Toward a purposeful design strategy for visually impaired Web users
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Abstract
The central premise of this research is the belief that using the Web non-visually is cognitively burdensome and tedious due to its complex, sight-centered design. There exists a literature gap on visually impaired (VI) users’ perceptions and experiences regarding Web site complexity. This paper reports the findings from a survey of 50 visually impaired individuals regarding perceived complexity and usability of a popular shopping Web site and its less complex version. Results show that significant gains in usability could be achieved by reducing complexity in Web design. A theoretical model of perceived complexity and associated propositions are presented to guide future research on improving the VI user experience of Web sites and Web applications.

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Introduction
The Web has become the most popular and indispensable technology for billions of people around the world. According to a report by Global Digital Insights, the number of Web users stood at 4.66 billion in January 2021, which constitutes 59.5 percent of the world population (Global Digital Insights). Using the Web has become a necessity rather than a convenience due to the restrictions imposed by COVID-19. We go online to perform almost every kind of routine — grocery shopping, ordering meals, paying bills, working and learning remotely, interacting with friends and family, and gathering information needed on a day-to-day basis. Online service providers are trying to attract more customers by updating their Web sites with new features, more advanced functions, aesthetically appealing advertisements, and depth and breadth of information. While this added complexity may have benefits for people who are typically sighted, it
People with vision impairment comprise an atypical group of users that employs different thinking and interacting approaches in digital environments. In this study, a “VI user” represents someone lacking the sight necessary to see content and controls displayed on a computer screen. They rely on the verbal rendition offered by the screen-reader (SR) to perceive, operate and understand such content and controls. The SR is a text-to-speech software that offers specialized keyboard commands for a range of operations. Keyboard commands enable the VI user to operate the computer and its applications non-visually. Three SRs popular among the VI user community are NVDA (40.6 percent), JAWS (40.1 percent) and VoiceOver (12.9 percent) (WebAIM, 2019). This non-visual Web interaction is characterized by sequential information processing as opposed to the parallel information processing afforded by sight (Giraud, et al., 2018).

Web interaction for a VI user is a listening activity. Arriving on a Web site, the user typically hears three SR announcements: title of the Web page, composition of the page in terms of interface objects (e.g., “Page has 3 frames, 2 headings, 20 links, 3 tables, ...”), and all text information available on the page serially from top left to bottom right (Babu, 2013; Babu and Xie, 2017; Xie, et al., 2018, 2015). The Tab key moves focus to the next active element or form field, and then announces its label (Buzzi, et al., 2010). Such elements or fields are rendered by the SR individually when they are embedded within a line of text or a paragraph (Babu and Xie, 2017). Consequently, the VI user “sees” each element (link, checkbox, radio button, etc.) on a separate line from the rest of that text. Numerous keyboard commands are available for a multitude of operations, majority of which are rarely used (Leuthold, et al., 2008). Commonly used commands for locating information within a Web page include the Heading Navigation command [H Key]) to navigate by section headings, the Find command [Insert + F keys] to perform keyword search, Arrow Navigation command [Up and Down Arrows] to read line by line), the Links List command [Insert + F7 keys] to navigate by links, and so on (WebAIM, 2019). The above simplistic description of Web interaction experience with an SR is intended to help the reader gain a basic understanding of how a VI user may engage with a Web site.

Literature informs that screen-reader mediated interaction is inherently ineffective and inefficient in dealing with complexity in the Web environment (Giraud, et al., 2018; Ramakrishnan, et al., 2017; Borodin, et al., 2010). The problem becomes particularly acute when performing tasks in content-rich Web sites; for instance, purchasing a product online typically takes five times longer for screen-reader users compared to typically sighted users (Puzis, et al., 2013). Consequently, studying Web site complexity from the VI user’s perspective is critical to effectively address the usability of the Web using screen readers.

Existing Web accessibility and usability standards, such as the Web Content Accessibility Guidelines (WCAG) 2.1, adopt a technocentric view of the problem, emphasizing interoperability between the Web site and the screen reader. Several studies with a user-centered approach to Web accessibility try to explicate the difficulties and situations experienced by SR users (Xie, et al., 2020, 2018, 2015; Babu, et al., 2010; Babu, 2015, 2013; Leuthold, et al., 2008; Lazar, et al., 2007; Leporini and Paternò, 2008; Takagi, et al., 2007; Borodin, et al., 2010). Literature informs that when retrieving information from complex Web sites, VI users tend to avoid the use of certain types of content and features. For instance, they avoid rich, dynamic, and interactive content fearing problems in finding desired information (Bigham, et al., 2007; Borodin, et al., 2010). Xie, et al. (2020) reports their preference for conducting simple keyword searches over using browse categories. Ramakrishnan, et al. (2017) reports that VI users get overwhelmed during their information search when encountering irrelevant or too much information. Giraud, et al. (2018) underscores the significance of irrelevant and redundant content in adding information overload for VI users. This implies irrelevant, redundant, voluminous, rich, dynamic, and interactive content as well as advanced search features, and browse categories add complexity to the design for VI information seekers.

Existing literature offers only glimpses of what Web site complexity represents in screen reader Web interaction. However, this does not clarify how VI users perceive Web site complexity, how this relates to their perception of Web site usability, and what aspects of the design contribute to their complexity perception. This represents a knowledge gap that must be addressed to offer VI users a seamless and
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enjoyable Web experience. This study aims to understand what constitutes a purposeful Web site design for screen reader use. Specifically, it investigates: (1) How does the perceived complexity of a Web site impact the user experience for people with vision impairment? And (2) What aspects of Web design contribute to perceived complexity for users with vision impairments?

Methodology

The questions raised in this study are how does perceived complexity of a Web site impacts the user experience for people with visual impairment, and what aspects of Web design contribute to perceived complexity for users with visual impairments. In order to address these questions, we created an experimental A/B design, in which an existing commercial site was compared to its less complex alternative created for this study. One of the more common tasks for Web users is shopping for goods and services online. In our study, we chose Amazon.com as an industry exemplar, which embodies many of the design principles believed to represent best practice. Its design served as the baseline for Web site complexity with regard to screen reader users. We then created its less complex alternative using the WIX Web site Builder platform. We focused on four tasks common to the online shopping experience: read product details, read customer reviews, read shipping information, and add an item to the cart. The selection of these tasks was not meant to be exhaustive, but representative, and thus, sufficient to explore the phenomena at the core of our research.

Working from the original Amazon.com design for a specific product, we crafted the experimental (less complex alternative) site by removing all information unrelated or tangentially-related to these four tasks from the interface. The notion of the negative impact of extraneous information in the interface has been shown by Giraud, et al. (2018), Chen (2018), and others to negatively impact user experience. Thus, we began with the assumption of a less complex interface, which would allow us to contrast different aspects of usability between the baseline design (followed by the Amazon site) and its less complex alternative (implemented in the experimental site). Each Web page of this experimental site was dedicated to a single task. Links from this page to other pages within the site were placed at logically appropriate locations to facilitate direct transition to a subsequent task. Labels of links and buttons were reworded wherever necessary to comply with the semantic labelling conventions for accessible Web sites (Franzke, 1995).

Drawing on the foundations of usability put forth by the Nielsen Norman Group (Pernice and Nielsen, 2001), we determined to investigate usability across five quality attributes: learnability, efficiency, memorability, errors, and satisfaction. Learnability, in their model, is described as “how easy it is for users to accomplish certain tasks when they come across a Web site design for the first time”. Efficiency is seen as how quickly a user can perform a task after they have learned the design. Memorability represents how easily a user can reestablish proficiency after an absence. Errors involve the number of errors users make, their severity, and ease of recovery from these errors. Perhaps the most subjective is satisfaction, which is meant to capture how pleasant it is to use the design. Using these quality attributes, we designed two post-Web site-use questionnaires with which to collect data regarding the usability of Amazon.com and experimental sites.

We invited screen reader users from around the United States to participate in this study. Invitation was shared via mailing lists maintained by major national and state organizations serving the VI community. A total of 71 volunteers accepted the invitation, of which 57 were determined qualified to participate. These participants were organized into two groups — A and B — to allow for reversal of the presentation order of the two sites. This was done to ensure no impact from order effect. Descriptive statistics are displayed as number (percentage) for categorical variables and mean (SD) or median (IQR) for continuous or ordinal variables. A Wilcoxon Sign Rank test was used for within subject comparisons. A Mann-Whitney test was used to assess the effect of order of presentation. For all tests, an alpha level of <0.05 was used to determine statistical significance.
Each group was asked to complete the four tasks (i.e., reading product details, customer reviews, shipping information, and adding an item to the cart) using one site after the other. After using each site, post-Web site-use questionnaire (see Appendix 1) were presented to gather opinion on usability of each site for each task. Regardless of the order of using the site, the second post-Web site-use questionnaire included two additional items — one to gather opinion about the better site in terms of usability/user experience, and the second for important design considerations behind these opinions. Specifically, we asked: (1) Comparing your experiences using the two Web sites you just looked at, which one had a more usable design in your opinion? And, (2) What was your reasoning behind your selection in the previous question? Please explain by citing three or four examples. Likert scales were used to gather opinion along the usability dimensions, open-ended questions were used to elicit participant responses to the additional items in the post-Web site-use questionnaire. Survey questionnaires were hosted using Google Forms.

Participant Responses to the open-ended questions served as the basis for performing a grounded theory analysis for inductive theory development (Glaser and Strauss, 1967). Central to this analysis is coding — “the process of developing codes, categories, and concepts” (Flick, 2014). Specifically, this entails aggregating text “into small chunks of information, seeking evidence for the code ... and then assigning a label to the code” (Creswell, 2013). Coding also enables teasing out structures and relationships among these concepts (Babbie, 2013). We followed the guidance offered in this body of literature to tease out eight concepts and their interrelationships pertinent to Web site complexity and screen reader user experience. Three independent coders, including two authors of this manuscript and a qualitative researcher, coded the rich qualitative evidence in several rounds until consensus was achieved and theoretical saturation was deemed to be accomplished. The process began by first identifying the central concepts related to perception of Web site complexity and VI user experience. Deeper analysis was conducted to identify design factors associated with such perception and experience. This revealed eight concepts/themes related to screen-reader user-friendly design — VI User Experience, Perceived Complexity, Navigability, Perceived Clutter, Linearity, Semantic Labelling, Task-Relevance of Content and Redundancy of Content. Further analysis was performed to identify which of these themes were interrelated. Finally, inferences were drawn regarding the ordering of these concepts/themes. This revealed four first-order concepts, two second-order concepts, one third-order concept, and one fourth-order concept. This study was approved under exempt status by the institutional review board at the University of Wisconsin-Oshkosh.

Results

Of the 57 survey responses received, seven were excluded from the analysis for incompleteness or discrepancy. The 50 responses analyzed represented VI participants with a broad range of experience using screen readers. Their browsing habits suggest these participants were active users of the Web and frequent online shoppers at the time of the study (see Figures 1 and 2). When it comes to how perceived complexity of a Web site affects the user experience for people with visual impairment, we found that the less-complex experimental site scored higher in all areas of usability; no statistical differences were noted with order of presentation, suggesting no bias was introduced with presentation of each site.

Results of qualitative analysis

In this section, we present results relevant to our second research question — What aspects of Web design contribute to perceived complexity for users with visual impairments? To answer this question, we conducted grounded theory analysis of the rich qualitative evidence gathered from the second survey, in particular responses to the item “What was your reasoning behind your selection [of the more usable Web site]? Please explain by citing three or four examples.” Of the 50 responses recorded for this item, a total of 44 were descriptive enough to infer perceptions regarding complexity. Of these 44, 36 responses were detailed enough to conduct grounded theory analysis regarding participants complexity perceptions and
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Analysis of the qualitative data followed Charmaz (2001), which suggests qualitative data should first be coded to identify categories of terms that remain close to the respondents’ language (see Table 2). We then consulted the literature and the data collection memos to develop focused coding categories. In the focused coding phase, the data were reanalyzed using categories from open coding as pre-existing codes and deliberately comparing the memos on all the participants’ comments. Focused coding involved creating codes are more directed, selective, and conceptual than word-by-word, line-by-line, and incident by-incident coding. Lastly, following the methodological guidance of Charmaz (2001), we categorized the focused codes through careful examination of the underlying assumptions, existing literature, and our own interpretations to produce a theoretical model.

The analysis identified eight themes that speak directly to the technological and the cognitive dimensions of a screen-reader user-friendly design. In the section that follows, we explain our interpretations and provide sufficient verbatim material from the raw data to ground the analysis fully. We have graphically summarized our proposed theoretical model in Figure 3 at the end of this section.

In the following, we present results relevant to each theme.

**Theme 1: Linearity**
One of the themes that consistently emerged from our qualitative analysis was linearity of the navigation structure. Two forms of linearity evident from the data include linearity of navigation paths and the linearity of workflow. Linearity of navigation paths was invoked by participants in referring to the straightforward nature of the path from the current location to a desired location within the Web site. The following quote offers evidence of user perceptions regarding linearity of the navigation structure:

“Another thing I liked about this alternative design was how it was structured. Each path from the main page leading to a branched page is straightforward; if you click the designated link, you go to the destination page, browse the information presented, and return to the main page by clicking the Back button. There is no need to use your brain as to where you need to go from point A to point B” (B02).

Referring to the experimental site, participant A04 invoked linearity of navigation paths as follows:

“It made my tasks extremely easy by organizing relevant information in dedicated locations that were easy to determine and navigate to. For example, the task of reading customer reviews was straightforward because of the ease with which I identified the link to the designated place from the main page ...” (A04).

As may be seen from these quotes, elements of the navigation path deemed relevant include the placement of links, pushbuttons, and blocks of text at logically appropriate points along the path. Linearity of workflow was invoked by participants in referring to the sequencing of the primary tasks afforded by the design. The primary tasks afforded by a shopping site like Amazon include searching for a product, reading details about a selected product, reading customer reviews, reading shipping options available, adding a product to the cart, etc. The experimental design employed in this study presented the shopping workflow by organizing content related to each of these tasks (starting with product details up to shopping cart) in a logical order. Recognizing the experimental site for its linearity of workflow, several participants appreciated how each Web page was dedicated to a single task. They explained how this enables them to simply go to a page, consume its information, and “get out” of it. The following quote from participant A06 captures evidence of linearity of work flow:

“Web site #2 was structured around four primary shopping activities — looking at product details, customer reviews, shipping details, and shopping cart. On the other hand, Web site #1 structure was difficult to comprehend” (A06)....”

Prior research on Web design for users with visual impairment has argued the benefit of linearity in aiding Web site navigation for users with visual impairment. This work has primarily focused on linear representation of the content on a single page to be rendered by screen reading technologies (Giraud, et al., 2018; Harper and Patel, 2014; Murphy, 2007). The experimental design went a step further and organizes navigation around tasks in such a way that users can traverse the sequence of activities associated with a particular task using a limited and consistent set of controls which limit their movement, allowing them to move forward and back within the sequence. Of the 36 participants who elaborated on their perceptions of Web site complexity, 19 commented on the importance of linearity of navigation structure. This leads us to offer the following proposition:

**P1**: Task-based linearity within the navigational structure of a Web site improves the overall navigability of Web sites for users with visual impairments.
Theme 2: Semantic labelling

Another common theme to emerge from the data was semantic labelling of interface objects. Interface objects identified by participants include links, buttons, images and section headings. They characterized semantic labelling as being thoughtful, clear, intuitive, purposeful, predictable, meaningful, and so on. Following set of quotes are presented as evidence of participants’ recognition of semantic labelling:

“Another good thing about the second design was how it named the links very thoughtfully. For example, the link to the shipping details page was named ‘look at shipping information.’ This clarified exactly what topic might be covered on the destination page. Contrast this to the first design where I could not tell which link might contain shipping details” (A01).

“Links to different pages within Web site #1 [experimental design] are worded in a way that as soon as you hear them, you can tell if they will lead you to the page, you are looking for” (B02).

“The second [original design] has checkboxes and buttons [that] may not correspond to what I think they do. So, I could make incorrect choices or buy the wrong thing altogether” (B01).

“You arrive at a ‘Go Back’ button which tells you are done on this page and may return to the previous page” (A08).

Appropriate and consistent labeling of controls has been shown to be beneficial to visually impaired Web users (Ramakrishnan, et al., 2017; Franzke, 1995; Giraud, et al., 2018). In this study, consistent task-specific labeling was used to simplify site navigation. Of the 36 participants who elaborated on their complexity perceptions, 16 recalled semantic labelling when asked to justify their selection of the screen-reader friendly design. This leads us to offer the following proposition:

P2: Task-specific semantic labeling improves navigability of Web sites for users with visual impairments.

Theme 3: Navigability

The third theme to emerge from the qualitative data analysis was the navigability of a design. Navigability was invoked by participants either in terms of efficiency in moving around, or in terms of predicting the path to a desired location. The following quote illustrates how navigability of the design was referred to in terms of efficiency:

“The first site [experimental design] was much more streamlined and straight forward. I was quickly able to navigate to the product description. Finding shipping details was a breeze. I was able to navigate and read reviews with minimal effort to find the information.” [B20]

On the other hand, the following quote illustrates how navigability was described in terms of predictability:

“Another thing I liked about this alternative design was how it
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Another interesting observation was the association of navigability with themes #1 and #2. Several participants appeared to relate navigability with linearity of design, while others related it with semantic labelling. For instance, in the following quote, participant B25 speaks of navigability along with “crisp labelling” (referring to semantic labelling) and “task-focused” (referring to linearity of task flow):

“Clean interface, crisp labelling, consistent layout and structure, navigable design, optimal information, task-focused” (B25).

The following quotes reinforce this assertion:

“Another example is the ease with which Web site 1 allowed me to move around the site in search of information I needed. The presence of heading shortcuts, the proper naming and placement of links, ... actually made the site very navigable.” [B18]

“For example, the customer review page had an accessible heading named appropriately, immediately followed by the comments of customers, and ending with the go back button. This left no scope for any thinking, distraction, confusion, or disorientation; as a shopper, you go [into] the page, read the reviews, and get out” (A01).

The above quotes imply navigability may be a second order construct potentially influenced by linearity and semantic labelling. Of the 36 survey respondents who elaborated their complexity perception, 21 cited navigability as an important consideration for screen-reader user-friendly design. This leads us to offer the following proposition:

P3: Task-based linearity and task-specific semantic labeling improve the navigability of Web sites for users with visual impairments.

Theme 4: Relevance of content

Another theme that reverberated throughout the analysis was the task relevance of the content presented. This is consistent with literature, which suggests content which is not relevant adds to the cognitive burden for visually impaired users who rely on screen reading technology (Harper and Patel, 2005; Murphy, et al., 2008; Chen, 2018). Content, as used in this study, refers to text, links, and sections. Participants repeatedly highlighted the importance of such content being directly relevant to the task at hand. The following quotes are presented as evidence of this assertion:

“The product page presents so much information, divided into so many sections, many of which seemed either irrelevant or having minimal utility for a shopper” (B05). “The product page [in the experimental design] contained nothing but necessary
details about the toothbrush ...” (B05).

“The second (experimental) design showed only [that] information that [was] directly relevant to the shopping task. On the contrary, the first [original] design showed information that distracted me. As an example, its main page had a section to leave reviews about the product that was totally irrelevant to a shopper who has not used the product yet” (A01).

“It was extremely easy for me to locate as well as look at the customer reviews, shipping details, and shopping cart on the first [experimental] Web site. On the other hand, ... [the original design] required me to go through a very large amount of text, links, headings and so on to find what I was looking for” (B06).

As the above quotes reveal, the task-relevance of page content refers not only to the direct relevance of details presented (text or links) to the primary tasks, but also to the direct relevance of the page sections and their titles. Additionally, the above quotes reveal that when thinking about task-relevance of content, participants frequently referred to its volume. Apparently, too much information was deemed undesirable because of the difficulty in evaluating its relevance to the task at hand. Of the 36 participants who elaborated on their complexity perceptions, 26 deemed task-relevance of content to be an important cognitive consideration for screen-reader usability. This leads us to offer the following proposition:

**P4**: Removal of content and controls which are not task-relevant will reduce the cognitive burden for users with visual impairments.

**Theme 5: Redundant content**

The presence of redundant content was mentioned as a source of confusion by several users in our study, as evidenced by the following comments:

“... there were so many duplicate links, for example two Details [links], and probably two or three ‘Add to Cart’ functions” (B05).

“Unlike the second site [original design], it [the experimental design] did not have any redundant information, creating no confusion as to which option to choose” (B02).

The “second site” here refers to the original Amazon design that contained numerous repetitive links, that add to the cognitive effort in dealing with ambiguity as the above quote demonstrates.

Redundancies demand extra time and effort needed to process and evaluate information. Literature informs that redundancy contributes to cognitive overload for VI users (Giraud, *et al.*, 2018). Of the 36 participants who discussed their experience with complexity, 12 mentioned redundancy in design as an important cognitive consideration for screen reader usability. This leads us to offer the following proposition:

**P5**: Removal of redundant content and controls from Web pages will reduce the cognitive burden for users with visual impairments.

**Theme 6: Perceived clutter**
This theme emerged from our analysis as a perceptual concept representing Web content or controls seemingly cluttering a design for screen reader use. Clutter was the term most frequently used by our participants when reporting the presence of irrelevant or duplicate information on a Web page. The following quote serves as evidence of the importance of perceived clutter for screen-reader user-friendly design:

“Aspects of the first [experimental] design that make it screen reader user friendly include ... Little to no extraneous or irrelevant information or clutter.” [B23]

As stated earlier, a deeper analysis of the data revealed the linkage of perceived clutter with both themes #4 and #5. Some participants perceived information not directly relevant to their task as clutter, while others saw redundancies as a form of clutter in Web design. The following quote illustrates how participants linked task-relevance of content with clutter:

“The second [experimental] Web site was much less cluttered without irrelevant info or annoying ads for other products that tend to hide the info you are really looking for” (A11).

In The following quote serves as evidence of the relationship between redundant information and clutter in Web design:

“Clutter: The 2nd [experimental] Web site did not have extraneous or redundant information” (A20).

The above quotes imply perceived clutter may be a second order construct likely shaped by the task-relevance of content and the redundancies of content/controls. Of the 36 survey respondents who elaborated their complexity perception, 19 cited clutter as an important consideration for screen-reader user-friendly design. In our theoretical model, we take the view that perceived clutter is comprised of task-irrelevant content and redundant content — both of which contribute to cognitive burden for screen reader users. Accordingly, we offer the following proposition:

**P6**: Redundant and task-irrelevant content represent perceived clutter in a design that increase the cognitive burden for users with visual impairments.

**Theme 7: Perceived complexity**

Navigability and perceived clutter were central themes easily distilled from participants comments. Collectively, we theorize the impact of these on user perceptions of complexity in design. Perceived complexity reflects the ease or difficulty with which users believe they could accomplish their task using the design (Nadkarni and Gupta, 2007). In our study, participants expressed their perception of complexity using cognitive, technological or informational concepts like understandability, cognitive load, disorientation, uncertainty, volume of information, page layout, action sequence, clarity and conciseness of information, intuitiveness of interface, etc. In the following, we offer a sample of quotes as evidence of the importance of perceived complexity for screen-reader user-friendly design:

“It [the experimental design] had a manageable information load ... simple layout ... light-weight design ... straightforward actions.” (A18)

“It [the experimental design] was easy to engage with because it does not overwhelm you with too much information,
sections, pages, and links” (A21).

“The second [experimental] Web site was clear and concise at first access” (A23).

“... the Amazon Web site [original design] lacked the intuitive interface to enable me to locate the customer review page” (A24).

“It [the experimental design] does not overwhelm you by presenting excessive information at once like the first site [original design]. It does not disorientate you with too many layering, section headings, links or images like the first site. It does not create uncertainty in your mind with slow transition between pages, unclear labelling of links or cluttering among needed information like the first site. It is easier to understand and navigate around compared to the first site” (A25).

As evident from the above quotes, perceived complexity is a multidimensional construct having an information processing component, an interaction component, and an information design component. A total of 36 out of the 50 respondents signaled the importance of perceived complexity for a screen-reader user-friendly design. Thus, we offer the following proposition:

**P7:** Navigability and perceived clutter impact user perceptions regarding the complexity of a Web site.

**Theme 8: VI user experience**

A final theme that emerged from our analysis was the link between perceived complexity and visually impaired user experience when dealing with complexity. This is revealed as a multidimensional construct having at least an emotional dimension and a functional dimension. Emotions evoked by a design perceived to be less complex were generally strongly positive (e.g., peaceful, comforting, reassuring, and enjoyable). Emotions associated with a design perceived as more complex were generally strongly negative (e.g., chaotic, cumbersome, overwhelming, unending, tortuous, and torture). The following quote captures both positive and negative emotional experiences of participants:

“Web site 1 [experimental design] makes it easier to shop for a product compared to Web site 2 [original design]. ... The emotional experience with this [experimental] design may be characterized as peaceful, comforting, reassuring, and enjoyable. [The] same things cannot be said about the design of Web site 2. The words that come to mind for this Web site experience are chaos, clutter, overwhelm, abyss, tortuous, torture, and so on” (B10).

The functional dimension of VI users’ experience represents the level of effort estimated in dealing with complexity. Similar to the emotional dimension, a design perceived to be less complex was generally believed to demand little to no effort during interaction, while a design deemed more complex was believed to demand more effort for interaction. This point will be evident from the following quote from participant B13:

“Overall, the experience using Web site 1 [experimental design] for these activities was a walk in the park, whereas the experience using Web site 2 [original design] was a trek up a
Of the 36 participants who elaborated on their complexity perceptions, 13 explicitly linked their user experiences with a design to its perceived complexity. This motivates us to offer the following proposition:

**P8**: Perceived complexity impacts the user experience for visually impaired individuals.

Each of these eight constructs have been argued individually by different scholars in literature, but not collectively. Our study casts them collectively as barriers to Web site usability for screen-reader users. Additionally, eight propositions were presented (throughout this section) to improve the VI user experience of a Web site. Based on this, we proposed the following theoretic model of perceived complexity in Figure 3.

![Figure 3: Theoretical model of each concept and their relationship](image)

The theoretic model of perceived complexity demonstrates the relationship between the eight concepts. It depicts that while the better linearity and semantic labelling contributes to better navigability of a Web site, irrelevance and redundancy of its content contributes to greater perceived clutter. Greater navigability reduces perceived complexity, while greater perceived clutter increases its perceived complexity. Ultimately, greater perceived complexity adversely impacts the VI user experience. Further research is needed to test the theoretic model empirically to validate and establish these relationships. This can be done experimentally by validating individual concepts as variables.

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**Discussion and conclusion**

The study reported in this paper was undertaken to explore what constitutes a screen-reader user-friendly Web design. The questions investigated were: How does the perceived complexity of a Web site impact the
user experience for people with vision impairment? And; What aspects of Web design contribute to perceived complexity for users with vision impairments? Employing an A/B experimental design and survey questionnaires, data from 50 VI participants was collected. Analysis revealed that significant gains in Web site usability could be achieved for screen reader users by reducing the complexity of its design. We found strong evidence to validate the claim that the reduced complexity in the experimental design will lead to greater usability and user satisfaction for screen reader users. In addition, survey data, which measured the different aspects of usability (Pernice and Nielsen, 2001), provided specific guidance regarding the difference in how usability constraints manifested in accomplishing core shopping tasks using the original Amazon design versus the experimental Web site design. We have further demonstrated with our design that accounting for these usability constraints resulted in a significantly greater user satisfaction score.

Figure 4: Comparative View of Task 1 Related Screen
Using the Web non-visually by listening to information read aloud by the screen reader is significantly more complicated than doing so by sight (Chandrashekar, 2010). The scant research on Web site complexity and VI user experience may be categorized under two broad contexts — Web navigation and online information retrieval. This body of literature identifies that banners, undescribed/unfamiliar content, multilayered navigation structures, tabular representations, visually-oriented navigation menus, improperly labelled navigation elements, unclear page layouts, and inconsistent navigation options as contributors to objective complexity in Web navigation (Vigo and Harper, 2014; Xie, et al., 2018; Leuthold, et al., 2008; Lazar, et al., 2007; Francisco-Revilla and Crow, 2010). Further, it identifies extraneous/redundant/voluminous/rich/dynamic/interactive content, advanced search features, and browse categories as contributors of objective complexity in online information retrieval (Bigham, et al., 2007; Borodin, et al., 2010; Xie, et al., 2020; Ramakrishnan, et al., 2017; Giraud, et al., 2018). The study reported in this paper seeks to consolidate these two streams of research under navigability and perceived clutter, and explicate their relationship to perceived complexity and screen-reader user-friendly Web design.
Limitations of the current study include the use of a convenience sample which could produce an element of selection bias with regard to user skill and adeptness with regard to SR usage. A possibility exists that the use of Amazon.com as a comparator introduces an element of bias as it is unlikely that study subjects were unfamiliar with the commercial site, and would likely have perceptions of the site, positive or negative, prior to participation in this study. However, the more revealing results of this study come from the qualitative analysis from which a theoretical model of how complexity mediates usability.

Findings revealed that perceived Web site complexity for screen reader users is a multidimensional
construct comprising of a navigability component and a clutter component. Navigability in turn was found to be a function of task-linearity of navigation structures and semantic labelling of navigation elements employed by the design. Clutter was found to be a perceptual construct being a function of the task-relevance of content/controls and redundancy of information displayed by the design.

In addition to the theoretical implications, findings of this study have important practical implications. It identifies seven constructs that represent important design considerations when building a screen-reader user-friendly Web site. It explains how the dynamics among task linearity, semantic labelling, content relevance, content redundancy, perceived clutter, and navigability impact user perceptions regarding Web site complexity, which in turn shapes the overall user experience. An understanding of these design considerations and their inter-relationships can assist designers, developers and online service providers to ensure effective usability and utility of their products and services for screen-reader users. Considering the high purchasing power of the visually impaired community, investing in a screen-reader user-friendly design could bring about significant returns for businesses.

This study highlights the importance of perceived Web site complexity as an important design factor behind usability and user experience. It shows that focusing on traditional sources of Web site complexity such as bulky graphics, animations, and inaccessible content is not enough. Attention must also pay to design features associated with perceived complexity such as things that represent clutter and navigation hurdles for screen reader users. Sources of perceived clutter (e.g., irrelevant, redundant, or voluminous text) as well as navigability hurdles (e.g., links or push buttons that are poorly labelled, placed illogically, or absent of shortcut mechanisms) could potentially hamper screen-reader usability of the design to the extent that a VI user gives up on the Web site. Consequently, findings of this study call for a new design thinking that considers Web site complexity more holistically to include both its objective and subjective dimensions.

This study showed that significant usability gains could be achieved by organizing the content of a Web site crisply around the main tasks it is intended to support. Therefore, developers, designers and online service providers could enhance the popularity of their Web sites and Web applications by structuring them around the core utilities. For example, shopping sites may be structured around the six core tasks — searching for a product, reviewing product details, reading customer reviews, reviewing shipping options, adding items to cart, and completing the check-out process. While secondary utilities, like writing a product review, selling a product, checking promoted products, etc. are also useful, presenting them should not come at the cost of the loyalty of VI consumers. These secondary tasks could potentially be presented using hamburger menus that may be expanded to display a list of options that correspond to the path to each secondary task. Primary tasks may be presented using a list of finite links on the landing screen that each correspond to the path to a specific task. This presentation strategy is evident on Walmart’s mobile app. The landing screen (see Figure 8) greets the visitor with a “Hello,” and asks “Where do you want to shop?” The first two options are Pickup & Delivery and Walmart.com. This keeps the interface clean and simple for the screen reader user, who does not need to hunt for a link to the desired location from within a “hay-stack”. Contrast this presentation strategy to that implemented on the desktop version of Walmart’s Web site (see Figure 9) that necessitates such a hunt. The task-oriented structure of the Walmart mobile app may be its strength, but it fares poorly when it comes to labelling and redundancy. For example, the two options on the landing screen are labelled “Hall Way Card Pickup & Delivery” and “Hall Way Card Walmart.com.” The redundancy problem is evident on the shopping cart screen (see Figure 10) where the name of each added item shows up four times consecutively. While it is not apparent from the visual presentation, the screen-reader detects four instances of each cart item. The item name, quantity, and price are read together by the screen-reader four separate times; once when the image is highlighted, when the description is highlighted, when the quantity is highlighted, and when the price is highlighted. As demonstrated in our experimental design, a more semantically appropriate labelling for the options could be “Go to Pickup & Delivery Area” and “Go to Walmart.com Online Marketplace.”
Figure 8. Landing screen for mobile app illustrating the implementation of task linearity
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Figure 9. Landing screen for Walmart desktop site offering a comparative view with the mobile app.
While compliance with design standards like WCAG 2.1 is necessary for technical accessibility of a Web site for screen-reading purpose, delivering effective usability and utility will require addressing cognitive and functional aspects of Web site accessibility such as perceived Web site complexity. Therefore, it is imperative to craft design guidelines to reduce specific aspects of perceived complexity — linearity of navigation structure, semantic labelling of navigation elements, task-relevance of content/controls, and redundancy of information. Following are some generic design guidelines that may be drawn from this study:

<table>
<thead>
<tr>
<th>Cart (1 item)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Value Whole Milk, 1 Gallon, 128 Fl. Oz.</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

EBT food eligible $1.49 Subtotal $1.49

Check out

Figure 10. Cart view from Walmart mobile app illustrating implementation of content redundancy
Guideline 1: Design the navigation structure around the primary purpose served by the Web site to ensure Task-based linearity.
Guideline 2: Label navigation elements using task-oriented semantic language and action verbs.
Guideline 3: Design each Web page to afford one or two tasks at the most.
Guideline 4: Ensure that content and controls on a Web page are directly relevant to the task(s) it affords without any ambiguity.
Guideline 5: Remove any duplicate content or control within a Web page.

This sample is offered to illustrate what broad topics are to be covered by design guidelines on Web site complexity for screen reader users. Further research is needed to identify the nuances of such design guidelines — specific recommendations, techniques, methods and features — for implementation purpose. Future research may employ in-depth exploratory studies with VI users, Web developers/designers, usability/UX professionals, and HCl scholars to create and experimentally validate such guidelines through prototyping.

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**Appendix 1**

| Table 1: Demographic details for participants *(N=50).* |
|-----------------------------------------------|---|---|
| **Male** | **Female** |
| Ethnicity | | |
| White | 14 | 10 |
| Black | 7 | 3 |
| Hispanic | 4 | 3 |
| Asian | 7 | 0 |
| Other | 1 | 1 |
| Age (years) | | |
| 10–19 | 3 | 0 |
| 20–29 | 10 | 6 |
| 30–39 | 9 | 6 |
| 40–49 | 5 | 2 |
| 50–59 | 4 | 1 |
| 60–69 | 2 | 1 |
| 70–79 | 0 | 1 |
| Operating system used | | |
| Windows | 31 | 13 |
| Mac OS | 2 | 4 |
| Screen reader used | | |
| Jaws | 20 | 7 |
| Mac Voiceover | 2 | 2 |
| Windows NVDA | 8 | 5 |
| Other | 3 | 0 |
| Experience with screen readers (years) | | |
| <1 | 0 | 0 |
| 1–9 | 12 | 3 |
| 10–19 | 11 | 9 |
| 20–29 | 7 | 5 |
| 30–39 | 3 | 0 |
| 40–49 | 1 | 0 |

Table 2: Sample of code distillation for each theme.

<table>
<thead>
<tr>
<th>Open coding</th>
<th>Quote</th>
<th>Focused coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear/unclear structure</td>
<td>“One difference was how they were structured. Web site #2 was structured around 4 primary shopping activities — looking at product details, customer reviews, shipping details, and shopping cart. On the other hand, Web site #1 structure was difficult to comprehend” (A06).</td>
<td>Linearity</td>
</tr>
<tr>
<td>Mismatched labels</td>
<td>“The second [original design] has checkboxes and buttons [that] may not correspond to what I think they do. So, I could make incorrect choices or buy the wrong thing altogether” (B01).</td>
<td>Semantic labelling</td>
</tr>
<tr>
<td></td>
<td>“The product page presents so much information, divided into so</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Necessary/useful details</th>
<th>“... there were so many duplicate links, for example two Details [links], and probably two or three ‘Add to cart’ functions” (B05).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navigable design</td>
<td>“Clean interface, crisp labelling, consistent layout and structure, navigable design, optimal information, task-focused.” [B25]</td>
</tr>
<tr>
<td>Overwhelming amount of information</td>
<td>“It was easy to engage with because it does not overwhelm you with too much information, sections, pages, and links” (A21).</td>
</tr>
<tr>
<td>Duplicate links</td>
<td>“The product page [of Mysite] contained nothing but necessary details about the toothbrush ...” (B05).</td>
</tr>
<tr>
<td>No irrelevant information or ads</td>
<td>“The second [experimental] Web site was much less cluttered without irrelevant info or annoying ads for other products that tend to hide the info you are really looking for” (A11).</td>
</tr>
<tr>
<td>Irrelevant information</td>
<td>“Overall, the experience using</td>
</tr>
<tr>
<td>Redundant information</td>
<td>“There were so many duplicate links, for example two Details [links], and probably two or three ‘Add to cart’ functions” (B05).</td>
</tr>
</tbody>
</table>
Better experience | Web site 1 for these activities was a walk in the park, whereas the experience using Web site 2 was a trek up a hill” (B13). | VI user experience

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