference on Human Factors in Computing Systems, San Jose, CA, USA.

Strauss, A. & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques.* Newbury Park, CA: Sage.

Sullivan, T., & Matson, R. (2000). *Barriers to use: usability and content accessibility on the Web's most popular sites.* Paper presented at the 2000 Conference on Universal Usability, Arlington, VA.

Sweller, J. (1988). Cognitive load during problem solving: effects on learning. *Cognitive Science, 12*, 257-285.

Tauscher, L., & Greenberg, S. (1997). How people revisit Web pages: Empirical findings and implications for the design of history systems. *International Journal of Human-Computer Studies, 47*, 97-137.

TechReady (2009). Braille Notetakers. Retrieved January 15, 2009, from www.techready.co.uk/Assistive-Technology/Braille-Notetakers

Thatcher, J. (1994). *Screen reader/2: access to OS/2 and the graphical user interface.* Paper presented at the ACM SIGACCESS Conference on Assistive Technologies, Marina Del Rey, California, USA.

The University of Texas at Austin (2008). Web Accessibility Policy. Retrieved January 15, 2009, from www.utexas.edu/web/guidelines/accessibility.html

Theofanos, M. F., & Redish, J. (2003). Guidelines for accessibile and usable Web sites: observing users who work with screen readers. *Interactions*, *10*(6), 38-51.

Thorndyke, P. W., & Hayes-Roth, B. (1982). Differences in spatial knowledge acquired from maps and navigation. *Cognitive Psychology, 14*, 560-589.

Tijerina, L., Palmer, E., & Goodman, M. J. (1998). *Driver workload assessment of route guidance system destination entry while driving.* (No. UMTRI-96-30). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

Torihara, S., Hirano, S., & Ishizaki, S. (2002). *2D Sound Screen Reader by Text-to-Speech from Information-Located Speaker(s) with Speaker-Matrix.* Paper presented at the The Seventeenth Annual Conference on Technology and Persons with Disabilities, California State University, Northridge, California, USA.

Trewin, S., Laff, M., Cavender, A. C., & Hanson, V. (2008). *Accessibility in virtual worlds.* Paper presented at the Conference on Human Factors in Computing Systems, Florence, Italy.

Tzovaras, D., Nikolakis, G., Fergadis, G., Malasiotis, S., & Stavrakis, M. (2002). *Designing and implementation of virtual environments for training of the visually impaired.* Paper presented at the ACM Assets 2002, Edinburgh, Scotland.

Usablenet (2008). LIFT Machine. Retrieved January 15, 2009, from www.usablenet.com/products_services/lift_machine/lift_machine.html

Vincente, K. J., Hayes, B. C., & Williges, R. C. (1987). Assaying and isolating individual differences in searching a hierarchical file system. *Human Factors, 29*, 349-359.

W3C (1999). Web Content Accessibility Guidelines (WCAG) 1.0. Retrieved January 15, 2009, from www.w3.org/TR/WCAG10

W3C (2006). Web Content Accessibility Guidelines (WCAG) 2.0. Retrieved January 15, 2009, from www.w3.org/TR/WCAG20

W3C (2008). Scalable Vector Graphics (SVG). Retrieved January 15, 2009, from www.w3.org/Graphics/SVG

Warner, E. S., Murray, A. D., & Palmour, V. E. (1973). *Information needs of urban residents*. Washington, D.C.: US Department of Health, Education and Welfare.

Watanabe, T. (2007). *Experimental evaluation of usability and accessibility of heading elements.* Paper presented at the W4A 2007, Baniff, Canada.

WebAIM (2009). Survey of preferences of screen-reader users. Retrieved February 3, 2009, from webaim.org/projects/screenreadersurvey

Wightman, F. L., & Kistler, D. J. (1997). Monaural sound localization revisited. *Journal of the Acoustical Socity of America, 101*, 1050-1063.

Wilson, T. D. (1999). Models in information behaviour research. *Journal of Documentation, 55*(3), 249-270.

Witkin, H. A. (1968). Cognitive patterning in congenitally totally blind children. *Child Development, 39*(3), 767-786.

Witkin, H. A., Oltman, P. T., Raskin, E., & Karp, S. A. (1971). *Group Embedded Figures Test Manual*. Palo Alto: Consulting Psychologiests Press.

Wolf, C., Koved, L., & Kunzinger, E. (1995). *Ubiquitous mail: speech and graphical interfaces to an integrated voice/email mailbox.* Paper presented at the Interact '95, Lillehammer, Norway.

Yankelovich, N., Levow, G. A., & Marx, M. (1995). *Designing SpeechActs: Issues in speech user interfaces.* Paper presented at the ACM CHI '95.

Zaidel, D. M., & Noy, Y. I. (1997). Automatic versus interactive vehicle navigation aids. In Y. I. Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 287-307). Mawaha, NJ: Lawrence Erlbaum Associates.

Zajicek, M., Powell, C., & Reeves, C. (1998). *A Web navigation tool for the blind.* Paper presented at the 3rd ACM/SIGAPH on Assistive Technologies, CA.

Zajick, M., & Morrisey, W. (2001). *Speech output for older visually impaired adults.* Paper presented at the IHM-HCI.

11.Vita

Jennifer was born on October 17, 1975, near Miami, Florida, to Bill and Susan Jobst. She holds a Bachelor of Science in Computer Science from the University of Texas at Austin, and a Master of Science in Technical Communication from Rensselaer Polytechnic Institute. She has worked in industry for Opnet Technologies and IBM as a technical writer. She is currently a usability specialist for Information Technology Services at the University of Texas at Austin.

Permanent address: 6306 Danwood Drive, Austin, Texas, 78759

This dissertation was typed by Jennifer Elizabeth Jobst.