2011

# Development and Evaluation of an Interface Aid to Support Web Based Information Seeking for the Blind Research Study

Carissa Ann Brunsman-Johnson
*Wright State University*

# Development and Evaluation of an Interface Aid to Support Web-Based Information Seeking for the Blind

A proposal submitted in partial fulfillment of the
Requirements for the degree of
Doctor of Philosophy

By

Carissa Brunsman-Johnson

M.S., Wright State University, 2006
B.S., The Ohio State University, 1993

2011

Wright State University

March 2, 2011

WRIGHT STATE UNIVERSITY
SCHOOL OF GRADUATE STUDIES

I HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER MY SUPERVISION BY Carissa Brunsman-Johnson ENTITLED Development and Evaluation of an Interface Aid to Support Web Based Information Seeking for the Blind BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF Doctor of Philosophy.

________________________________
S. Narayanan, Ph.D., P.E.
Dissertation Director

________________________________
Ramana Grandhi, Ph.D.
Director, Ph.D. in Engineering Program

________________________________
Andrew Hsu, Ph.D.
Dean, School of Graduate Studies

Committee on Final Examination

________________________________
S. Narayanan, Ph.D., P.E.

________________________________
Nikolaos G. Bourbakis, Ph.D.

________________________________
Jennie J. Gallimore, Ph.D.

________________________________
David B. Reynolds, Ph.D.

________________________________
Ling Rothrock, Ph.D.

________________________________
Wayne L. Shebilske, Ph.D.

# Abstract

Brunsman-Johnson, Carissa. Ph.D., Department of Biomedical, Industrial, and Human Factors Engineering, Wright State University, 2011. Development and Evaluation of an Interface Aid to Support Web Based Information Seeking for the Blind.

Information seeking on websites has become more and more challenging for people who are blind. Screen readers attempt to make that task easier by introducing new commands and functionality but there still exists a fundamental gap in the difficulty for people who are blind compared to their sighted counterparts. This research identifies the strategies used by people who are blind and sighted to create an information seeking model, develop the Keywords Expected for Your Search (KEYS) conceptual model for assisting task performance and evaluate a KEYS prototype of this concept for information search and retrieval.

This information seeking model was developed by conducting an initial experiment and then validating the model using data from a similar study. The model defines information searching strategies used for both participants that were sighted and blind. Primary information search strategies for the web were identified. The model demonstrated the primary search strategies in the model were keyword based and are the foundation for information seeking on websites for both groups of participants.

The KEYS conceptual model for assisting task performance was developed. It includes rules and a keyword library to support information searching for users who are blind. A KEYS prototype was developed to test the conceptual model. The prototype was implemented by controlling the results of the list of links and virtual find commands, which are two of the more commonly used primary search strategies for users who are blind.  The evaluation sought to determine the aids' impact on workload, number of commands used, search success, path direction and time to complete a task.  Comparisons of the participants who were blind with and without the KEYS prototype were made as well as comparisons to sighted participants.  Age group comparisons and age of blindness onset were also compared.

The results of the experiment demonstrated that the KEYS prototype significantly improved information searching for users who are blind by lowering all measured variables.

A primary contribution of this research was to demonstrate that providing keyword support improves information searches.  Implementing the KEYS can produce a significant difference in how users who are blind search for information on webpages.

# Table of Contents

# List of Tables

# List of Figures

# ACKNOWLEDGEMENTS

The opportunity to pursue my Doctoral degree under the guidance of Dean S. Narayanan has been a privilege. His support extended beyond my pursuit of a Doctoral degree and included my quest for a career with consideration for future development. I will always consider him a colleague and friend.

I would also like to thank Dr. Wayne Shebilske for his untiring assistance. He provided guidance in the area of disabilities research as well as guidance in life. He is a genuine role model of selfless giving and encouragement for learning.

Committee member Dr. Jennie Gallimore took time to serve on my committee and offer guidance. All committee members, Dr. Nikolaos Bourbakis, Dr. David Reynolds, Dr. Ling Rothrock quickly responded to my questions and offered support and consensus.

Thank you also to the faculty and staff of Biomedical, Industrial and Human Factors Engineering especially Daisy Stieger and Sherry Cwiakala**,** the Ph.D. Engineering program and the Dean's office. The faculty and staff always took a personal interest in my questions and needs and ensured I would be successful.

The African proverb: "It takes a village…" can be applied to the effort and people required pursuing a Doctoral degree. The village is my family and friends who have supported me through this journey. My husband and father have been participants and testers throughout my academics while my mother has ensured my children were well cared for and loved. It is my hope that my children will see this Doctoral degree as a life lesson in what can be accomplished with hard work and determination. My heartfelt thanks go to my children and family for all their love, patience and support for me throughout my academic career.

The rest of my village includes Ryan Miller who tested every piece of software and gave wonderful critiques along with Srikanth Nadella for his creative programming solutions for my dream-like requirements for the aid. Their professionalism ensured the aid worked flawlessly for my participants. I would also like to thank Eric Duffy and all the members of the National Federation for the Blind local chapters for opening their conference to me and volunteering for this experiment. Their encouragement and interest in this project is greatly appreciated. Dr. Amy Doll as well as the Office for Disabilities at Wright State University also provided wonderful assistance in finding participants.

Thank you IGERT fellowship for providing training and education in assistive technologies and funding for my academic pursuits.

# 1. Introduction

Websites use a Graphical User Interface (GUI) design that is considered a major advance in computer interface designs. GUI is heavily visual in nature and requires a visual interaction for both the inputs and the outputs to the system. Symbols and graphics have allowed users to quickly learn how to interact with the system and aid with information seeking. The World Wide Web (WWW) has brought the GUI interface to new levels by including streaming media, real time collaboration, interactive documents and pop-up windows to enhance the interactive visual experience. Though GUI aids usability for sighted users, it is unfavorable to users who are blind. To date, the main method for making the web accessible is to encourage designers to use the guidelines developed by the World Wide Web Consortium (W3C) and continue the advancement of assistive technologies such as screen readers. The W3C has developed accessibility guidelines, Web Content Accessibility Guidelines (WCAG), that are created to make websites accessible at the interface level but do not address the issues discovered during information seeking. For instance, determining where information is located when a screen reader reads linearly through the website from top to bottom (Salampasis, Kouroupetroglou, Manitsaris, 2005).

The most popular assistive technology used for accessing websites by people who are blind is a screen reader. A screen reader can verbally read the website from top to bottom or send the text to a tactile, electronic Braille device. This capability requires the sensory substitution for vision in web information seeking to be auditory speech and/or tactile Braille. The screen reader reads the HyperText Markup Language (HTML) code and not what is visually displayed on the screen. A website designer could produce a website that is visually similar to another but can be coded very differently. For instance, font that is size 14 may be similar to an HTML coded header level 1 or <H1>. Since the screen reader reads the HTML code, it would not be able to perform a search of the all the headers on the page if the designer used a large font size instead of a header level 1 code. Eliminating the header level 1 code makes the text less important and prevents the screen reader from gaining information from the website to aid the users information searching.

The functionality of the screen readers can be very useful; however, all commands require several keystrokes and must be memorized by the user. Screen readers have difficultly detecting dynamically changing content that is associated with complex websites. Other web enhancements, such as streaming media, block the verbal reading of the site and are not easily turned off. In addition to these issues, information seeking on websites with a screen reader is done serially which is not the intent of web pages (Craven, 2003; Salampasis et al., 2005). The entire site is read from top to bottom in one long string of data. This interpretation of a website encourages people who are blind to develop a mental model of the website as one long string of data or vertical list (Murphy,Kuber, McAllister, Strain & Yu, 2008).

Mental models formed by users who are sighted are more spatial. Web pages are designed to be visually scanned and consist of visual landmarks to aid visual users in the task of information seeking (Maeda, Fukuda, Takagi & Asakawa, 2004). Other visual cues include navigational sidebars being placed in a visually noticeable location (Nielsen & Tahir, 2001), similar items grouped together (Nielsen & Tahir, 2001) with white space indicating the separation (Thissen, 2004) and context. Visually designed websites may limit the information provided for screen reader users when information seeking and therefore, produce a mental model that is different from a sighted users.

Understanding the users' expectations and mental model has implications in interface design (Carroll & Olson, 1987). Interface designs should allow users to easily determine how the system works so they can successfully complete tasks and meet their goals (Carroll & Olson, 1987). Therefore, if the systems interface exhibits characteristics of the users' mental model than the users would be able to understand the system, information seek successfully and perhaps reduce the errors associated with using the system (Carroll & Olson, 1987). The system should function as the user expects it to function. This research provides design suggestions for website design and assistive technology aids.

## 2. Research Overview

This research summarizes the current research in the area of information seeking and mental models produced in users who are blind. Based on this data and results of experiment one, a descriptive model of information seeking is produced. The Keyword Expected for Your Search (KEYS) was created with rules and a library for how to support users who are blind with information searching within a website. The KEYS assists users that are blind by supporting their mental model and experience based on ecology. KEYS enhances the most commonly used search strategies, which are all keyword based, by increasing the availability of keywords on the website and in the search results. A prototype of the KEYS concept was implemented within a screen reader and adapts the search results. The KEYS prototype was then evaluated based on five dependent variables: workload, number of commands, path direction, success and time.

The research paper is formatted into three phases (Figure 1). Phase one includes the background of key research in information seeking for users who are blind in addition to mental model development and results from experiment one. That is followed by phase two and the development of the KEYS and KEYS prototype which was shaped by the research observations. It then concludes with phase three which evaluates the KEYS prototype and the significance of this research.

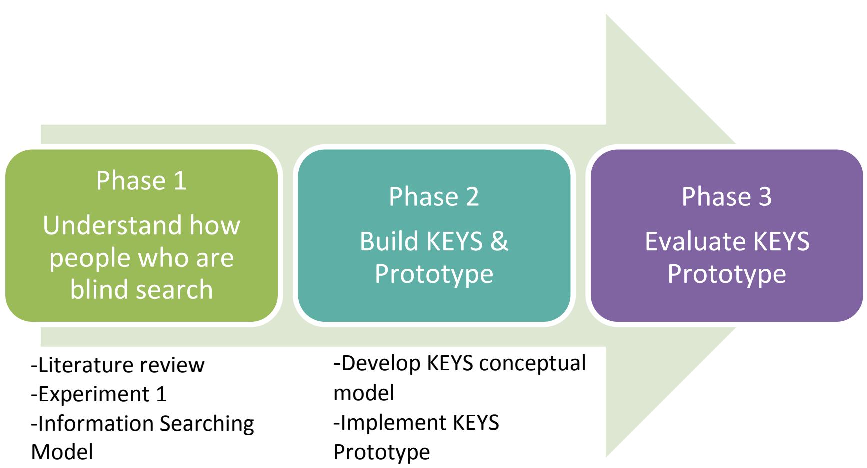



**Figure 1. Research Overview Phases.**


# 3. Phase 1: Understand how people who are blind search

## 3.1 Background

The strategies and mental models of users who are blind is the subject of much research. Understanding the users' expectations and mental model has implications in interface design (Carroll & Olson, 1987). A user feels successful when the system functions as the user expects it to function. Information on mental models provides design suggestions for websites and assistive technology aids. The theories researched and the assistive technologies created are based on information seeking strategies such as travel metaphors, Information Foraging (Card et al., 2001), spatial information and multimodality. The following is a summary of the different methods and research areas for information searching on webpages or web portals for people who are blind and sighted.

### 3.1.1 Mental Models

Currently, the mental models of sighted users are defined and used as the basis for building systems by Human Factors Interface designers. To develop an interface to support the user who is blind, knowledge of their mental model and experience will need to be defined. Current research and theories on the development of mental models for users who are blind is also discussed. This section describes the development and evidence to support a mental model for users who are blind and how that may differ from sighted users.

There are many definitions for mental models and how they relate to human computer interfaces. Carroll and Olson (1987) defines a mental model as the basic knowledge associated with how a system functions. Marchionini (1998) defines mental models as "dynamic mental representations of the real world." Users develop mental models to make it easier to use a system again in the future (Marchionini, 1998). These models are used to predict outcomes and actions for all types of objects or systems and for different domains (Marchionini, 1998; Kurniawan & Sutcliffe, 2003). These models are dynamic because they change or are reinforced based on experience and learning (Marchionini, 1998). The definition used by Jacobson (1998) for developing a mental model is "a process composed of a series of psychological transformations by which an individual acquires, stores, recalls and decodes information about the relative locations and attributes of the phenomena in his everyday spatial environment." Therefore, construction of mental models is related to prior experience (Zhang, 2008) and familiarity of the system. This does not mean that the experience and familiarity of the system produces an accurate model (Carroll & Olson, 1987). Mental models form how the user believes the system behaves based on previous experience. Mental models not only represent the functionality of the system, but also the structural characteristics (Marchionini, 1998). Therefore, mental models contain information about how the system works and how it is spatially organized.

The mental model theory is used to create interfaces for websites as well as other systems. The significance of using this model is mentioned by Nielsen (2005) and Marchionini (1998). The importance of designing an interface based on a user's mental model is significant to the usability, information seeking and accessibility of the website interface. Therefore, understanding the mental model of the user who is blind is necessary to design an assistive technology or website interface to aid information searching. Much research is compiled for determining the mental model of sighted users as well as users who are blind. There is also evidence showing that the mental model for sighted may be different from users who are blind. The following sections develop the information that is currently theorized about mental models for both groups.

### 3.1.2 Travel Metaphor

A travel metaphor is one method of assisting people who are blind with information seeking. This theory suggests that users who are blind information seek in a style similar to wayfinding, a method used to describe how people traverse the real world. Two studies conducted by Passini and Prouix (1988) and Passini, Prouix and Rainville (1990), explored how people who are blind explore the real world and discovered that they travel using wayfinding, similar to a sighted person. They discovered that people who are blind tend to form mental models that used significantly more information than people who are sighted and the information tends to be of a different type and source (Passini & Proulx, 1988). Harper, Stevens and Goble (1999) also cited that the mental models were also more 'egocentric' in nature (based on user not environment) when describing distance and route. A possible explanation for these differences is a lack of preview or overview for people who are blind (Harper et al., 1999). Harper et al. (1999) describes the World Wide Web (WWW) as containing a "degree of travel as well as reading" and feels screen readers only assist blind users with the reading portion of navigating the WWW and do not seem to be interested in aiding the blind user in traveling the WWW. Goble, Harper and Stevens (2000) believe that traveling in the real world involves navigating from one location to another regardless of destination and should be associated with WWW information seeking. Harper et al. (1999) draw the following parallels to blind travel and website information seeking: lack of preview, planning at onset or forming plan as progress, cueing (waypoint markers or landmarks) for orientation and finally, feedback. As stated by Goble, et al. (2000), the research discovered in blind travel could assist designers in providing better information seeking for blind users on websites.

Wayfinding theory (Tan & Wei, 2006) suggests that users search for information by performing three processes: forming a mental model, decision generation and decision execution. Forming a metal model requires users to organize information from past experience as well as information produced from the current website to form a mental model or representation. This model is then used to decide how to approach a website. Mental models are created using landmarks, route and survey knowledge. Landmark knowledge is used for orientation while route information is used to determine how the landmarks are connected and finally, survey knowledge is an understanding of the surrounding environment. For example, a sighted user may use a company logo as a landmark and know that it will always be located on the top, left part of the page. Figure 2 demonstrates wayfinding in the real world. Landmarks are the home, grocery, post office and work. The route knowledge describes the routes discovered to get from one landmark to the next. For instance, one may know how to travel from home to work or home to the grocery. The survey knowledge is the connecting of these landmarks and routes to get an overview of the area. The survey knowledge provides the information to go from home to the grocery and then to work, etc. Mental models can be created by visually scanning a website for clues. Individuals who are blind must scan the website by verbally listening (Theofanos & Redish, 2003) to create a mental model. Kuber, Yu and McAllister (2007) argued that with a screen reader, developing a mental model of the planned spatial layout for a website is a challenge for users who are blind. Users who are blind are unable to establish the landmarks intentionally created by the designers but will instead use landmarks that are unintended (Takagi, Saito, Fukuda & Asakawa, 2007). This may be part of the reason Craven (2003) discovered that people who were blind take more than twice the number of steps or keystrokes compared to sighted people and three to five times longer time to complete a task. The additional impact of attempting to form a mental model while using a screen reader and a browser has a much higher cognitive load compared to sighted (Takagi et al., 2007). Not only is it cognitively demanding but it is also tedious and time consuming for the user. This suggests that designing websites that have landmarks noticeable to a screen reader user may improve information seeking.

Wayfinding is not performed exactly in the same method for people that are blind and sighted. However, both group's wayfinding real world method is thought to map to how they perform website information searching [Harper et al., 1999 and Tan & Wei, 2006). The Dante Project (Yesilada, Stevens, Harper & Goble, 2007) uses a similar theory to transcode webpages based on a travel metaphor for people who are blind. Items on a webpage are identified as travel objects and then given meaning in terms of the layout of the webpage. Some travel objects used in the Dante Project are waypoints, orientation points and travel assistants. “Mobility semantics define how these objects are used and authoring semantics define how these objects are presented” (Yesilada et al., 2007). The transcoding creates webpages that are fragmented but simple in design to allow screen readers easier access. Their study results used the NASA Task Load Index (TLX) as a method to measure the differences in their new transcoded webpages compared to the original. The early testing shows some satisfaction with the method though there are still some serious negative comments they are still working through. For instance, the transcoded webpages are fragmented and were found confusing. Users also felt the transcoding eliminated the ability to use any mental model or strategy they may have developed for the website.

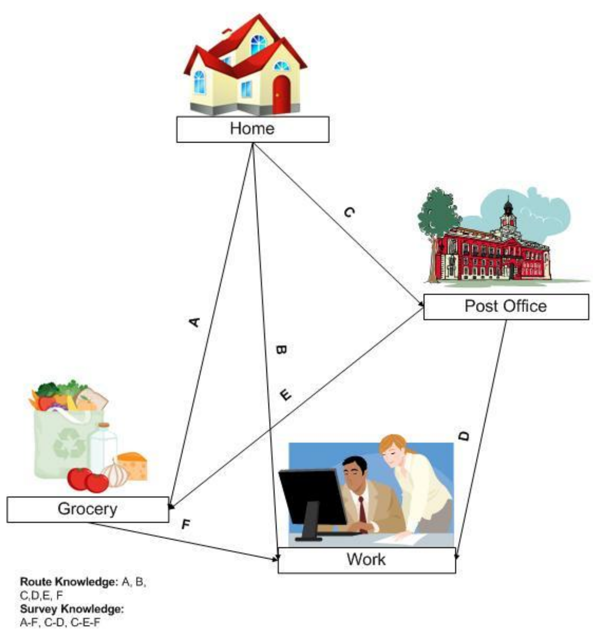



**Figure 2.** Demonstration of Wayfinding

Figure 3 is a process flow based on Tan and Wei’s (2006) “New wayfinding diagram” that demonstrates wayfinding used in website information seeking. Information cues are provided from context, images, headings or page structure. Sighted users have expectations based on their previous experience with websites. In an eye gaze study conducted by Nielsen (2006), users formed an F-shaped pattern to scan a webpage. This demonstrates there is an expectation that important information and content lies structurally on the top, middle and left side of a webpage.

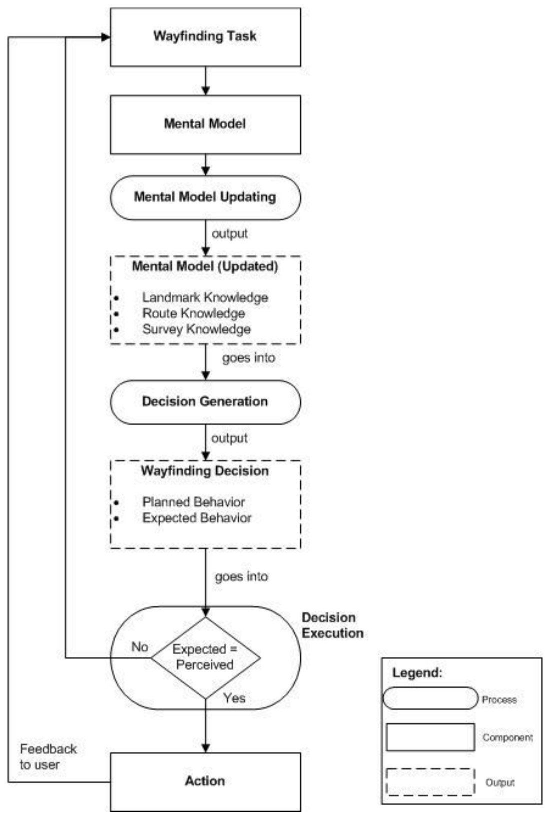



**Figure 3. New Wayfinding Diagram based on Tan and Wei (2006).**

Salampasis et al. (2005) added Metadata to webpages and created a specialized browser to read these webpages. The annotated webpages with the Metadata content reorganized the website into “visual” divisions and attempted to aid the user with landmark and route decisions. Though many users who were blind liked the additional information the Metadata provided, there was no improvement in the time or keystrokes required to complete the tasks.

Research by Marchionini (1998) on sighted users describes different information seeking strategies that demonstrate some similarities with wayfinding. Marchionini (1998) classifies strategies as analytical or browsing. The analytical strategies are described as planned and goal driven while browsing is more heuristic. Marchionini's (1998) definition of browsing strategies includes several used for "within-document" information seeking. These strategies are scanning, observing, navigating, and monitoring. Scanning requires users to compare the mental image of the data they are seeking to the information they are seeing, such as looking for patterns. Current website designers enhance this strategy by highlighting and enhancing some information. Observation is based more on chance than analyzing of data on the website to find the desired information. Website designers provide multiple views of the same information to assist with this strategy. In Marchionini's navigation strategy, users follow a predefined route. This strategy uses cues from the application to assist the user's route selection. Though the term navigating can be interchangeable with information seeking, this research will refer to Marchionini's strategy as "Marchionini's navigation" when referring to his strategy. Monitoring is a strategy similar to scanning, but while the user is reading about the data of interest, they are also monitoring for other data that may be interesting but maybe unrelated. Information seeking uses these strategies at various stages. Though these strategies are not defined as part of the wayfinding theory, they can apply to different parts of the wayfinding flow chart on Figure 3. For instance, the scanning is done to visually select landmarks and routes and Marchionini's navigation is following a route determined in the information processing phase of wayfinding.

### 3.1.3 Information Foraging

Card et al. (2001) created a theory called the "Information Foraging Theory" for how sighted users search for information. This theory states that people information seek using "information scents" similarly to how animals search for food (Takagi et al, 2007; Juvina & van Oostendorp, 2008). This process involves determining the significance or relevance of information or scent compared to a goal.

Websites provide cues to indicate if users are close to the desired destination or information. These visual cues can exist in the main content, links, headers, images, etc. Takagi, et al. (2007) performed a study to test if this theory worked for users who are blind for information seeking. They used the IBM Home Page Reader (HPR) and, at the time of the study, it was the most prominent screen reader in the area tested. No pre-test or prior training was administered prior to the experiment. The IBM HPR screen reader commands are slightly different compared to the commands used in JAWS which today has more advanced commands. The main commands for the HPR screen reader at the time of the study included methods to advance 1 or 10 lines of data. Takagi et al. (2007) described the information seeking strategies witnessed as "exhaustive" (one line at a time) and "gambling" (jumping 10 lines at a time). There was evidence of information scent when a user would start using the "gambling" method and change their strategy to "exhaustive" when the content started to appear related to the information they were seeking. Though Information Foraging is under a separate heading, it can be considered a type of wayfinding.

#### 3.1.4 Other methods

Including additional modes as a method for providing more information to users that are blind has also been researched. Kuber et al. (2007) used haptic tactile feedback to create landmarks to assist users who are blind with spatial orientation. Kuber et al. (2007) were able to map some feedback to page elements. Kuber et al. (2007) did not theorize on the selection of elements chosen to be haptic and if they assisted with information seeking. Rotard, Taras and Ertl (2008) created a tactile browser that converts webpages to display on a tactile pad. Though many graphics on a website may not aid in information seeking, this tactile pad is able to show tables, mathematics, as well as maps. This tool has many applications for electronic learning systems. It may not improve information seeking since the entire website must still be parsed.

A haptic mouse with additional non-speech audio was created by Yu, Kuber, Murphy, Strain and McAllister (2006) to provide panning of the website. This device was also used to provide spatial information to the participants who were blind. At the conclusion, few of the participants who were blind were able to describe the spatial layout of the website. Donker, Klante and Gorny (2002) also attempted to use audio to provide spatial and layout information. Subjects interacted using a joystick and loudness varied to indicate spatial information for webpage attributes such as headers, paragraphs and tables. The results were not better than the baseline condition of viewing the website with a screen reader only. It was discovered that visual cues that indicated association of information such as color and font were not being conveyed by their system.

Auditory earcons (Roth, Petrucci, Assimacopoulos & Pun, 2000) have been used to create a 3-D environment in which the sounds help with location while using a touch tablet. Each sound was mapped to a HTML feature. This was designed to assist users who are blind to create a mental model of the spatial layout of the webpage. The tool was not tested for information seeking tasks.

Walshe and McMullin (2006) created a WebTree Browser that created a hierarchical version of the website, but required accurate coding of the original website. The original website needed to be accessible to allow proper creation of the tree.

Hillen and Evers (2007) created a second, separate interface window to enable users who were blind to learn about a link before it was selected. It was believed that this information would assist the users in building a mental model of the entire website. However, the results of the study indicated that a second interface was confusing and the participants were not interested in building a mental model of the whole website.

Research has been conducted to provide support for individuals who are blind who are seeking information on websites; however, the research has not provided a satisfactory solution. The users' strategies may have changed recently since screen readers have continued to add new features that allow advanced searching through the website instead of line jumping. It is unclear whether continuing the current research approaches will solve the problems given that they have only provided very slight improvements. There may also be a general lack of understanding of how a user who is blind seeks information on a website. Adding modality may be a solution, but it is unclear what modality and what information to provide. Experiment one was conducted to gather more information to address these issues.

#### 3.1.5 Ecology

Up to this point, mental models have been mapped directly to the interface design. Since mental models are built from previous experiences, a website should be designed to expand on those experiences. Applying previous strategies to new experiences is what Peirce (cited by Bennett & Flach, 2011) defined as assimilation . Obviously, a designer cannot design an interface based on one specific mental model. The goal would be to design for best case mental models that represent all the "collective knowledge" (Bennett & Flach, 2011) about the ecology or situation.

To further that line of thinking, Peirce introduced a model that added ecology to mental models and interfaces (cited by Bennett & Flach, 2011). This triadic model in Figure 4 represents the importance of the ecology or situation on the actions of the user. Not only is the mental model important but also the ecology or situation in which the user is performing. The inclusion of ecology in the design of interfaces was defined by Bennett and Flach (2011) as "work context matters."

The triadic model uses Pierce's description of abduction (1931-1935, cited by Bennett & Flach, 2011) on how people learn a system or develop a mental model by using it. Expectations of the environment are made based on past experience and only changed if the environment responds differently than expected. The environment is experienced through the person's actions. Using Peirce's model of abduction, the goal of an interface designer would be to allow users to apply their previous strategies to the new interface and reduce the need to modify their expectations. In summary, maximize the assimilation and minimize the accommodation. Since accommodations are made through trial and error learning, providing a method to teach the interface can also reduce accommodation (Bennett & Flach, 2011).

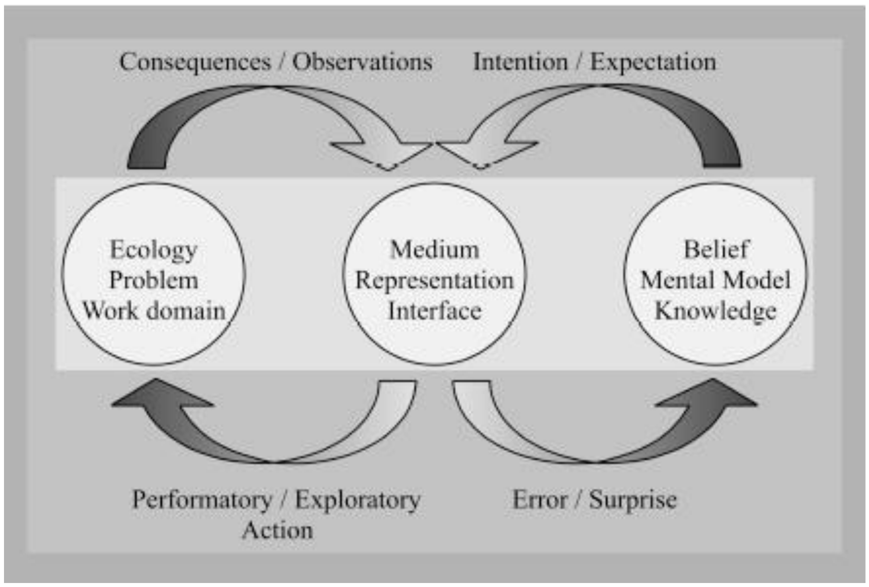



Figure 4. Triadic model of abduction (Bennett & Flach, 2011).

Gibson (1977, cited by Bennett & Flach, 2011) used the term affordances to explain the opportunities for learning an environment provides. This can also be applied to interface design as the opportunities the interface provides for the user. Therefore, the ecology or environment can provide opportunities, but the user needs to be able to recognize or interpret them. One way to achieve the most success with affordance recognition is to design a website that can present information in many ways to allow different interpretations. The objective of an interface is to encourage successful interactions and expectations (Bennett & Flach, 2011). Bennett and Flach (2011) defined the role of a designer is to “build representations so that the interpretations of the operators using those representations will correspond with the meaning in ecology." In other words, "guide successful action" (Bennett & Flach, 2011).

## 3.2 Experiment One Method and Results

Experiment one was conducted to gather more information on the techniques and strategies used to search for information within websites for users who are blind and sighted. The current version of screen readers (JAWS v10) and current websites were used in this experiment. The observations from this experiment were used to propose a descriptive model for information searching on websites.

Experiment one conducted basic tasks on a local banking website (Wright-Patt Credit Union), a shopping website (Amazon.com) and a website of the users' choice. After each task a spatial layout question was asked. The spatial questions were asked to determine whether a basic spatial layout was learned while using the website. The first two tasks (Q1 and Q2) were performed on the Wright-Patt Credit Union (WPCU) website. The tasks included finding particular information such as an interest rate. The third (Q3) task was performed on Amazon.com and involved locating a book on the New York Times Bestseller list. The final task (Q4) asked the user to demonstrate information seeking on a website in which they were familiar.

Three participants who were blind in experiment one were considered high functioning JAWS users and were assessed using the Usability Proficiency Assessment Tool (Shebilske, Ganesh & Narakesari, 2008). This tool was used to assess the knowledge and website experience of the participant. This allowed the participants to be categorized by skill strength and not by subjective measures. This assessment allowed participants from experiment one to be compared to three users who are blind in a study conducted by Shebilske et al. (2008) and also discussed in Shebilske, Narakesari, Alakke, Douglass and Faulkner (2009). Shebilske et al. (2008) tested the accessibility of an insurance website for performing information seeking tasks.

Five people who were sighted were also observed in the information searching tasks in experiment one. The spatial questions were conducted by asking participant to point to section of website in which they believed the information was located.

Many researchers believe that providing more spatial information for users who are blind will improve their information seeking and further develop their mental model, especially when wayfinding. Though spatial information may be useful for viewing maps, images and tables, it has not proven to be significantly useful for information seeking. However, in experiment one, users who are blind were aware of the spatial layout of a website and could guess the region of the website in which the data were located. Though the users who are blind had spatial knowledge, they felt it was not useful to them in information seeking.

Similar to findings by Takagi et al. (2007), the participants who are blind primarily used a small number of commands to information search on a website. These few commands are considered the primary search strategies (PSS) and are listed in Table 1. The PSS's are considered the favorite methods to conduct information searches. They include commands for listing the links, listing the headers, site search, virtual find and Google. The PSS's for sighted users included the site search, virtual find and Google and the visual scan. Google was mentioned and demonstrated in the 4$^{th}$ task (Q4) by the participants in each group as a tool they commonly used to search for information on their favorite website.

Sighted users started their search 65% of the time with a visual scan of the homepage. That did not always include the bottom part of the homepage that was not visible on the screen. This visual scan is considered a PSS based on comments by participants using a think aloud method as they were completing the tasks. These comments indicated that the users were visually scanning the website for information. Only after a PSS was completed were other commands attempted.

For the purposes of experiment one, Google was classified as a PSS. Even though it is most commonly used as an Internet search engine, participants used it to go directly to the data they were searching within a specific website. It could also be considered a hybrid of the site search and virtual find.

**Table 1: Primary Search Strategies (PSS)**

| Blind | Sighted |
|---|---|
| Ctrl F -Virtual Find<br>Insert F7 -Links list<br>Insert F6- List of headers<br>Site Search<br>Google | Ctrl F -Virtual Find<br>Site Search<br>Google<br>Visual Scan |

The PSS's are commands that are favored and used first or most prominently in a website information searching task. Insert F7 is a command that produces a pop-up box that lists the links on a webpage in the order they appear. A user can read through all the links but the most common method is to use a shortcut by typing in a letter that will jump the cursor to the links that start with that letter. All participants in experiment one and the Shebilske et al. (2008) study used a shortcut when using the Insert F7 command. Basically, the user is selecting a keyword and using the first letter to see if the keyword is located at the start of a link on the webpage. Insert F6 works similarly to Insert F7 but the list consists of headers instead of links. Ctrl F is the virtual find and produces a pop-up text box in which to type a keyword and then searches for matches in the contents of the present webpage. For sighted users, this command will initiate the browser to highlight each keyword found on the webpage. For the user who is blind, this function can read the first match and a previous match but another command is required to further search the rest of the webpage for matches. A site search refers to the search text box that is present on a webpage that allows the user to search the entire website and is maintained by the website owner.

It was also observed that there was a favored PSS by the participants who were blind (Table 2). Insert F7, the command to list the links on the webpage, was used first 64% of the time to perform an information search.

**Table 2: Most common PSS to use first when information searching for blind participants**

| PSS | Present Study Participants (blind only) | Shebilske et al. (2008) participants (blind only) | Percentage used 1st |
|---|---|---|---|
| Insert F7 | 5 | 9 | 14/22 = 64% |
| Ctrl F | 1 | 5 | 6/22 = 27% |
| Site Search | 1 | 0 | 1/22 = 4.5% |
| Google | 1 | 0 | 1/22 = 4.5% |
| Insert F6 | 0 | 0 | 0 |
| **Total** | 8 | 14 | 100% |

A binomial test was conducted using a coin flipping metaphor to test the hypothesis that the probability is equal for a user to start with a secondary search strategy or a primary search strategy. A secondary search strategy is any other strategy the participant may know and attempt when their primary strategies no longer work. The second hypothesis (H02) tests the data from the Shebilske et al., (2008) study using the same hypothesis. The null hypothesis, that primary and secondary search strategies are used equally was rejected for both studies. These results are summarized in Table 3.

Table 3: Binomial Test Results for Hypothesis

<table>
<tr><td colspan="5">H01: Chances are equal that a user from either group will start with a primary search strategy or a secondary search strategy for experiment one.</td></tr>
<tr><td>Probability of Success</td><td>Trials</td><td>Successes: B before C</td><td>Resulting p-value (two-tailed)</td><td>Conclusion</td></tr>
<tr><td>.50</td><td>31</td><td>29</td><td>p<.0001</td><td>Reject H01</td></tr>
<tr><td colspan="5">H02: Chances are equal that a user will start with a primary search strategy or a secondary search strategy in the Shebilske et al. (2008) study.</td></tr>
<tr><td>Probability of Success</td><td>Trials</td><td>Successes: B before C</td><td>Resulting p-value (two-tailed)</td><td>Conclusion</td></tr>
<tr><td>.5</td><td>35</td><td>34</td><td>p<.0001</td><td>Reject H02</td></tr>
<tr><td colspan="5">H03: Sighted and Blind groups behave differently (using both studies data).</td></tr>
<tr><td>Sighted</td><td>Blind</td><td colspan="2">Resulting p-value (two-tailed)</td><td>Conclusion</td></tr>
<tr><td>20/20</td><td>18/20</td><td colspan="2">z=0.7 and p>.05</td><td>Fail to Reject H03</td></tr>
</table>

The third hypothesis (H03) test determined if the sighted and blind groups behaved differently. This test combined the data from both studies (Experiment one and Shebilske et al., 2008). Results of this test were not significant, therefore the null hypothesis and the concept of differences between the groups was not rejected. Future research with additional data is needed.

The PSS that are currently in use today as illustrated by this study are different from previous research findings of random skipping of lines as demonstrated in Takagi, et al. (2007). Users who are blind and sighted now use strategies similar to a search engine such as Google in which keywords are used. The commands that are listed as the PSS are the first, most commonly used search strategies but they are also significant because they all require keywords. Visual scanning is considered a keyword search based on the comments made by participants such as "I can't seem to find it (New York Times Bestseller)" and "I knew the value was 7% so I was looking for a 7 on the page." Research conducted by Liu (2005) discovered that one of the reading styles used most often on webpages is browsing and keyword spotting. Though the participants mentioned some keyword spotting during the think aloud section of experiment one, it is difficult to determine if only keyword spotting is occurring or if orientation or other browsing techniques are also being performed.

Both groups indicated that knowing the correct keyword is important in their information seeking strategy. For instance, if a user is trying to find the contact information for a company, they might use the Insert F7 command to get a list of links on the page then use the shortcut "C" to find the "Contact us" link. The user will look through all the links that start with a "C" but will not be able to find the contact information immediately if the website names its link "About us." Since the PSS used by both groups are keyword based, guessing the correct keyword is critical to ensuring the information can be found quickly and efficiently.

Users who are blind used the PSS's 68% of the time as their first command on entering a website regardless of whether the task is considered orienting or not. The PSS were used first 92% of the time when general orienting commands were eliminated. This suggests that the PSS are commonly used upon entering a website.

Sighted users started with a visual scan 65% of the time. For the two participants that used the visual scan first, both used another PSS next. The participants that used a PSS as their first command and were not successful resorted to another PSS second.

### 3.2.1 Information Seeking Proposed Model

To model the information searching strategies of users who are blind and sighted, a flowchart was created based on the results from experiment one data (Figure 5.) The purpose of this flowchart is to establish a preliminary descriptive model that future research can refine. The number of participants for experiment one was three which is too few to develop a definitive conclusion; however, significant observations were made that can lead the future research in this area. The observations captured in this flowchart are the behavior of users who are blind beginning their information search with a PSS after some general orientation. If the first attempt to find information with a PSS is not successful a user may try another PSS before progressing with a secondary search strategy. All of the PSS's involve the use of keywords.

Sighted users have the same tendencies to begin an information search with a keyword based PSS. The underlined data in the flowchart in Figure 5 defines differences for sighted users.

The flowchart is divided into three sections. Section A captures the general orientation navigation process conducted by users. This navigation is defined as moving around the page such as traversing a table or a form. For sighted users this would include commands such as a "tab" to move from one form field to the next. Visual scans provide some initial orientation for sighted users. It is difficult to determine how much of the visual scan is considered orientation since many of the comments by the participants insinuated searching for data. For users who are blind, this process includes listening to the website, using the "H" header command, to read a few headers and the up and down arrows. Francis Robinson created a method, SQ3R, for determining the basic idea in reading material (cited by Flemming, 2008). The first step is to survey the material by reading headers or other summary type materials. Commands in JAWS such as "H" for reading the headers are included in the general orientation section because of this similarity in surveying. These commands tended to be the first commands completed when the webpage opened or after a search brought the user to an unknown location.

Section B of Figure 5 is the PSS section in which users tend to use a keyword command to start their information search. A PSS is selected based on which strategy the user prefers. If it is their first visit to a website, the initial listening may assist in deciding if their preferred strategy will work for this website. Users who are blind progress with the PSS they are most comfortable using and only change that strategy if the strategy will not support their information search. Sighted users must also determine if their preferred strategy will work on the particular website. It appeared sighted users change their strategy less often than users who are blind mostly because they are successful more quickly.

Section C of Figure 5 contains the secondary search strategies used when both groups are unsuccessful and have already tried their PSS's. Secondary strategies are any other command they may know and is analogous to 'throwing the kitchen sink' at the website. These strategies are often less efficient and include reading through the entire website line by line. Only the users who were blind mentioned they would resort to calling for assistance if they were unable to successfully find the information. Experiment one did not force sighted users to progress much beyond their first two commands or use a secondary search strategy since they were successful at finding the information with the PSS's.

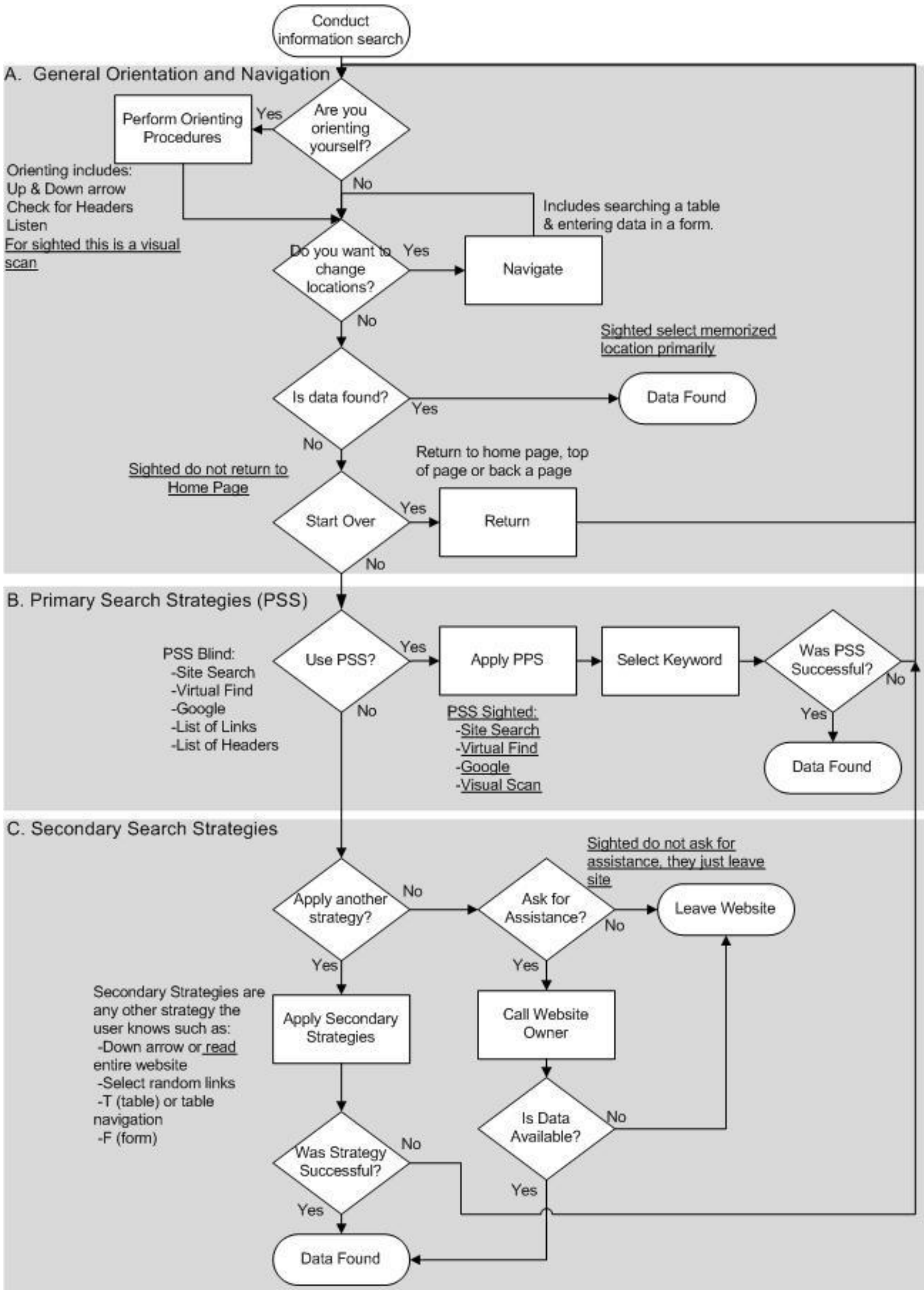



**Figure 5. Web-based information seeking model. Underlined data indicates difference in users who are sighted.**

To validate the web-based information seeking model, the Shebilske, et al. (2008) study task data which was conducted on an insurance website were used. A total of three users who were blind used JAWS to conduct up to 6 tasks per user. To summarize, three participants from experiment one conducting 4 tasks per participant were used to create the model and three participants from the Shebilske, et al. (2008) study performing up to 6 tasks each were used to validate it. Not all participants in the Shebilske, et al. (2008) study completed all 6 tasks due to time limitations. Experiment one and the data from 15 tasks in the Shebilske, et al. (2008) study were used to validate the model. If a user's information seeking commands flowed through the model, it was determined to fit the model. All of the tasks tested flowed through the model. Sighted users tasks were also fit in the model but rarely progressed to Section C of Figure 5 before data were found and the task completed. Data was not available to validate this model for sighted users.

The search strategies used in experiment one and the Shebilske, et al. (2008) study provided little to no contextual information to the user. This provided little opportunity for the participants to determine the scent of the information they were seeking. One could consider selecting a relevant header or link a method of making the scent stronger even though the intent was not to be closer to the data, but to reach the data. The users intended goal was to find the specific destination directly not to get closer to it. Since the intention of reaching the data directly was not always obtained, information foraging was demonstrated.

Wayfinding was also difficult to observe since few landmarks were mentioned by the participants. The PSS used did not provide paths or routes for the users to determine location and distance.

The prevalence of keyword based PSS's does provide an opportunity for interface designers to further enhance the use of keywords on a webpage. Words such as "the" and "a" in the beginning of headers and links interferes with shortcut searches done with the list of links or list of headers commands. One participant was asked to find a link for "The Phantom of the Opera." After searching links starting with a "P" and being unsuccessful, the user tried "F" thinking they may have misspelled phantom and then discovered it was a "T" that they needed to use.

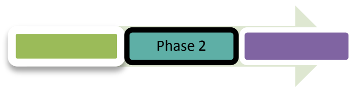
Indicating the context of every link would also assist users who are blind. While searching for an insurance agent, a participant was forwarded to a link for "I am an insurance agent." This context was not expected and confused the user.

Information that designers believe is important tends to be highlighted and displayed to catch sighted users attention. This information can be obtainable to users who are blind if it is displayed in a method in which they can search, for instance, in headers or links. Both groups tended to use the first, most prominent link or header found. The banking website used in this study had a marketing name for its savings account and when it was not spelled correctly or the word "savings" was used, incorrect matches appeared and made the search much more difficult. Though their savings account name is catchy it was not searchable to users who were blind. However, sighted users were able to discover the savings account information based on the surrounding context.

In summary, experiment one illustrated two future research objectives for information seeking for users with and without sight.

Objective 1: Creating a tool to assist users with keyword strategies.

Objective 2: Refine the web-based information seeking model for both groups.




# 4. Phase 2: Build KEYS and Prototype

## 4.1 The Problem

Websites are difficult to information search if they do not perform as expected based on a mental model and ecology relationship. Experiment one showed differences in times to complete a task for users who are blind and those who are sighted. User who are blind took anywhere from 2 to 42 times longer than sighted users. Currently research offers slight improvements and is has been quickly outdated with the advances in screen reader technology. Experiment one determined that information seeking on websites starts and progresses with the PSS's, which are keyword based. Based on the information seeking model's Section B of Figure 5, PSS's are the favorite method to search for information on a website for people who are blind and sighted. The weaknesses in these methods are the requirement of selecting an accurate keyword or discovering the correct keyword.

Phase two involves developing a keyword based conceptual model to support information searching described as objective one previously. The conceptual model, called the Keywords Expected for Your Search (KEYS), will be defined and implemented in a prototype. Using Peirce's model in Figure 3, KEYS uses the idea of the "collective knowledge" (based on Peirce, 1931-1935, cited by Bennett & Flach, 2011) to support keyword based searches in order to maximize assimilation, increase affordances and minimize accommodation. The KEYS will attempt to overcome the keyword placement issues in links as well. In Phase three, the KEYS prototype will be evaluated.

## 4.2 KEYS

The KEYS is a conceptual model that includes rules and a keyword library as demonstrated in Figure 6. Specifically, KEYS includes a set of rules for enhancing success with the PSS's by adding contextual information, changing keyword placement, misspelling support and adding keywords such as knowledge-based domain keywords, synonyms and web equivalent words stored in a library. Increasing the appearance and number of keywords on the webpage will increase the affordances or opportunities for success by the user.

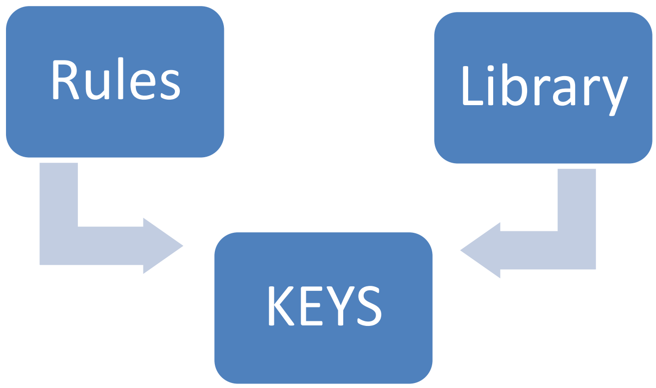



**Figure 6. KEYS Conceptual Model.**

A KEYS prototype was developed to evaluate the KEYS concept. This prototype was incorporated into the code of the open source screen reader, NonVisual Desktop Access (NVDA) that was adapted to emulate JAWS. The KEYS prototype manipulated the results of the screen reader when the participant used two of the more common PSS's (listing of links and virtual find). This prototype was hardcoded to display results following an interpretation of the KEYS rules. The description of how each rule was interpreted and implemented is described in the next section.

A physical library was not produced, however, a virtual library comprised of a synonym program (WordNet 2.1 by Princeton University), a text file for adding expected words (NVDA webpage text file), and a text file to make equivalents (Search Keyword text file) was created.

The NVDA screen reader was initially programmed to emulate JAWS. NVDA was already similar to JAWS but to ensure an easy adjustment for JAWS users, the NVDA screen reader was changed further. The virtual find command was slightly different requiring an Insert Ctrl F command. There is a JAWS find command that uses these three keystrokes so it was easy for the participants to adjust to this change. For the purposes of this document, the virtual find will still be addressed as Ctrl F to eliminate any confusion.

### 4.2.1 The KEYS Rules

There are seven rules that comprise the conceptual model of KEYS. Each rule is explained followed by how it was implemented in the KEYS prototype.

#### *4.2.1.1 Rule 1: Provide contextual information for keyword searches*

Several of the PSS's lack contextual information when they are performed. For instance, Ctrl F is the virtual find command that requires a keyword to be typed into a text box. The browser searches for a match to that word on the current webpage and will highlight the word. A sighted user can visually scan the surrounding area to determine the context. A user who is blind will have to select each occurrence of the word and listen to the surrounding words to determine if that occurrence of the word is appropriate. Likewise, the Insert F7 list the links command on a webpage but does not mention where the link may exist on the page or under what header or subject it is located. Surrounding information will be evaluated and added to the results of a search to provide context for keywords in links or on the webpage. For instance, if "agent" is put in a virtual find of an insurance website, information about whether the word "agent" is in the "select an agent" header or "Becoming an agent." This analysis for determining context will consist of the following three methods: category or header association, visual separations, color groupings and keyword location.

##### 4.2.1.1.1 Category or Header association

Category or header information located near the keyword will be included in the search results. Interfaces that include category information in their searches were proved to be more effective than other methods of displaying search results in a study conducted by Drori and Alon (2003).

##### 4.2.1.1.2 Visual separations from surrounding area

Visual groups are described as Way Edges by Yesilda et al. (2008). They are space, lines or blocks that group information together. Designers tend to group similar items together (Nielsen & Tahir, 2001) with white space indicating the separation (Thissen, 2004). Thissen (2004) claims that items that are close to one another are “perceived as belonging together” according to the Law of proximity in website design. The Proximity Compatibility Principle defined by Wickens and Carwell in 1995 (cited by Rothrock, Barron, Simpson, Frecker & Ligetti, 2006) suggests that items that pertain to the same task should be located physically close together. Additionally, when words appear near the searched information, it is assumed to be in the same context (Song & Broza, 2003). Sighted users can take advantage of websites that group similar items with the same font size or color. Relating the word to its immediate surrounding is not easily done by users who are blind. Keyword searches with a screen reader list all occurrences of the word but do not relate any contextual information about the information around the word. Search performance improves when contextual information is added to the search (Moskovitch & Shahar, 2009). The difference in the information seeking behavior of users who are blind compared to sighted users may be caused by the lack of context information (Bigham, Cavender, Brudvik, Wobbrock, Ladner, 2007). The context of this visually grouped information can be provided in the results of keyword search strategies to enhance the keyword meaning.

##### 4.2.1.1.3 Color groupings

Similar to the method of grouping information using physical lines or white space, color also demonstrates similarity in information. Thissen (2004) describes the Law of Similarity as grouping items which look as though they belong together. This is primarily accomplished with colors so items appear visually similar.

##### 4.2.1.1.4 Attribute knowledge

Contextual information does not have to be limited to the information surrounding the matched keyword but can also describe the match itself. For instance, knowing if the keyword match is found in an image description or a link can assist the user in deciding if that keyword is the one they want to select. These all combine to form the first rule of the keyword framework.

##### *4.2.1.1.5 Rule 1 implementation in the KEYS Prototype*

Contextual information was supplied in two ways. The first method involved the virtual find (Ctrl F) command result. In JAWS or the NVDA screen reader, a virtual find command provides a text box for the user to input the word they wish to search. The first match of the word is read and the user can proceed to the next match with a new command. This technique requires the user to listen to each match one at a time. In the KEYS prototype, the virtual find command produces a pop-up box after the searched word has been entered by the user. This pop-up is similar to the list of links (Insert F7) pop-up. It allows the user to hear about each match prior to selecting one. The prototype indicates how many matches were found on the page and the number of the match selected by the user out of the total. Context information is provided by indicating if the matched word is a link, combo box, image, text or another HTML attribute. The attribute is displayed before the link name in the result list. For matches that were found in a link, the word "link" was indicated in front of the listing. Combo boxes displayed the word "combo"; images displayed "image" and text matches were left blank. Listing the attribute information of the matched word provides more information to the user. Many times a user is on the page they believe the information they are seeking is located but accidentally select the link option and move from the page. The user could select the match that has a text attribute to ensure they would stay on the current page.

The second method used to provide contextual information of the searched word is to use the phrase "-under." The "-under" phase follows the link name. More information about the link is located after the "-under" phrase. The format is as follows: *link name* –under *significant text located above link*. For example, the banking website has several links titled "Learn More." These link names are not informative to the user because they did not indicate what one could learn more about. One of the

"Learn More" links was located under bold text, "New Website."   The "-under" phase was added to the end of this link to provide more information and now reads as "learn more –under New Website." Providing this information allows the user to decide if the link is valid for their information search.  This method was used for links only and appeared in links that were in the results of both the virtual find and list of links commands.

##### *4.2.1.2 Rule 2: Make the first word in a link or header the keyword or most significant word in the phrase.*

For keyword searches that involve headers and links such as list of headers (Insert F6) and list of links (Insert F7), the keyword shall be the first word.  The first letter of the first word is searched with shortcuts when a user types in one letter to jump to the next occurrence of a result that starts with that letter.  Since these shortcuts are applied to the keyword based search methods, the first word of the header or link is the only one searched.  Rearranging the presence of keywords in a header or link may create a successful search.  Headers or links that start with "the" or "a" are difficult for users to search with shortcuts as described in experiment one when a participant was searching for "The Phantom of the Opera."

###### *4.2.1.2.1 Rule 2 Implementation in KEYS prototype*

Links were added to the results list that rearranged the words to provide the more significant word first.  This ensured the link would be easier to find when the user searched using first letter shortcuts.

##### *4.2.1.3 Rule 3: Eliminate meaningless information from link descriptions.*

Screen readers will default to the name of the image or link if website designers do not add alternative text.  For instance, an image may have the name, "images/logo.gif", and that name will appear in the results of a list of links command (Insert F7) on the webpage.   The name of the image," logo.gif", may be useful but the path information ("images/..") makes reading the link tedious and unsearchable using shortcuts. Eliminating the unnecessary path information from the link description will allow users to perform searches on the relevant information.

###### *4.2.1.3.1 Rule 3 Implementation in KEYS prototype*

The KEYS prototype created an additional link that eliminated the unnecessary path information. This new link was added to the results list for both the virtual find and the list of links commands.

##### *4.2.1.4 Rule 4: Provide keyword enhancement without changing the overall configuration of the original website*

Some researchers have replaced the original website with an adapted website such as Semantic Web (Harper & Bechhofer, 2005) which adjusted their augmented page by using XHTML and CSS coding. These adaptations can create a website that is very different from the original website. Changing the webpage focus with a new webpage pop-up is shown to cause confusion and frustration (Lazar, Allen, Kleinman & Malarkey, 2007; Hillen & Evers, 2007). Therefore, the adaptations made for KEYS will be made to the original page and cause minimal change in the basic layout or structure of the website. The keywords can be added to links or headers that are not seen on the visible page but are included in the HTML code and/or can be added visually.

###### *4.2.1.4.1 Rule 4 Implementation in KEYS prototype*

Keywords were added to the results of the virtual find and list of links commands to ensure the integrity of the original website. These additional keywords in the results pop-up do not change the format of the original website and prevent any confusion additional words distributed on a website might cause.

##### *4.2.1.5 Rule 5: Expected and knowledge based keywords from the library will be added to the website to support common tasks on the website*

Consistency of keywords and actions is part of Shneiderman's eight golden rules for interface design (Shneiderman & Plaisant, 2005). According to Narayanan et al. (2000), opposing terminology between the designer and the information seeker prohibits successful seeking. Neilson (2006) also suggests using “keywords that match users’ search queries” since users are becoming more dependent on using search techniques. Websites may use some common words that have been accommodated or learned by the user when information seeking on the website. These words tend to be assumed present on other websites in the domain as well.

A survey was used to find the expected keywords that should be available for the tasks conducted on each domain website. In the present research, a banking and an academic website was used to evaluate the KEYS prototype. The specific tasks are typical tasks performed on the website. The survey helped determine what keywords are expected while performing the specific tasks for the banking and academic website. KEYS adds these keywords to the website to assist in performing the specific tasks when using keyword based search strategies.

###### *4.2.1.5.1 Rule 5 Implementation of KEYS prototype*

Each webpage had an accompanying NVDA Webpage text file that was read to produce the search results. In this text file, the expected words gathered from the survey were added to a link. For instance, a link that was titled “interest” would also have words such as “dividend “or “rates” that pointed to that same link. In the results list these words would also appear with the link “interest” so the user would have many options to select the same link. These words acted as a road map to finding the information the user was seeking.

##### *4.2.1.6 Rule 6: Add words that are synonymous or considered web equivalent to keyword searches.*

A response to any keyword search can also be a word that is synonymous to the searched keyword. Users demonstrated attempting the same PSS with different keywords when their first attempt was unsuccessful. Returning a more complete list of results may ensure success with fewer commands. This would be similar to adding a thesaurus to every keyword search.

The WWW contains keywords that are considered synonymous but are not represented in a thesaurus. These include phrases such as "About Us" and "Contact Us." They are considered web equivalent since they can be interchangeable but may not mean the same in the English language. It is never clear which phrase will be used on a website. A user may conduct a search on the list of links on the webpage and types the shortcut key of "A" looking for the common term "About Us." If the website has "Contact Us", the search will be unsuccessful. If the phases are considered web equivalent, both phrases will be searched and the "Contact Us" link will display with the other "A" words in the result list. This may allow the user to be successful without having to try other possibilities, listening to the complete list or considering their search unsuccessful.

###### *4.2.1.6.1 Rule 6 Implementation of KEYS prototype*

In the virtual find search results pop-up, a window was created that displays synonyms to the word entered in the search text box. WordNet2.0 (Princeton University, 2010) was used to supply the synonyms. The results list appears as two windows; the top would be any exact matches and expected words that were also matched, the bottom window includes the synonyms. The bottom synonyms are labeled "Possible matches" and can be read by using the tab button. The prototype also indicates how many possible matches were found on the webpage.

##### *4.2.1.7 Rule 7: Include common misspellings of a word*

Checking for misspelled words and including any possible correct spellings in the search results may reduce the number of commands required to search for information. If a word is not found on the webpage, the library can suggest words or determine other words that are located on the webpage that are spelled similarly to the search term. One participant in experiment one indicated that spelling was sometimes difficult for users who were blind that used Braille. Braille contains truncated versions of words to reduce the space and typing required. This can cause the user to forget the original spelling since it is not used. This rule suggests determining if a word is close in spelling to another word located on the webpage and including it as a possible result.

##### *4.2.1.7.1 Rule 7 Implementation of KEYS prototype*

A basic spell checking algorithm was used to check that the word entered in a virtual find text box was correctly spelled. The aid would then search the website for variations on the word spelling and display those results as well.

## 4.3 Using the KEYS Prototype

The KEYS prototype implements the KEYS rules by manipulating the results of the virtual find (Ctrl F) command and the list of links (Insert F7) command. The process used to produce the results of a virtual find command is illustrated in Figure 7. The process begins with the user typing Ctrl F and a text box appearing to prompt the user to enter the word they wish to find on the webpage. Once the word is entered, the KEYS prototype checks the word for misspellings. The word is then sent to the WordNet dictionary file to find synonyms of the word. Synonyms are then searched on the webpage and the NVDA Webpage text file to see if any matches occur. The matched synonyms and their attributes are displayed in the lower window. The word typed is then compared to the NVDA Webpage text file and the Search Keyword text file that includes expected or equivalent matches. A NVDA Webpage text file (Figure 8) is created for each page and includes the renamed links and additional expected keywords. Words were also linked as equivalent in the Search Keyword text file. These types of equivalents used for the Wright-Patt Credit Union (WPCU) and Wright State University (WSU) Engineering websites are located in Table 4. The exact word and all expected and equivalents (words found in the NVDA Webpage and Search Keyword text files) were also searched for matches on the webpage and displayed in the results on the top window.

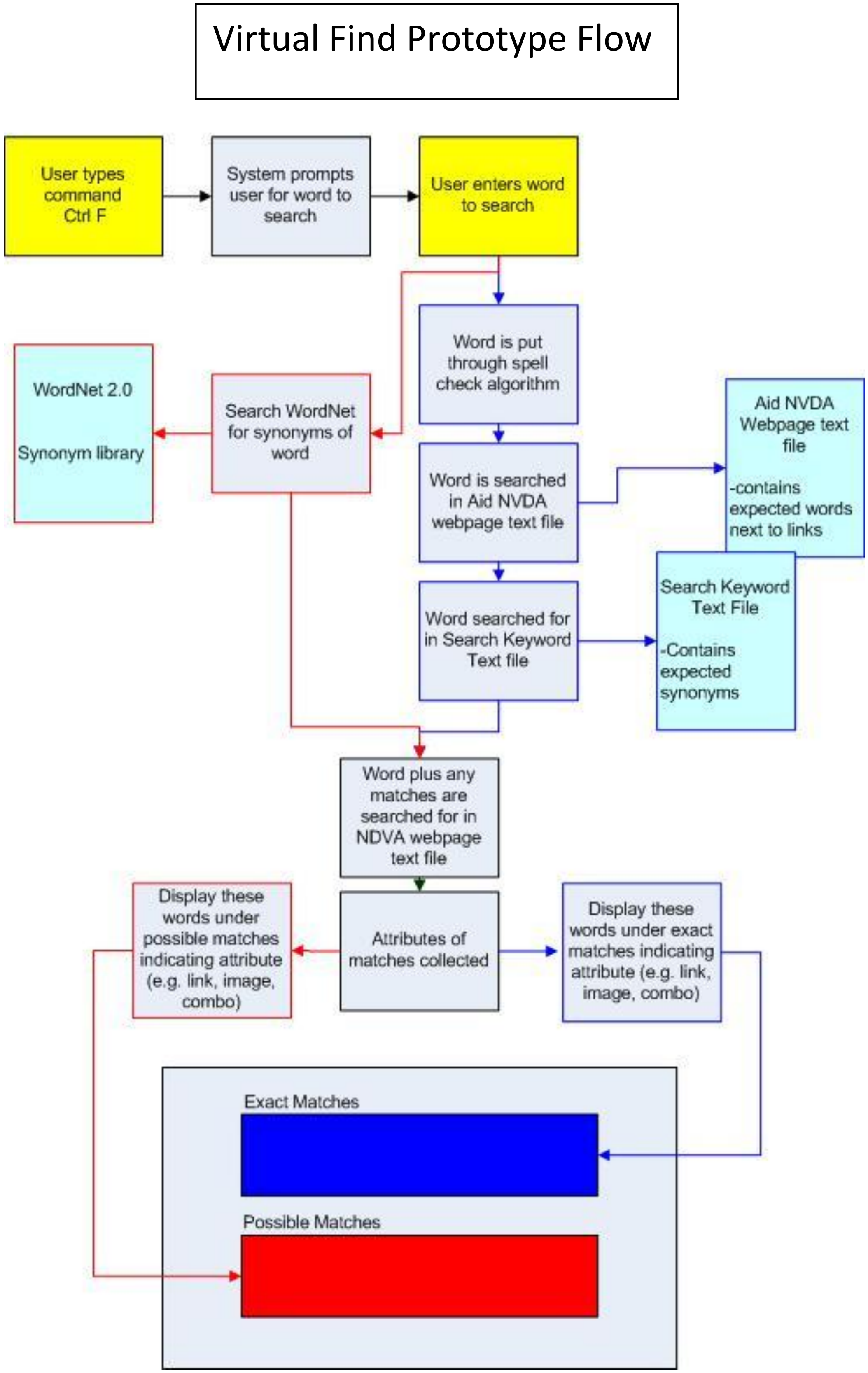



**Figure 7. Virtual Find Prototype Flow.**

The NVDA Webpage text file shows the name of the link and then after the "=" sign are the renamed and added expected words for the link.

```
Wright-Patt Credit Union
images/locations.gif=Locations
images/contact.gif=Contact Us
images/privacy.gif=Privacy
images/security.gif=Security
Wright-Patt Credit Union
images/careers.gif=careers
images/become_member.gif=Become a member
images/lev1_wphm_f2.gif=home
images/lev1_deposit_acct.gif=deposit account,routing number,savings,checkings,account,i
images/lev1_mortgages.gif=mortgages
images/lev1_auto_lend.gif=auto lend,Car loan,Loan for car,Forms for car,Used car financ
images/lev1_personal_loans.gif=personal loans
images/lev1_credit_cards.gif=credit cards,Visa,Mastercard,apply for credit card,forms f
images/lev1_invest.gif=invest
images/lev1_smallbiz.gif=small biz
images/hm_why_choose_off.gif=Why Choose WPCU
images/hm_about_off.gif=About WPCU
images/eligible%20button%20-%20off.gif=Eligible button
images/comm_outreach_off.gif=Community outreach
images/resource%20center%20button%20-%20off.gif=Resource center button
images/BRAC%20Inbound%20button%20-%20off.gif=BRAC inbound button
images/2nd%20member%20stories%20off.gif=Member stories
```

**Figure 8. NVDA Webpage text file.**

**Table 4: Words linked in the Search Keyword text file**

| Equivalents for WPCU website |
|---|
| Truesaver, Savings<br>Dividend, interest, rate, APY<br>Loan, credit |
| **Equivalents for WPCU website** |
| Grades, GPA<br>Admission, requirements, entrance, pre-requisites |

As described, the virtual find produces a text box for the user to type the word that they would like to find on the webpage. This text box then disappears from the screen. In JAWS and NVDA, the cursor points at the first occurrence of the word and the screen reader reads it. This is illustrated in Figure 9 where the word "savings" has been entered into the search text box. The box in Figure 9 indicates the first occurrence of the word "savings" and where the cursor will be located.

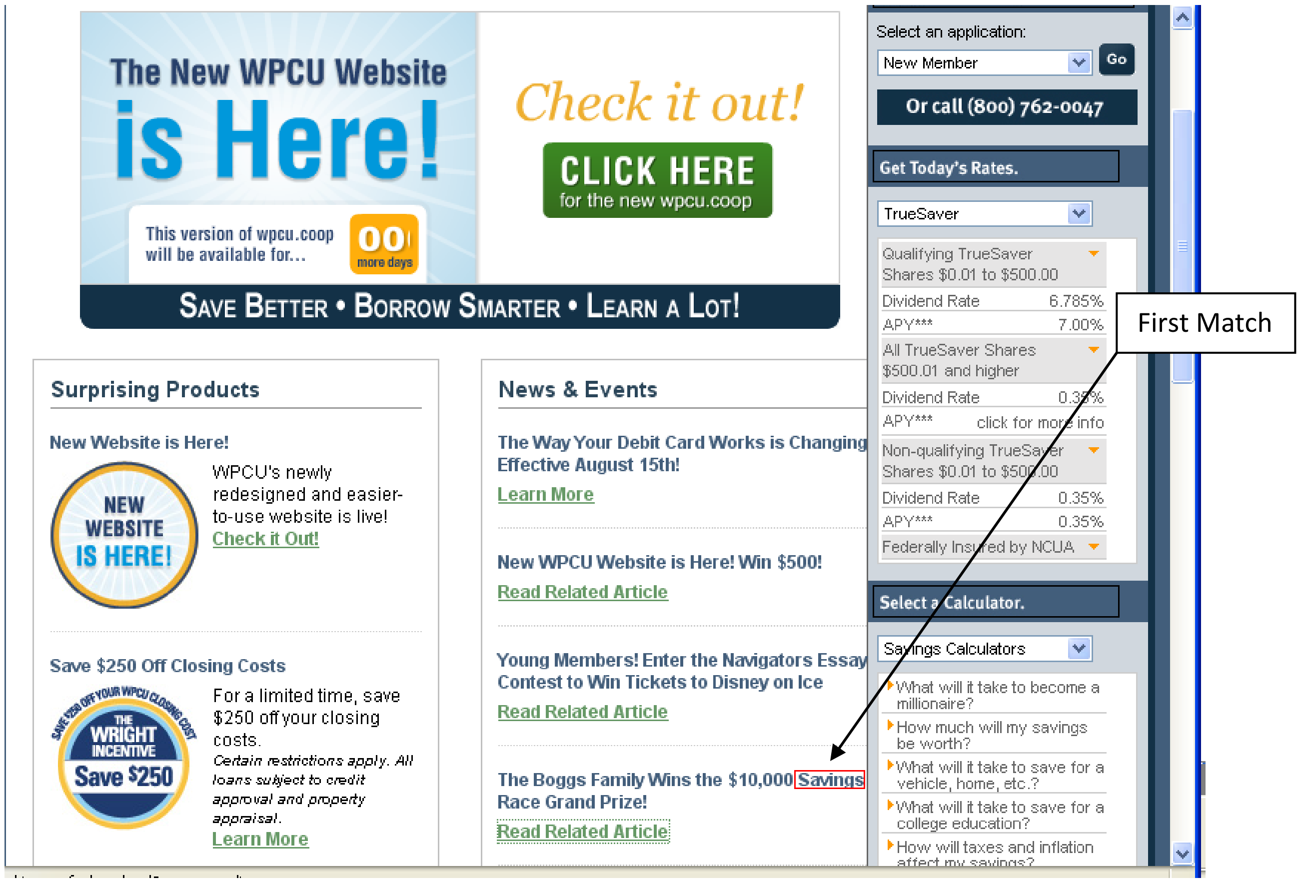



Figure 9. Virtual Find (Ctrl F) with JAWS or NVDA in which the word "savings" is being searched. The box depicts the first occurrence and placement of the cursor.

The screen reader will read the phrase in which the word "savings" was found. The user can type another command to jump to the next occurrence of the word on the webpage. The user will know when they have listened to all matches when they begin to hear the selections repeat.

As shown in Figure 10, the KEYS prototype works slightly different. The user enters the search word, in this case "savings", into a text box. The KEYS prototype presents the results of the search in a pop-up similar to the result listing for the list of links or list of header commands. As described earlier, the matched word and any expected words are displayed in the top window of the results pop-up. The number of matches is read to the user by the screen reader as well as the match number of the selected item as the list is parsed. The bottom window displays any synonyms to the entered word that appear on the webpage.

The results and the some of the rules that are shown in this example are indicated on Figure 10. Rule 1 is demonstrated by including the attribute information for the each matched words. The phrase "-under" is also used to show the context of the link. Rule 6 is the synonym listing on the bottom window and Rule 7 is the misspelling algorithm used prior to the listing of the results.

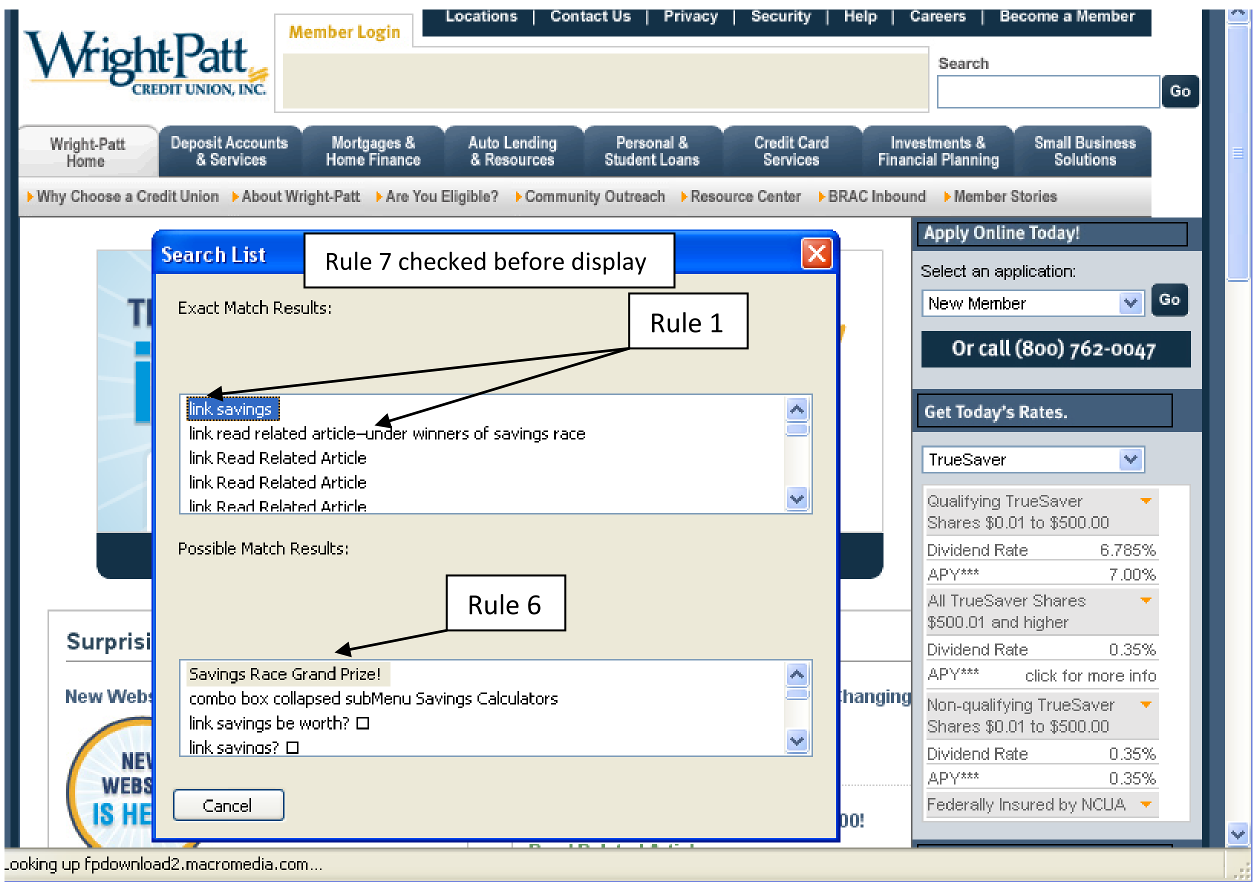



Figure 10. Virtual Find (Ctrl F) with the KEYS prototype when "savings" is being searched.

The list of links command follows the process flow illustrated in Figure 11. Once the user types the Insert F7 list of links command, results appear. The results include the actual links on the website and the additional links with keywords following the KEYS rules. These additional links that are added to the results list include the expected, equivalent and renamed links that point to the original link.

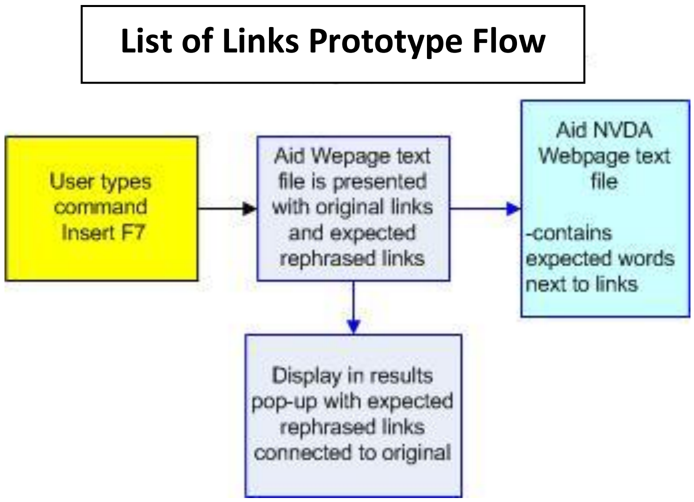



Figure 11. List of links prototype flow.

Figure 12 demonstrates a basic result pop-up produced when a screen reader such as JAWS or NVDA perform a list of links command. As described earlier, the WPCU webpage was not programmed to include alternative text so the screen reader listed the image names. The image names could be useful in determining information about the link if the path information was not present. For instance, the image name “locations.gif” is easily guessed to be about the locations. However, when the path name is included, “images/locations.gif”, the text becomes unsearchable using shortcuts and tedious to hear with a screen reader.

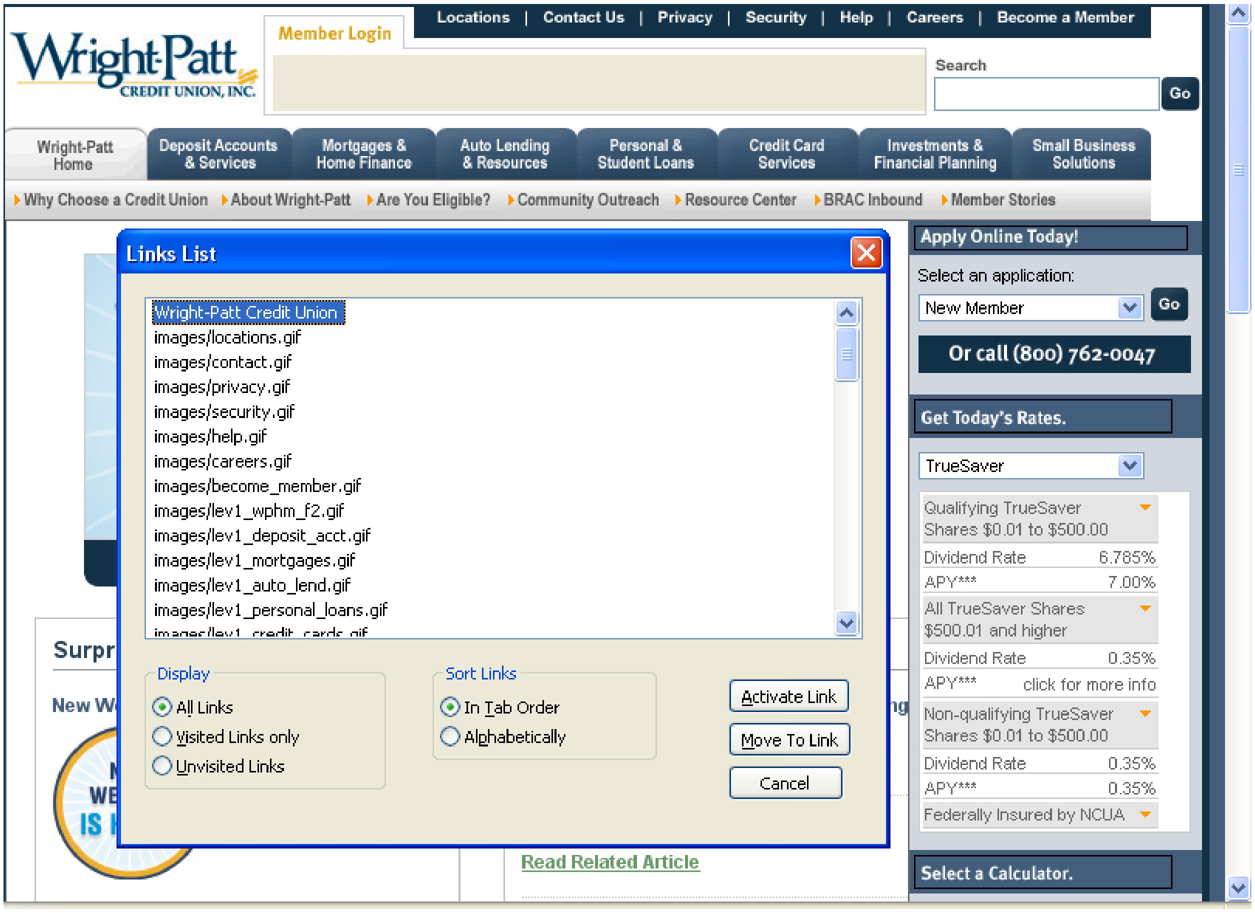



Figure 12. List of links (Insert F7) with JAWS or NVDA.

The KEYS prototype includes more links using expected, equivalent and rephrased links as seen in Figure 13. The original links are not eliminated; the prototype adds more links to the result list. The result demonstrates how several of the rules are implemented. Rule 2 rearranged the phrase “account interest” to read “interest for accounts” since “interest” is an expected word. The original website was not modified which follows Rule 4 in the KEYS. The path information was eliminated in the link named “images/lev1_deposit_acct.gif” by adding a new link “deposit account” following Rule 3. Since “deposit account” was not listed as an expected word, words such as “savings” and “checking” were added to the results that all link to the “deposit account” webpage. These additional words in the results follow Rule 5.

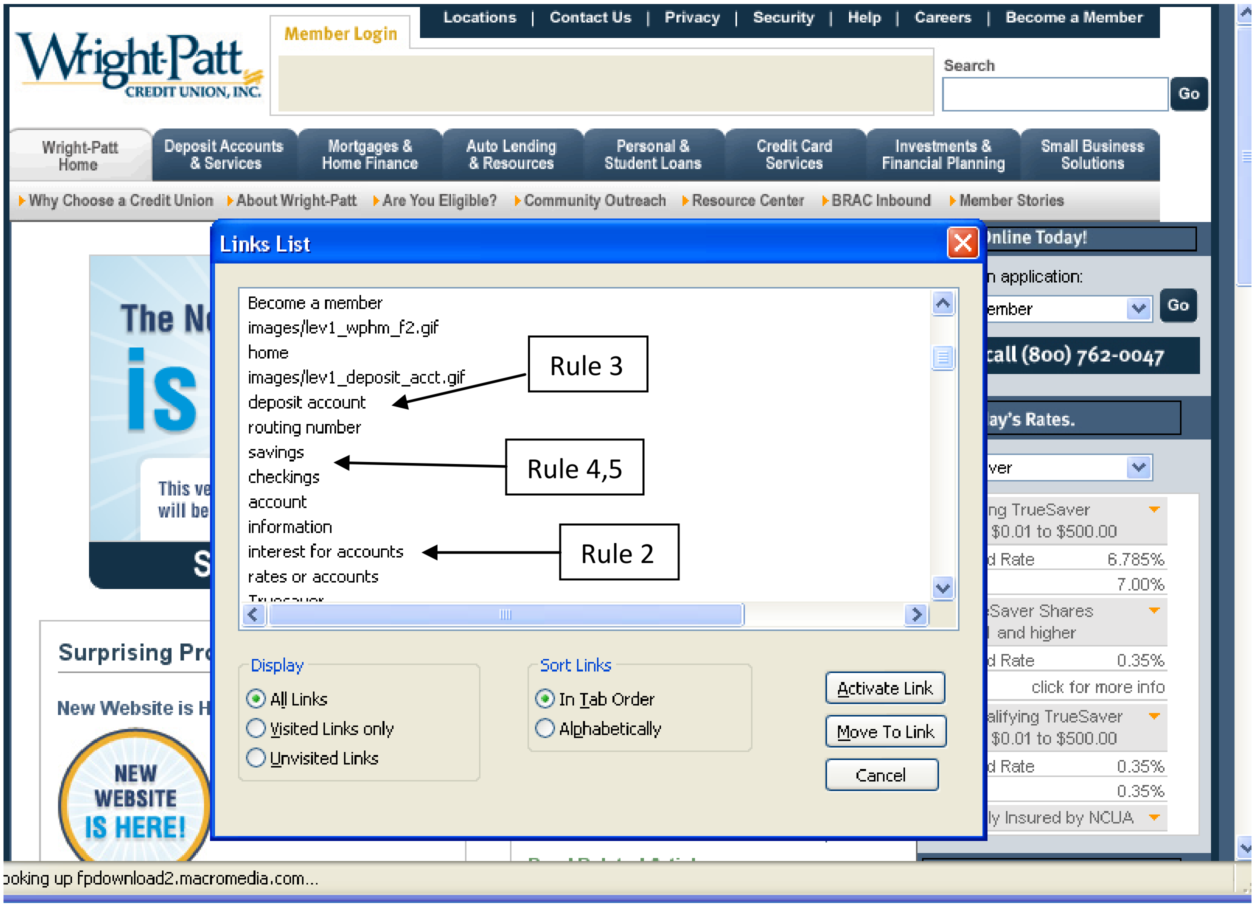



Figure 13. List of links (Insert F7) the KEYS prototype.


# 5. Phase 3: Evaluating the KEYS

There were two versions of NVDA used for this study to allow a comparison of the participants performance with and without the KEYS. The first version of NVDA was programmed to be similar to JAWS so it would be familiar and easy to learn. This version was then changed further to create the second version that added the KEYS rules. For simplicity, the remainder of the paper will identify the NVDA with the KEYS concept simply as the KEYS prototype.

## 5.1 Methodology

### 5.1.1 Participants

The KEYS prototype evaluation used participants who were blind and sighted. Users who were blind were recruited through the WSU's Office of Disabilities and the National Federation of the Blind (NFB) State of Ohio and Dayton chapters. The research was conducted at the NFB State of Ohio Conference in Columbus, Ohio and at the WSU Usability lab. Twenty-two participants who were blind and sixteen sighted volunteered to participate in the study. Each subject was paid for their participation. To participate, subjects who were blind were screened to meet the following conditions:

- Participants must use the JAWS screen reader as their primary screen reader of choice,
- Participants are required to be proficient with JAWS and JAWS website commands.

### 5.1.2 Hypothesis

There are five hypotheses used to evaluate the KEYS prototype. Table 5 lists the hypotheses, the dependent variables used to test them and the expected results based on the current research and the results from experiment one.

Table 5: Hypotheses used to evaluate KEYS Prototype

| Null Hypothesis | Dependent Variable | Expected Results |
|---|---|---|
| **H01:** *For users who are blind the number of successful tasks is the same with and without the KEYS.* | Success | Increased success with the KEYS |
| **H01:** *The number of first selections that are in the right direction is the same with and without the KEYS.* | Direction | Increased number of first selections that are in right direction |
| **H03:** *The means for the TLX workload is the same with and without the KEYS.* | Workload (NASA TLX) | Lower workload for KEYS |
| **H04:** *The number of commands used is the same with and without the KEYS.* | Number of Commands | Lower number of commands |
| **H05:** *The time it takes to complete the task is the same with and without the KEYS.* | Time | Time to complete task is faster with the KEYS |

### 5.1.3 Experimental Design

The experimental design is a mixed factorial. The following measures were selected for this test design:

**Independent Variables:**

- ID (identification # of subject)- blocked
- KEYS (with / without KEYS aid)- within
- Domain Type (banking/academic) – between

The variable, domain type, is between subjects so each participant conducted tasks on only one domain. Two website domains were selected, an academic website and a banking website. WSU's College of Engineering website and the WPCU website were selected due to familiarity and access to the website materials. The Wright-Patt Credit Union website was used in experiment one described earlier so some information about the site is already established and comparisons can be made. The KEYS prototype is only being tested on these two domains and further generalization will require additional testing. Each subject who was blind was randomly selected to perform tasks on the WSU Engineering website or the WPCU website. The orders of the task questions were counterbalanced using a balanced Latin square. The order in which the KEYS prototype was used was also balanced using a small n-design technique, ABBA, to prevent learning of the website. All A's are the tasks done using the KEYS while the B's are without the KEYS. This enables each participant to be a balanced set of data to reduce confounding. It was important to have the participant repeating work on the same domain website to be able to compare each user to their own performance with and without the KEYS .

Sighted participants were tested using a between website domain design. They did not use the KEYS so they conducted all 4 tasks for one website in random order. The orders of the questions were counterbalanced using a balanced Latin square. Table 6 illustrates the number of participants that conducted tasks in each of the domains.

Table 6: Experiment variables

| Experiment Variables and Number of Participants | | | |
|---|---|---|---|
| Variable | | # Sighted participants tested | # Blind participants tested |
| Domain Type | Banking | 9 | 12 |
| | With and Without Aid | | |
| | Academic | 7 | 10 |
| | With and Without Aid | | |
| Total | | 16 | 22 |

**Dependent Variables:**

- Mental workload using the NASA TLX
- Number of actions or commands
- Direction
- Success
- Time

The workload associated with each task was assessed using the NASA Task Load Index (TLX). NASA TLX is a subjective workload assessment tool which derives an overall workload score based on a weighted average of the ratings of six subscales. The subscales include mental demand, physical demand, temporal demand, performance, effort and frustration in which each participant ranks between 0-20. The value of zero indicates low input of the subscale while twenty is a high input of contribution for the workload.

Number of actions or commands as a dependent measure has been used in prior research versus evaluating every keystroke (Thatcher, 2006) to analyze users who are blind. These actions are commands such as links selected and search commands used and not movements such as up and down arrowing to scroll through the text or the equivalent mouse scrolling for sighted users.

Direction records the first command used and determines if the selection leads to the information that is being searched. If the command leads the user to the information, the path is determined to be correct.

Success is a binomial that indicates the user was able to find the information they were searching for and time is the number of seconds required to complete the task.

### 5.1.4 Apparatus

During the experiment the following data were captured: video, audio and keystroke information using Morae software by TechSmith with a Logitech webcam. NVDA's log file was programmed to store a list of all commands used during testing. Mozilla Firefox version 3.5.8 was the web browser recommended for use with NVDA.

### 5.1.5 Tasks

The experiment contains tasks that are information seeking for the website tested. Four tasks were performed on each website. The tasks were worded awkwardly to prevent prompting the participant with a keyword. The tasks are considered similar and equal in difficulty. They all require similar levels of searching to find the information asked.

The following banking tasks were performed:

1. Find the document you need to complete to get a car loan for a car you would like to purchase.
2. You are setting up a Paypal account and it requires your account routing number. Find the routing number for WPCU.
3. Would you incur any annual costs for having a WPCU credit card?
4. Can you earn money by keeping it in a savings account at WPCU?

The following academic tasks were performed:

1. What is the lowest grade value accepted into the college of engineering?
2. What time can you be shown around the WSU campus?
3. Does the WSU college of Engineering offer a higher level degree in Electrical engineering?
4. Does WSU's College of Engineering offer an undergraduate degree in biomedical engineering?

## 5.2 Experimental Procedures

Prior to testing participants, the KEYS library was populated by conducting an online survey. The testing for the KEYS evaluation was conducted at one time with each participant completing a pre-test, training on the NVDA screen reader and KEYS prototype, completing 4 tasks with NASA TLX workload questions asked after each task and followed by a few final questions.

### 5.2.1 Online Survey for expected keywords

This online survey was conducted using the general public. Common keywords from this survey were used to enhance the proposed KEYS prototype for the experiment. The survey asked participants to suggest expected words based on the tasks for each domain. The top 3-4 keywords were added to the websites keyword library and search results. The entire results are listed in Appendix A. The survey was put online and completed by 54 people. Recruiting for the survey was done on Facebook and through Wright State University listserv. These same task questions were used for the testing portion of the experiment.

### 5.2.2 Test Day Pre-Test Survey

A pre-test survey was completed to determine basic characteristics of the user and their Internet use. This survey was conducted immediately prior to testing on test day. The pre-test survey is shown in Appendix C.

### 5.2.3 Training

Prior to testing, each participant who was blind was given some basic instructions on the difference between NVDA and JAWS screen readers. They were given time to practice using the screen reader as well as ask NVDA commands similar to those they use frequently in JAWS. The participants were then given time to use the KEYS prototype and become familiar with its functionality. Participants were given time to ask questions before continuing to the testing portion. Sighted participants did not use the prototype and therefore were not trained on it. They proceeded directly to the testing portion of the study.

### 5.2.4 Testing

Participants were tested at WSU and at the NFB State of Ohio Conference. The test design was used to ensure completion of the test within 90 minutes. Participants entered the test room when they had time during the conference. Sighted participants were tested at WSU Usability Lab.

### 5.2.5 Post-test Survey

The participants who were blind were asked to compare the tested website with and without the KEYS prototype and asked to provide basic comments on the prototype. The post-test survey questions are located in Appendix D.

## 5.3 Results

The results from the surveys, as well as the testing, are described in this section. Additional data is also included in the Appendix and will be referenced throughout the section.

### 5.3.1 The Participants

#### *5.3.1.1 Participants who were blind*

All twenty-two participants who were blind were asked some basic questions in a pre-test survey to assess their comfort level with information seeking and their Internet usage. Based on these questions, all but one participant used the Internet on a daily basis. The one participant, who did not use the Internet daily, used the Internet weekly. Table 7 shows some replies to the survey (Survey is shown in Appendix C).

Table 7: Participants who were blind pre-test survey responses

| Survey Question | Replies (sample amount and answer) |
|---|---|
| How comfortable are you at browsing the Internet? | 16-Very comfortable<br>5-Comfortable<br>1- Not very comfortable |
| How comfortable are you browsing with that screen reader? | 18-Very comfortable<br>3- Comfortable<br>1- Not very comfortable (same person that was not very comfortable above) |
| Familiar with NVDA screen reader | 9-Familiar<br>1-Very familiar<br>12-Never heard of it |
| Uses for the Internet | 8-Conducted less than 4 uses<br>14-Conducted more than 5 uses |
| Effort level for searching on a website | 4-Very easy<br>15-Somewhat easy<br>1-Not very easy<br>2-Difficult<br>0-Very difficult |
| Use of banking websites | 4-Daily<br>4-Once a week<br>4-Once a month<br>1-Less than once a month<br>9-Do not use banking websites |
| Use of academic websites | 7-Daily<br>0-Once a week<br>4-Once a month<br>3-Less than once a month<br>8-Do not use academic websites |

All of the participants identified JAWS as their primary screen reader and some participants had tried other screen readers. A few participants had heard of the NVDA screen reader but our version of NVDA was slightly different to emulate JAWS. Many of the participants hurried through the training and felt it was not necessary since the NVDA screen reader was so similar to JAWS. There were a few occasions when a participant wanted a specialty command which was not available in NVDA but they were able to navigate around without it.

The participants who were blind were separated in age groupings by decades. Only one participant was in their 50's and one in their 60's so they were added to the 40 and over group. The number of participants in each age group and their genders are listed in Table 8.

**Table 8: Age groupings and gender of participants who are blind**

| AGE GROUP (years) | No. of Participants | GENDER | No. of Participants |
|---|---|---|---|
| 20-29 | 6 | Male | 13 |
| 30-39 | 4 | Female | 9 |
| 40 and over | 12 | | |
| TOTAL | 22 | | |
| Average age of blind= 38.2 years | | | |

The NASA TLX workload scores for each participant were compared based on the age the participant was diagnosed as blind. The analysis of the data in this research found no significant difference and results are summarized in Appendix E. Further research in this area will be required to draw conclusive results.

#### *5.3.1.2 Participants who were sighted*

Sixteen sighted participants from Wright State University completed the test. Every sighted participant used the Internet daily. Since all the sighted testing was completed at WSU, all of the participants had visited an academic website though not necessarily the WSU Engineering website. All of the sighted participants considered websites either very easy or somewhat easy to search for information. The remaining replies to the pre-test survey questions are located in Table 9.

Table 9: Sighted participants pretest survey responses

| Survey Question | Replies |
|---|---|
| How comfortable are you at browsing the Internet? | 15- Very comfortable<br>1- Comfortable<br>0- Not very comfortable |
| Uses for the Internet | 0-Conducted less than 4 uses<br>16-Conducted more than 5 uses |
| Effort level for searching on a website | 6-Very easy<br>10-Somewhat easy<br>0-Not very easy<br>0-Difficult<br>0-Very difficult |
| Use of banking websites | 5-Daily<br>7-Once a week<br>2-Once a month<br>0-Less than once a month<br>2-Do not use banking websites |
| Use of academic websites | 11-Daily<br>4-Once a week<br>1-Once a month<br>0-Less than once a month<br>0-Do not use academic websites |

The sighted participants used the Internet in more ways than the group that is blind. Some of the differences may be because the sighted group was composed of students that may be required to do more activities on the Internet. Though several participants who were blind were also students or professors, the remaining participants may not need to use the Internet as often or for different types of tasks.

The number of sighted participants in each age group is in Table 10. Sighted participants have an average age approximately 10 years younger than the average age of the participants who were blind. There is a majority of male participants in both the sighted and blind groups (Table 8 and 10).

Table 10: Age Groups and gender of sighted participants

| AGE GROUP (years) | No. of Participants | GENDER | No. of Participants |
|---|---|---|---|
| Under 20 | 1 | Male | 12 |
| 20-29 | 11 | Female | 4 |
| 30-39 | 2 | | |
| 40 and over | 2 | | |
| TOTAL | 16 | | |
| Average age of sighted is= 27.8 years | | | |

The age groups were compared using t-tests to determine if any differences occurred based on the NASA TLX scores and participant's age. There were no significant differences found in age groups for participants who were blind. Results of the age group analysis are shown in Appendix F.

### 5.3.2 KEYS Prototype

The KEYS prototype was evaluated by comparing the TLX workload scores, TLX subscales, number of actions/commands, time to complete task and a post-hoc measurement of success and direction between the NVDA screen reader with and without KEYS. Each of these comparisons provides insight into the performance of the aid.

#### *5.3.2.1 Hypothesis 1- Success*

Success was a binomial metric for comparing the results of using the screen reader with and without the KEYS prototype. Success measured whether or not the task was completed with the participant finding the information. Some participants were unable to complete all of the information seeking tasks. Many felt they had tried every strategy they knew and put considerable time into the activity but were still unable to find the information and requested to stop. They mentioned that they would have normally stopped much sooner and called the company for the information since they were unable to find it on the website.

This data on successfully completing a task was compared using an odds ratio and basic probability. The odds ratio for success is 47.095 based on the data in Table 11. Success is far more likely with the KEYS prototype compared to information seeking without it. The probability of success using the KEYS prototype is 98%, and 48% without the KEYS prototype. This demonstrates that the participants were able to complete tasks with the KEYS prototype that they may not have been able to complete without it.

**Table 11: Odds ratio for successfully completing task (blind participants)**

| Success With and Without KEYS | | | |
|---|---|---|---|
| | YES | NO | TOTAL |
| KEYS | 43 | 1 | 44 |
| NO KEYS | 21 | 23 | 44 |
| TOTAL | 64 | 24 | |

#### *5.3.2.2 Hypothesis 2- Direction*

Direction is another binomial metric used to determine if the participant's first selection (activated hyperlink) on the website took the participant on the path to find the information they were seeking. If the path chosen could take the user to the correct information, it was considered the right direction. If the correct information was not located in that path, it was considered the wrong direction.

The odds ratio for the right direction is 29.29 based on the data in Table 12. The right direction is far more likely with the KEYS prototype. The probability of choosing the right direction on the first selection with the KEYS prototype is 93.2%. The probability of choosing the right direction on the first selection without the KEYS prototype is 31.8%. Though several of the participants that started in the wrong direction were able to successfully complete the task, the KEYS prototype started participants in the right direction more often.

**Table 12: Odds ratio for first selection direction (blind participants)**

| Direction with and without KEYS | | | |
|---|---|---|---|
| | Right | Wrong | TOTAL |
| KEYS | 41 | 3 | 44 |
| NO KEYS | 14 | 30 | 44 |
| TOTAL | 55 | 33 | |

#### *5.3.2.3 Hypothesis 3- NASA TLX workload*

The NASA TLX workload data were collected after each task was completed. The data was analyzed using a three-way ANOVA with repeated measures on two factors. The independent variables were the identification number of the participants, the website tested and an indicator of whether the KEYS prototype was being used and the replication. The replication factor identified the first task with the KEYS prototype or first task without the KEYS prototype compared to the second for each. The prototype indicator and the replication variable were the repeating factors. The full factorial model showed no significant interactions. The model demonstrated normality and the residuals adequately scattered for equality of variance testing. The factors, replication and website, and all factor interactions were not significantly different.

Two outliers in the data set were identified and the sensitivity of the model to these outliers was analyzed by removing them. There was not a difference in the results when the outlier data was removed so they were left in the data set.

The scores for the TLX ranged from 0-100 and the means for with and without the KEYS prototype are located in Table 13. The TLX scores are defined by the higher scores indicating a perceived harder workload.

Additional analysis was conducted on the TLX score to further determine the difference within a few interesting subscales; mental demand, performance, effort and frustration. To prevent inflation of the Type I error rate, Bonferroni's adjustment was made to the p value. There are a total of 5 effects analyzed and 5 separate tests which would reduce the p value to 0.01 from .05 for significance.

The NASA TLX workload score for the aid pototype showed a significant difference at a $p \leq .01$. Eta partial squared ($hp^2$) calculations were used to determine the effect size. The calculation for $hp^2$ is $SS_{effect} / (SS_{effect} + SS_{error})$. The effect size gives the level of association between the independent variable (aid) and the dependent variable (TLX score) and how they are related. The effect size related to using or not using KEYS is .29, therefore, 29% of the variance of the TLX score outcome is attributed to this variable.

**Table 13: TLX score analysis**

| | TLX score Mean | P value | SS effect (Aid) | SS Error | Effect Size ($hp^2$) |
|---|---|---|---|---|---|
| KEYS | 58.79 | .0097 | 2309.59 | 5645.57 | .29 |
| NO KEYS | 48.49 | | | | |

Mental demand determines how much thinking, deciding or other mental activity was required to perform the task. Tasks performed with and without the aid showed significantly different mental demand scores for a $p \leq .01$. The effect size demonstrated 60% of the variance in the mental demand score was attributed to the aid. The means and effect size calculation data is in Table 14 below.

**Table 14: Mental demand TLX subscale analysis**

| | Mental Mean | P value | SS effect (Aid) | SS Error | Effect Size ($hp^2$) |
|---|---|---|---|---|---|
| KEYS | 34.64 | <.0001 | 11687.97 | 7786.29 | .60 |
| NO KEYS | 57.80 | | | | |

Another subscale is performance and it involves how successful the participant felt they performed the task. This measure rates differently in that a higher value means the participant felt their performance was good and a low value is a poor performance. Tasks performed with and without the KEYS prototype showed a significant difference in performance scores for a $p \leq .01$. The effect size demonstrated 37% of the variance in the performance score was attributed to the Aid variable. The means and effect size calculation data is below in Table 15.

**Table 15: Performance TLX subscale analysis**

| | Performance Mean | P value | SS effect (Aid) | SS Error | Effect Size ($hp^2$) |
|---|---|---|---|---|---|
| KEYS | 73.52 | .0025 | 9102.83 | 15275.95 | .37 |
| NO KEYS | 53.15 | | | | |

Effort is a subscale that determines how hard the participant felt they had to work (both mentally and physically) to perform the task. Tasks performed with and without the KEYS prototype showed a significant difference in effort scores for a $p \leq .001$. The effect size demonstrated 50% of the variance in the effort score was attributed to the Aid variable (Table 16).

**Table 16: Effort TLX subscale analysis**

| | Effort Mean | P value | SS effect (Aid) | SS Error | Effect Size ($hp^2$) |
|---|---|---|---|---|---|
| KEYS | 38.29 | .0002 | 14875.15 | 14606.44 | .50 |
| NO KEYS | 64.42 | | | | |

The last TLX subscale analyzed is frustration. Frustration is a subscale used to determine how discouraged, irritated or stressed the participant felt by performing the task. Tasks performed with and without the KEYS prototype showed a significant difference in frustration scores for a $p \leq .01$. The effect size demonstrated 37% of the variance in the frustration score was attributed to the Aid variable The means and effect size calculation data are shown in Table 17.

**Table 17: Frustration TLX subscale analysis**

| | Frustration Mean | P value | SS effect (Aid) | SS Error | Effect Size ($hp^2$) |
|---|---|---|---|---|---|
| KEYS | 31.98 | .0025 | 10467.93 | 17534.82 | .37 |
| NO KEYS | 57.89 | | | | |

The summary of the TLX workload and the subscales analyzed were all were found significantly different with and without the KEYS prototype. The means and significance values are summarized in Table 18.

**Table 18: Summary of means with significance**

| | TLX | Mental | Performance | Effort | Frustration |
|---|---|---|---|---|---|
| AID | 58.79** | 34.64**** | 73.52** | 38.29*** | 35.98** |
| NO AID | 48.49 | 57.80 | 53.15 | 64.42 | 57.89 |

**Note: Level of significance **p<.01, ***p<.001, ****p<.0001)**

#### *5.3.2.4 Hypothesis 4- Number of Commands*

The number of commands required to complete a task were evaluated with and without the KEYS prototype. The number of commands includes all data collected, not just the successful tasks. There was a significant difference between conditions (with and without KEYS) for the dependent variable number of commands with a $p \leq .001$ . The effect size for this variable was .52 meaning 52% of the variance was attributed to the type of Aid (Table 19).

**Table 19: Number of commands analysis**

| | No. of commands Mean | P value | SS effect (Aid) | SS Error | Effect Size ($hp^2$) |
|---|---|---|---|---|---|
| KEYS | 4.46 | .001 | 941.57 | 860.52 | .52 |
| NO KEYS | 11.02 | | | | |

#### *5.3.2.5 Hypothesis 5- Time*

The time required to complete a task is compared with and without the KEYS prototype. The time data includes all the tasks performed, not just the successful tasks. The time used for an unsuccessful task was the time the participant decided they were unable to find the information. They were not given a time limit or cut-off to complete the task but were asked to work on the task as long as they were comfortable.

Time is significantly different with a $p \leq .001$ for aid (with or without KEYS). Aid has an effect size of .52 meaning 52% of the variance in these scores was attributed to the Aid variable (Table 20).

**Table 20: Time analysis**

| | Time Mean (seconds) | P value | SS effect (Aid) | SS Error | Effect Size ($hp^2$) |
|---|---|---|---|---|---|
| KEYS | 297.21 | .001 | 1295777.61 | 1189218.25 | .52 |
| NO KEYS | 541.24 | | | | |

#### *5.3.2.6 Additional Analysis: Comparison of participants who were blind and sighted*

Results for sighted participants were compared to the data for the participants who were blind with and without the KEYS prototype. These data were analyzed using a one-way ANOVA. Models showed normality and the residuals adequately scattered for equality of variance testing. Some of the following dependent variables required transformations to meet model assumptions. Partial Eta squared and Eta squared is approximately equivalent for one-way ANOVA's so Eta Squared is used in the effect size calculations. The calculation for Eta squared is $SS_{effect}$ / $SS_{total}$. All pairwise comparisons are analyzed using Tukey's Studentized Range Statistic (Tukey's Test) with a $p \leq .05$.

Below are the comparisons made with all of the participants for the TLX workload score, the TLX subscales effort and frustration as well as the number of commands and time to complete tasks. The remaining comparisons can be found in Appendix G.

##### 5.3.2.6.1 NASA TLX workload

Table 21 displays the ANOVA table for the TLX score. The means and effect size for the TLX score for all three groups; blind without KEYS prototype, blind with KEYS prototype, and sighted are calculated in Table 22 and 23. The effect size demonstrated 19% of the variance in the TLX score was attributed to Aid for the three groups.

**Table 21: ANOVA Results for TLX Score.**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 10470.16 | 5235.08 | 17.57 | <.0001 |
| Error | 149 | 44406.92 | 298.03 | | |
| Corrected Total | 151 | 54877.08 | | | |

**Table 22: TLX workload and sample size with means**

| AID | Sample Size | Mean |
|---|---|---|
| Blind no KEYS | 44 | 59.07 |
| Blind with KEYS | 44 | 48.98 |
| Sighted no KEYS | 64 | 39.12 |

**Table 23: Effect size for TLX score comparison for all participants**

| SS effect (KEYS) | SS total | Effect size ($h^2$) |
|---|---|---|
| 10470.16 | 54877.09 | .19 |

The mean TLX workload score was reduced by participants who used the KEYS prototype which means participant's perceived workload was lowered. There was a significant difference with a $p \leq .05$ for participants with and without the KEYS prototype. However, there was still a significant difference between participants who were blind with the KEYS prototype and sighted participants. A box diagram of the groups in located in Figure 14 and the pairwise comparisons are shown in Table 24.

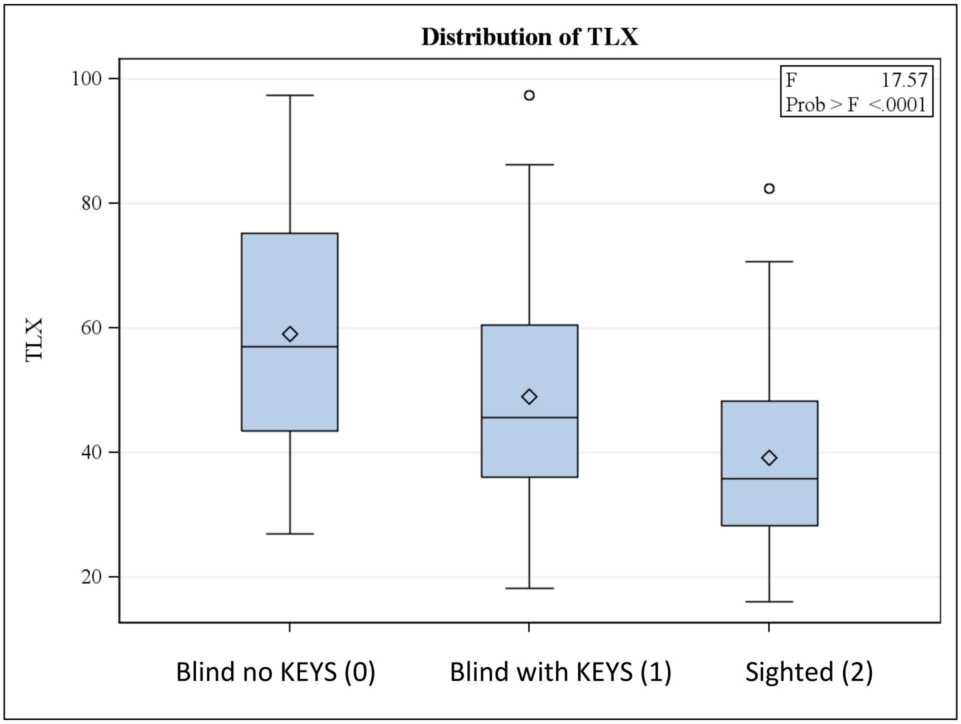



**Figure 14. Mean NASA TLX workload scores for each group.**

**Table 24: Pairwise comparisons NASA TLX workload score**

| AID Comparison | Description | Significance at p≤.05 |
|---|---|---|
| **0 - 1** | Blind without KEYS compared to blind with KEYS | Yes |
| **0 - 2** | Blind without KEYS compared to sighted | Yes |
| **1 - 2** | Blind with KEYS compared to sighted | Yes |

### 5.3.2.6.2 Effort TLX Subscale

The three groups were compared for the perceived effort the participants felt the tasks required. The ANOVA table is in Table 25 and the means and sample sizes are located in Table 26. The effect size, calculated in Table 27, demonstrated 34% of the variance in the effort subscale score was attributed to the Aid (blind without KEYS, blind with KEYS and sighted).

Table 25: ANOVA Results for Effort Score.

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 50948.91 | 25474.46 | 38.09 | <.0001 |
| Error | 149 | 99653.17 | 668.81 | | |
| Corrected Total | 151 | 150602.08 | | | |

Table 26: Effort subscale sample size and means

| AID | Sample Size | Mean |
|---|---|---|
| Blind no KEYS | 44 | 64.34 |
| Blind with KEYS | 44 | 38.68 |
| Sighted no KEYS | 64 | 20.14 |

Table 27: Effort size for effort subscale comparison for all participants

| SS effect (aid) | SS total | Effect size ($h^2$) |
|---|---|---|
| 50948.91 | 150602.08 | .34 |

The three groups were significantly different from one another in the pairwise comparisons for the effort subscale. The box graph is shown in Figure 15 and the two way comparisons are located in Table 28.

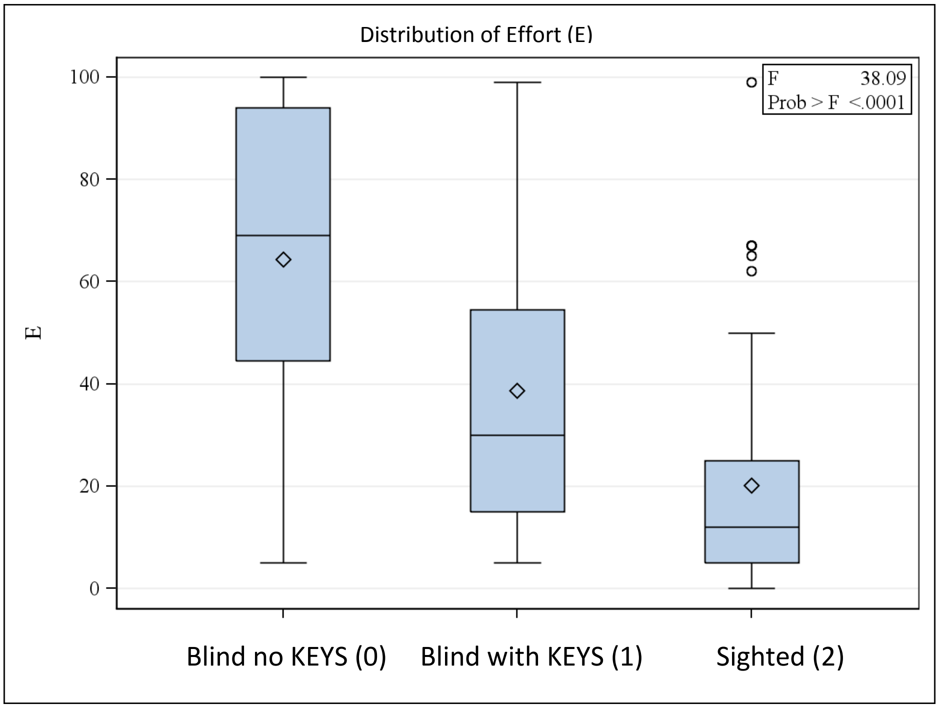



**Figure 15. Mean NASA TLX score for effort for each group.**

**Table 28: Pairwise comparisons effort subscale score**

| AID Comparison | Description | Significance at p≤.05 |
|---|---|---|
| **0 - 1** | Blind without KEYS compared to blind with KEYS | Yes |
| **0 - 2** | Blind without KEYS compared to sighted | Yes |
| **1 - 2** | Blind with KEYS compared to sighted | Yes |

###### 5.3.2.6.2 Frustration TLX Subscale

The three groups were compared for how much frustration they felt completing the tasks. The ANOVA table is shown in Table 29 and the means and sample sizes are in Table 30. The effect size, calculated in Table 31, demonstrated 35% of the variance in the frustration subscale score was attributed to the aid type (blind without aid, blind with aid and sighted).

Table 29: ANOVA Results for Frustration Score.

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 377.78 | 188.89 | 39.44 | <.0001 |
| Error | 149 | 713.69 | 4.79 | | |
| Corrected Total | 151 | 1091.47 | | | |

Table 30: Frustration subscale sample size and means

| AID | Sample Size | Mean |
|---|---|---|
| Blind no KEYS | 44 | 54.55 |
| Blind with KEYS | 44 | 36.86 |
| Sighted no KEYS | 64 | 14.03 |

Table 31: Effect size for frustration subscale comparison for all participants

| SS effect (KEYS) | SS total | Effect size ($h^2$) |
|---|---|---|
| 377.78 | 1091.47 | .35 |

The pairwise comparisons for each group were significantly different from one another. The box graph is shown in Figure 16 and the pairwise comparisons are located in Table 32.

To meet model assumptions, frustration values were transformed by adding 1 (some values of zero were present) and then performing the square root of the frustration value.

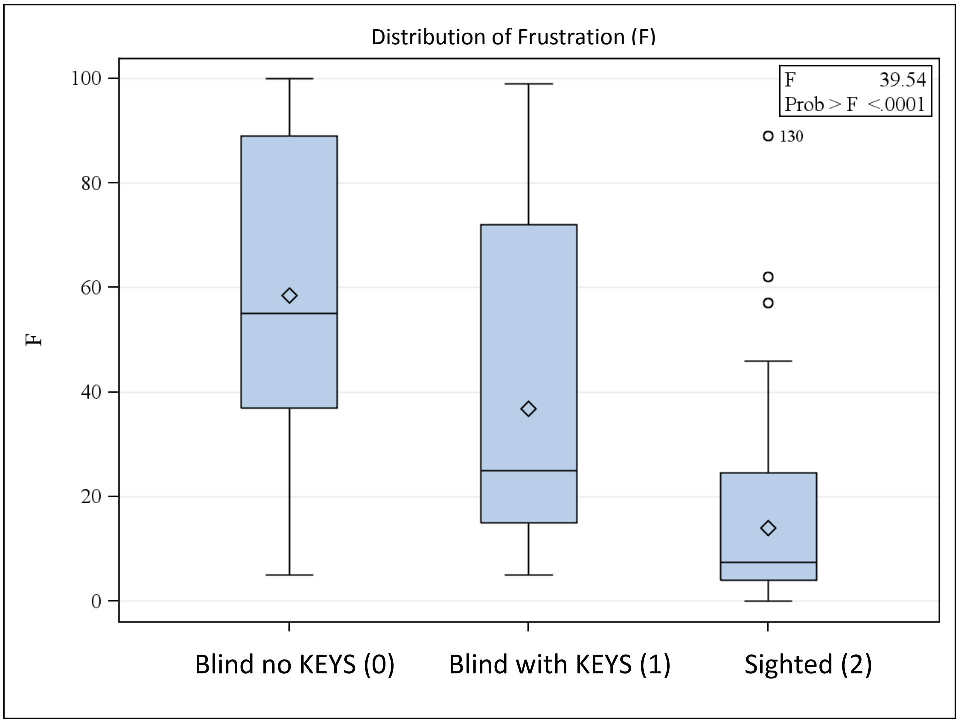


Figure 16. Mean NASA TLX score for frustration for each group.

Table 32: Pairwise comparisons for frustration subscale

| AID Comparison | Description | Significance at p ≤.05 |
|---|---|---|
| 0 - 1 | Blind without KEYS compared to blind with KEYS | Yes |
| 0 - 2 | Blind without KEYS compared to sighted | Yes |
| 1 - 2 | Blind with KEYS compared to sighted | Yes |

#### 5.3.2.6.4 Number of Commands

The number of commands used to perform the information searching tasks was calculated in two ways. First the data were analyzed with all participants, regardless of the success of finding the information. The second method was to compare only the data in which the participant was successful in finding the information. The first analysis below is the accumulation of all the data and participants number of commands.

The ANOVA table is shown in Table 33 and the means and sample sizes are shown in Table 34. The effect size, calculated in Table 35, demonstrated 24% of the variance in the number of commands was attributed to Aid (blind without KEYS, blind with KEYS and sighted).

**Table 33: ANOVA Results for the number of commands.**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 1565.97 | 782.98 | 23.48 | <.0001 |
| Error | 149 | 4968.35 | 33.34 | | |
| Corrected Total | 151 | 6534.31 | | | |

**Table 34: Number of commands sample size and means**

| AID | Sample Size | Mean |
|---|---|---|
| Blind no KEYS | 44 | 11.11 |
| Blind with KEYS | 44 | 4.48 |
| Sighted no KEYS | 64 | 3.78 |

**Table 35: Effect size for the number of commands comparison for all participants**

| SS effect (KEYS) | SS total | Effect size ($h^2$) |
|---|---|---|
| 1565.97 | 6534.32 | .24 |

The number of commands was significantly different ($p \leq .05$) for the comparison of participants who are blind with and without the KEYS prototype. A statistically significant difference in number of commands was also found between blind participants without KEYS and sighted participants. Mean number of commands for participants who are blind using the KEYS prototype and participants who are sighted were not significantly different. The box graph is shown in Figure 17 and the pairwise comparisons are located in Table 36.

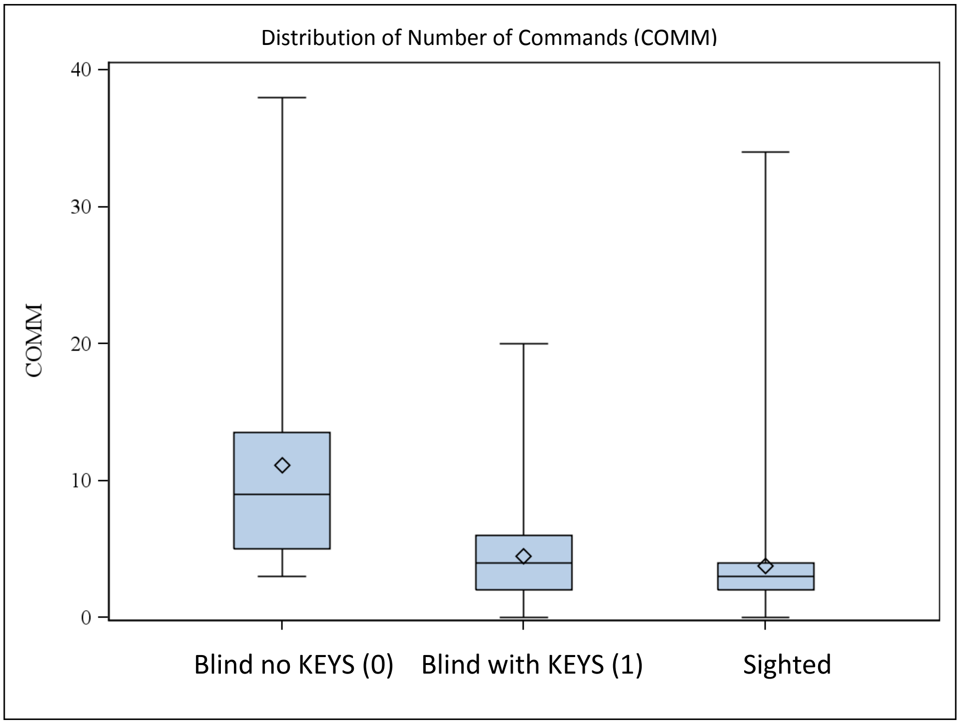



Figure 17. Mean number of commands for each group regardless of task success.

Table 36: Pairwise comparison for all groups with the number of commands

| AID Comparison | Description | Significance at p≤.05 |
|---|---|---|
| 0 - 1 | Blind without KEYS compared to blind with KEYS | Yes |
| 0 - 2 | Blind without KEYS compared to sighted | Yes |
| 1 - 2 | Blind with KEYS compared to sighted | No |

The second method to analyze this data contains only successful tasks. The ANOVA table is shown in Table 37 and the means and sample sizes are located in Table 38. The effect size, calculated in Table 39, demonstrated 14% of the variance in the number of commands was attributed to the Aid condition. This value is 10% smaller than the previous calculation of all command data. Notice the sample sizes are now much smaller for the participants who are blind without the KEYS prototype.

Table 37: ANOVA table for number of commands for successful tasks

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 449.41 | 224.71 | 9.90 | .0001 |
| Error | 125 | 2838.59 | 22.71 | | |
| Corrected Total | 127 | 3288.00 | | | |

Table 38: Commands using only successful tasks

| AID | Sample Size | Mean |
|---|---|---|
| Blind no KEYS | 21 | 54.55 |
| Blind with KEYS | 43 | 36.86 |
| Sighted no KEYS | 64 | 14.03 |

Table 39: Effect size for number of commands for successful tasks

| SS effect (KEYS) | SS total | Effect size ($h^2$) |
|---|---|---|
| 449.41 | 3288.00 | .14 |

The number of commands with successful tasks was significantly different with a p≤.05 for the comparison of participants that are blind with and without the KEYS prototype as well as the comparison of participants without the KEYS prototype and sighted. Number of commands was not significantly different between participants who are blind using the KEYS prototype and participants who are sighted. The box graph is shown in Figure 18 and the pairwise comparisons are located in Table 40.

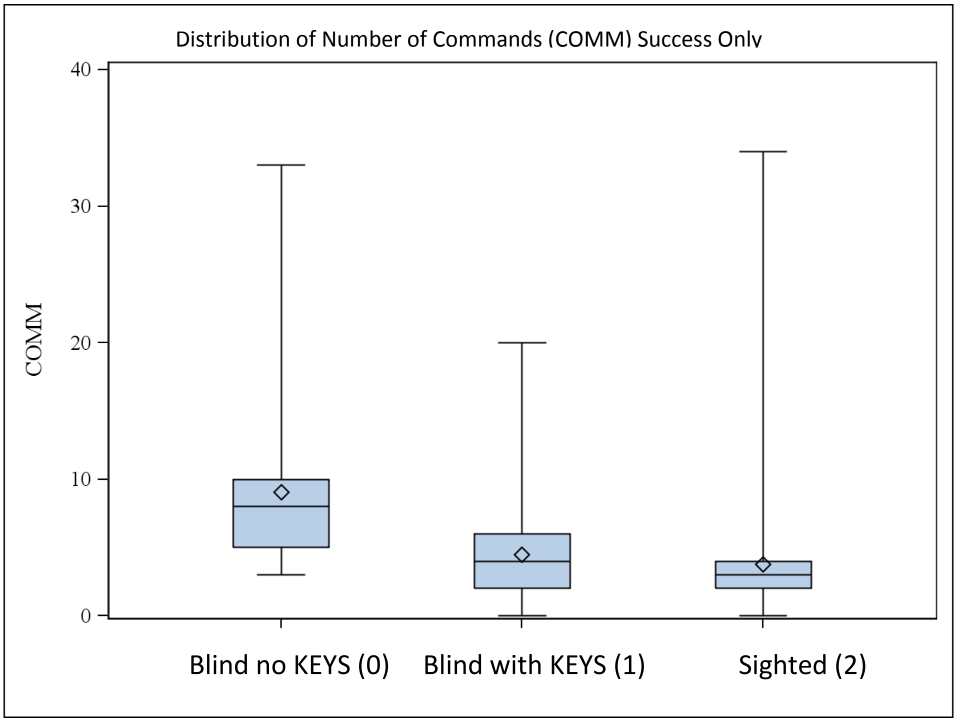


**Figure 18. Mean number of commands for each group for successful tasks.**

**Table 40: Two way comparison for all groups with the number of commands for successful tasks**

| AID Comparison | Description | Significance at p≤.05 |
|---|---|---|
| **0 - 1** | Blind without KEYS compared to blind with KEYS | Yes |
| **0 - 2** | Blind without KEYS compared to sighted | Yes |
| **1 - 2** | Blind with KEYS compared to sighted | No |

It is interesting to note that the range for sighted users' number of commands can progress as high as the range for participants that are blind without the KEYS prototype. The reason for this phenomenon is that two of the sighted users were keyboard driven and seldom used the mouse. For this reason they needed to use many more commands to navigate the website than a mouse user would require.

##### 5.3.2.6.5 Time to Complete Tasks

The time to complete the information seeking tasks was calculated in two ways just like the number of commands analysis in the previous section. First the data were analyzed with all participants, regardless of their success of finding the information. The second method was to compare only the tasks in which the participant was successful in finding the information. The first analysis below is the accumulation of all the data and participants times.

The ANOVA table is shown in Table 41 and the means and sample sizes are located in Table 42. The effect size, calculated in Table 43, demonstrated 43% of the variance in the time was attributed to the aid type (blind without KEYS, blind with KEYS and sighted).

**Table 41: ANOVA table for time to complete tasks**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 137.18 | 68.59 | 92.41 | <.0001 |
| Error | 149 | 110.59 | 0.74 | | |
| Corrected Total | 151 | 247.78 | | | |

**Table 42: Time sample size and means**

| AID | Sample Size | Mean (seconds) |
|---|---|---|
| Blind no KEYS | 44 | 536.02 |
| Blind with KEYS | 44 | 297.84 |
| Sighted no KEYS | 64 | 72.25 |

**Table 43: Effect size for the time to complete a task**

| SS effect (aid) | SS total | Effect size ($h^2$) |
|---|---|---|
| 137.18 | 247.78 | .43 |

The time to complete tasks was significantly different for each group pairwise comparisons with a $p \leq .05$ for all comparisons. The box graph is shown in Figure 19 and the pairwise comparisons are located in Table 44. The time values needed to be transformed by taking the logarithmic transform ($\log_{10}$) in order to meet model assumptions.

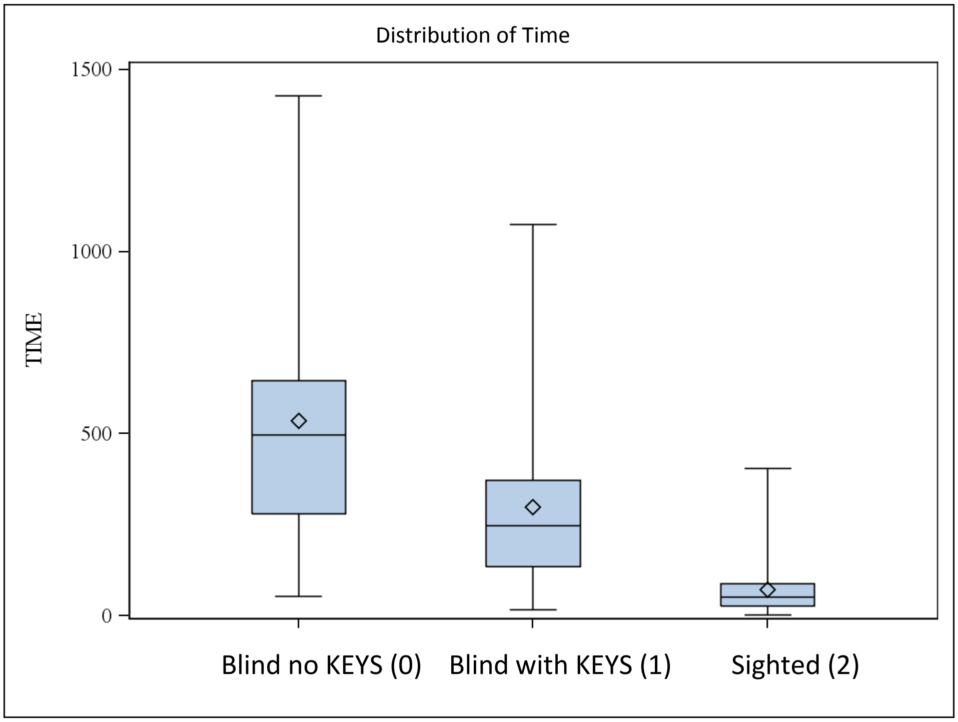


Figure 19. Time to complete tasks regardless of success.

Table 44: Pairwise comparison for all groups for the time to complete tasks

| AID Comparison | Description | Significance at p≤.05 |
|---|---|---|
| **0 - 1** | Blind without KEYS compared to blind with KEYS | Yes |
| **0 - 2** | Blind without KEYS compared to Sighted | Yes |
| **1 - 2** | Blind with aid compared to sighted | Yes |

The second method to analyze the time data contains only successful tasks. The ANOVA table is shown in Table 45 and the means and sample sizes are located in Table 46. The effect size, calculated in Table 47, demonstrated 33% of the variance in the number of commands was attributed to Aid. This value is 10% smaller than the previous effect size calculation. The sample sizes are much smaller for the participants who are blind without the aid.

Table 45: ANOVA table for time for successful tasks

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 84.06 | 42.03 | 52.68 | <.0001 |
| Error | 125 | 99.73 | 0.79 | | |
| Corrected Total | 127 | 183.79 | | | |

Table 46: Time sample size and means for successful tasks

| AID | Sample Size | Mean |
|---|---|---|
| Blind no KEYS | 21 | 386.19 |
| Blind with KEYS | 43 | 296.30 |
| Sighted no KEYS | 64 | 72.25 |

Table 47: Effect size for the time to complete successful tasks

| SS effect (aid) | SS total | Effect size ($h^2$) |
|---|---|---|
| 84.06 | 183.79 | .33 |

The time to complete tasks successfully was significantly different for the comparison of participants who are blind using the KEYS prototype compared to sighted. There is also a significant different between and blind without the KEYS prototype to sighted. However, there is no significant difference found for participants who are blind with and without the KEYS prototype. This is different than the previous finding that involved all time data. The box graph is shown in Figure 20 and the pairwise comparisons are located in Table 48. To meet model assumptions, time values were transformed taking the logarithmic transform ($log_{10}$).

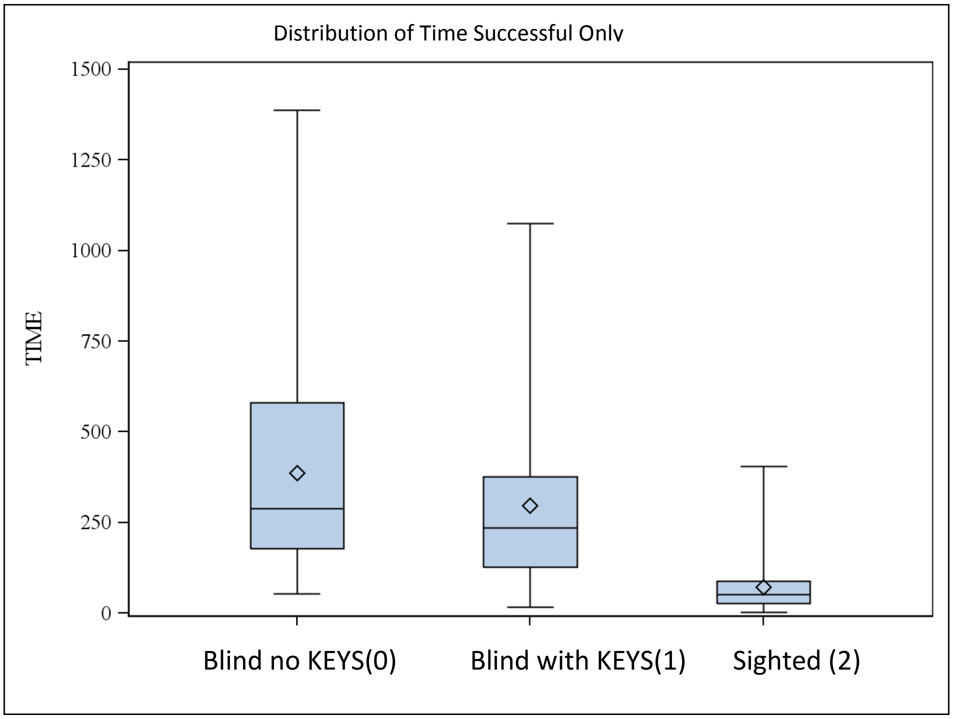



**Figure 20. Time to complete successful tasks.**

**Table 48: Two way comparison for all groups with the time to complete tasks successfully**

| AID Comparison | Description | Significance at p≤.05 |
|---|---|---|
| **0 - 1** | Blind without KEYS compared to blind with KEYS | No |
| **0 - 2** | Blind without KEYS compared to sighted | Yes |
| **1 - 2** | Blind with KEYS compared to sighted | Yes |

The results comparing these three levels of the Aid variable shows the mean $Log_{10}$(time) for the blind with KEYS and without KEYS was not significantly different when only successful tasks are analyzed. This is an interesting result that cannot be explained analytically but there are a few theories. It can be assumed that if the participants had taken more time they could have been successful therefore increasing the number of successes as well as the time to complete them. Also, there were 8 participants that were unable to successfully complete two of their tasks without the KEYS. This accounts for 16 of the 23 tasks that were not completed successfully. One could assume that the KEYS enabled users who are not considered high functioning screen reader users to perform more successfully or more like a high functioning screen reader user. All 8 of those participants that were unable to successfully complete a task without KEYS were successful on all their tasks with the KEYS.

### *5.3.2 Comparing age groups for participants that are blind*

The participants were compared by their age groups, 20-29, 30-39, 40 years and over. T-tests were performed to see if there were any significant differences among the age groups. The TLX workload score, each of the subscales, number of commands and time were compared. The data were separated by tasks with and without KEYS. None of the comparisons were significantly different though two were close to the $p \leq .05$ and may be considered for future investigation. The two comparisons that were close to significant were the frustration levels between the 20's age group and the 40's as well as the 30's age group and the 40's. The means for the comparisons are available in Appendix F.

### 5.3.3 Post-test Survey

The final questionnaire after task completion asked participants to rank the website with and without KEYS. The options included: very easy, somewhat easy, not very easy, difficult, and very difficult. For purposes of analysis, the change from somewhat easy to very easy is one step change. Of the 22 participants, 8 felt the aid made the website a one step change easier, 5 felt it made the website 2 steps easier, 5 felt it was 3 steps easier and 1 felt it changed the website by 4 steps. Three of the participants felt it didn't change the ease of the website at all. One of the participants was an expert JAWS user and commented on feeling disoriented because the aid added words to the website that were not really there. The participant did feel, however, that with more practice with the KEYS prototype, one may learn to orient better and make the connection to the expected words and the words supplied on the webpage. Connecting the expected words with the actual words on the website could provide a way to learn the website.

Comments made about the KEYS prototype were all very promising. Many felt the KEYS prototype increased the odds of finding the information. They felt it provided more context, more suggestions and overall more options. Many also liked the synonym assistance. Participants felt the KEYS prototype helped them perform searches faster and more easily. One participant commented on liking the find command in the aid that summarized the number of matches for the word they were searching. Two participants felt they could have performed better if they had the JAWS commands instead of NVDA. Reviewing participant test data showed that part of their struggle with the website had to do with their selection of words or impatience to read the options and JAWS may not have aided them in these tasks.

### 5.4 Observations

Experiment one drew conclusions about search commands that were most often used. These strategies were coined the primary search strategies (PSS). In this experiment, the virtual find (Ctrl F) was prevalently the favored strategy. In fact, 78% of the time it was the first command used. The list of links command was also favored with 15% of the participants using it as their first command. The comparison of the experiment one data and the KEYS prototype evaluation is located in Table 49. These results show that the two favorite PSS's have switched positions. This may not represent a global trend since the KEYS prototype added several more links in the list of links result, which could have been considered tedious to read through, making the virtual find command easier to use. It does still demonstrate that both of these commands are well known and favored to search for information on a website. This can further strengthen the necessity for the website to provide words that are relevant and will match the users search word.

Table 49: Primary Search Strategy usage

| PSS | Pilot Study and Shebilske et al. (2008) participants from Table 2 first command when enter section B flowchart | Current Study First command |
|---|---|---|
| Insert F7 | 14/22 = 64% | 13/88=15% |
| Ctrl F | 6/22 = 27% | 69/88=78% |
| Site Search | 1/22 = 4.5% | 0 |
| Google | 1/22 = 4.5% | 0 |
| Insert F6 | 0 | 1/88=1% |
| Other | | 5/88=6% |
| **Total** | 100% | 100% |

One observation is that participants who were very successful with the virtual find (Ctrl F) command used partial words as their search word such as “rout” for routing. Other users that were not as successful attempted to conduct a search using entire phrases such as “grade level in engineering”. Researching how a user selects words would be useful to research in the future to assist with screen reader training for keyword selection.

Of the participants that started with a virtual find (Ctrl F), they were successful 70% of the time. Participants that started with a list of links (Insert F7) command were successful 100% of the time.

Since the webpages were hardcoded for the KEYS prototype, there could have been a problem with participants wandering off the hardcoded webpages. Fortunately, enough of the webpages were hardcoded so users did not search on webpages that were not programmed during the study.

Users were very interested in the synonym section of the KEYS prototype, but while completing the tasks, it was seldom used. This may have occurred because of the specialized words used in an academic and banking domain did not produce synonyms that were useful. The participants may also have simply forgotten about the option since it was a new concept.

## 5.5 Discussion

Many techniques to assist people who are blind with information searching on websites have used wayfinding and other travel metaphors as well as spatial solutions. The novel approach adopted in this research of using keywords and focusing on improving the success of the current search strategies has been shown to be beneficial. The KEYS conceptual model is built on the notion of assimilation and context (Bennett & Flach, 2011) using rules and a keyword library to provide users with keywords that are expected and putting them in context. The KEYS model attempts to match expected words from the users' mental model with the word on the webpage to assist in information seeking. Gathering expected words is a common marketing practice for many domains and providing more of these words on a website could potentially support more users.

The participants who were blind were able to perform tasks successfully, regardless of their level as a screen reader user, 98% of the time. Only 48% of the tasks were successful without the KEYS prototype. The websites tested are not very accessible and with the assistance of the KEYS prototype, participants who were blind could find the information in which they were searching at a very high success rate. This reduces the negative effects of an inaccessibly designed website on search performance for users who are blind. This also indicates that lower functioning screen reader users can perform at a higher level with the KEYS prototype.

The KEYS prototype assisted users in making their first selection on the website in the appropriate direction to find the information they were searching. This acts as a springboard for users to start their search. It was observed that users who were blind would attempt a search from whatever page they were currently located. This knowledge might encourage web designers to create less hierarchical websites with fewer levels so the most prominent information is located on every page, especially the home page. If the KEYS concept assists with the first step and the website has fewer levels, information may be found faster for users who are blind.

In the pairwise comparisons for the number of commands required to complete the tasks, the participants who were blind using the KEYS prototype did not perform differently from the sighted participants. This occurred for the calculations that involved all tasks and only successful tasks. There was a significant difference between the number of commands for the users who were blind without KEYS and sighted. This result indicates that the KEYS tool has promise for closing the gap between users who are blind and sighted. The fewer commands may indicate a more effective search strategy with the KEYS concept.

The analysis in this research had a large variance even though there are significant differences in the dependent variables. In this study, users who were blind were not assessed for their screen reader skill level such as they were in experiment one. However, simply by observation, it could be determined that the skill levels of the participants encompassed the entire spectrum from beginners all the way to experts that teach how to use screen readers. This spread in skill level may explain the variance in the measurements.

The time required for users who are blind to information seek on websites will always be longer than sighted simply because the screen reader is auditory, however, a strong searching tool could get information more quickly and compete with sighted completion times.

The KEYS prototype may allow users who are blind to conduct a keyword scan similar to users who are sighted. Users who are sighted are able to do a synonym comparison while they are scanning the website. For instance, one of the tasks completed in this research study asked for the amount of money one could earn by keeping money in a savings account at WPCU. The online survey determined that the keyword “interest” was expected on the webpage. However, the correct banking term used on the website was “dividend.” Though a sighted user may not know the exact definition of a dividend, they may have been able to guess that it would be similar to the expected word, “interest”, in which they were searching.  A user that is blind is unable to make that comparison because the word "dividend" was not expected and not found as a match when the word "interest" was searched using search commands.  The KEYS prototype can provide word matches to alternatives that the user may not be able to predict without visually seeing the option.

Aids such as the KEYS prototype can give more accessibility control and functionality to the screen reader user instead of with the website designer.  This research demonstrates that some of the accessibility issues for a website involve the words used on the website.  In other words, providing KEYS support can assist a user who is blind when the website is not accessible.

The results also indicate that making a change in the virtual find and list of links (Ctrl F and Insert F7) commands alone can make a significant difference.  These two commands are heavily favored for a majority of the information searches conducted on webpages.  This is very useful for screen reader developers who want to improve their customers' performance.  A designer can simply manipulate the website to ensure results in these two commands represent the information accurately making their website better for information searches.

Two implications to web designers include: ensuring the word choice for describing a link or other attribute needs to be what the users of the website expect to find, and checking the results of a search command (Insert F7 and Ctrl F) to ensure good results.  The words used throughout the website should also be expected and the language should not alienate the users.

The KEYS prototype was a hard-coded program to evaluate the concept of adding keywords and context to a website.  The KEYS prototype was developed to support specific pages with only two commands (virtual find and list of links).  Even with these limitations, the KEYS prototype made great strides in improving the information searching for people who are blind.

Participants in the study were happy with the aid and liked the additional options for searching for keywords on the page. The additions of keywords were not considered overwhelming even though the addition increased the number of results the participant had to parse.

Overall the KEYS prototype brought users who were blind closer to the efficiency of a sighted user on these websites by increasing their success rate, starting their search in the right direction, reducing their workload and number of commands required to complete a task. The results support the KEYS as a methodology for increasing the accessibility of websites for information seeking.

## 5.6 Research Contributions, Potential Applications and Future Research

### 5.6.1 Research Contributions

The research literature on web-based information seeking for people that are blind has included such tactics as using travel metaphors (Yesilada et al., 2007), information foraging (Takagi et al, 2007; Juvina & van Oostendorp, 2008) and multi-modal solutions (Kuber et al., 2007; Rotard et al., 2008; Yu et al., 2006; Donker et al., 2002). Though these solutions have had limited success by providing solutions that are similar to real world travel or providing spatial information, the current research indicates the KEYS concept and prototype may be an important and useful alternative. This research demonstrates that current screen reader users are heavily dependent on search tools when information seeking and by providing support for keyword selections, they can significantly improve their searching success.

Other significant contributions to the study of information searching for both users that are blind and sighted are as follows:

1. Additions to W3C accessibility standards

   The W3C accessibility standards include the following two guidelines:

Guideline 12- Provide context and orientation information. This guideline refers to adding descriptions to frames and form fields and adding grouping commands in HTML.

Guideline 1- Provide equivalent alternatives to auditory and visual content. This guideline refers to adding alternative text to a website object.

These guidelines may aid in creating a more accessible website but they do not go far enough. Based on the significance of using the appropriate and expected keywords, an addition to these two guidelines is needed. This research demonstrates that using the appropriate and expected words placed with the most significant word first will also improve the websites accessibility.

2. Information seeking improvement for sighted and blind

It is documented that difficulties in designing a website for audio users (users that are blind) is similar to difficulties encountered when designing for small device users (Harper & Bechhofer, 2005). Since the screen size is significantly smaller for these devices, the amount of website shown is reduced and visually scanning the entire page is inhibited. Designing a website that can be assessed with better keywords and without this overall visual scan will improve the usability of these small devices for sighted users. .

3. Better understanding of blind and sighted navigation

Understanding how both group's information seek is evolving and documenting the process that is currently used by the people will encourage interface designers to take these techniques into consideration. Understanding how these groups search for information has implications for the design of websites as well as continued research in the area of improving navigation for people who are blind.

### 5.6.2 Potential Applications

This research will enable screen reader developers to see the significance of keywords and their context. Many of the features in the KEYS concept could be easily added to a screen reader. The technology is already available such as providing synonyms, correcting spelling, indicating the number of matches in a find and showing the attributes of the matched words. Other enhancements such as adding additional words may require additional development.

Enhancing screen readers to be able to read what is shown on the screen versus the HTML code would also allow the screen reader to provide more contextual information when not provided in the code.. Developing a technique to allow web designers to provide more than one option to name a link would also assist users of screen readers by providing more options.

Integrating dictionaries that already exist such as WordNet (Princeton, 2010) that are lexical and may have expected words linked together, integrating them into website search capabilities and/or a screen reader is likely to enhance website searching. As indicated by the online survey, words people expect to find on a website are not always present and including expected words may improve searching for all users. Creating libraries of words for specific categories of websites may be a future application to support both blind and sighted.

The techniques discussed above may be used for small screen devices to assist users (sighted and blind) in going directly to the information they are seeking. With a small screen even sighted users ability to perform a visual scan are minimized.

### 5.6.3 Future Research

The current research provides some areas that may be of interest for future research. The KEYS concept used many hardcoded additions for keywords so research using different keyword techniques is of interest. Users who are blind search a website similar to a database search. Creating a toolset that approaches the website as a database and using the database search tools such as Boolean phrase or natural language searching is an important area for  future research.

The current research did not separate the 7 KEYS concept rules to determine which rule might provide the most assistance.  Research to determine which rule is most effective may provide more information for application developers so they may focus their design, directly affecting cost. .

Researching the strategies users perform to select a keyword from their mental model is a topic for future research.  Some users were more effective at determining if a keyword was relevant and producing keywords for virtual find searches.  This research demonstrated how important keywords are for information searching but little is known on the strategy used for selecting a keyword from ones' mental model.  It was observed that a user can be skilled at the screen reader and skilled at keyword selections.  This research did not solicit information about education levels and occupations to determine whether there is a relationship with effective keyword generation.  Training to use screen reader could also include how to generate and identify a good keyword.

The age at which a user was diagnosed as blind and the relationship to performance is also a topic for future research.  This research provided some basic comparisons but further exploration may bring more data for information seeking on a website.

## 5.7 Conclusion

This research observed a change in the strategies users who are blind use to search for information on a website compared to previous research. This change requires new advances to support these strategies. The technique to support these information seeking strategies is demonstrated in this research by providing keyword assistance, specifically using the KEYS concept. The methods implemented in this study are only one possible implementation of the KEYS concept. However, the support through keywords has shown to significantly improve a user's success and performance when searching for information regardless of skill level with the screen reader. The keywords are expected and represent the ecology. All this is in an effort to close the performance gap between users that are blind and sighted.

## APPENDIX A - Online Survey Questions and Results

**Table A-1: Responses from online 1-4 for WPCU website**

| Q1 | #Resp | Q2 | #Resp | Q3 | #Resp | Q4 | #Resp |
|---|---|---|---|---|---|---|---|
| loan | 27 | routing number | 21 | credit/ card | 29 | interest | 29 |
| car | 15 | account info | 10 | fee/s | 14 | accounts | 7 |
| auto | 5 | my accounts | 9 | visa | 2 | savings | 4 |
| financing | 4 | personal | 2 | my account | 2 | rates | 3 |
| lending | 1 | checking | 2 | rates | 1 | apr | 1 |
| | | online banking | 1 | annual fee | 1 | personal banking | 1 |
| | | bank | 1 | finance | 1 | apy | 1 |
| | | information | 1 | charge | 1 | certificate of dept | 1 |
| | | locate | 1 | | | investment | 1 |
| | | | | | | types | 1 |
| | | | | | | calculations | 1 |
| | | | | | | current | 1 |
| | | | | | | checking | 1 |

**Table A-2: Responses from online 1-4 for WSU website**

| Q1 | #Resp | Q2 | #Resp | Q3 | #Resp | Q4 | #Resp |
|---|---|---|---|---|---|---|---|
| gpa | 15 | campus tours | 17 | electrical eng | 19 | biomedical | 17 |
| requirements | 15 | tour | 12 | degree | 15 | undergrad | 10 |
| admission | 6 | visit | 9 | programs | 5 | degrees | 10 |
| minimum gpa | 4 | schedule | 4 | majors | 3 | programs | 6 |
| entrance req | 3 | admission | 3 | academics | 2 | majors | 3 |
| grades | 3 | contact us | 2 | school | 1 | academics | 2 |
| application | 2 | future students | 1 | admission | 1 | college | 1 |
| future students | 2 | college visit | 1 | college | 1 | | |
| academic | 2 | | | engineering | 1 | | |
| current student | 1 | | | undergrad | 1 | | |
| grading scale | 1 | | | | | | |
| enrollment grades | 1 | | | | | | |
| students | 1 | | | | | | |
| new students | 1 | | | | | | |
| grade point | 1 | | | | | | |
| program req | 1 | | | | | | |

## APPENDIX B - IRB proposal summary and consent letters

**Title:** Development and Evaluation of an Interface Aid to Support Web Based Information Seeking for the Blind Research Study

**Investigators:** Carissa Brunsman-Johnson, S. Narayanan, Ph.D., P.E.

**Purpose of Research:**

The research study aims at testing a keyword framework to determine if it increases the efficiency of users who are blind when they conduct information seeking tasks within a website.

**Background:**

Experiment one, documented in the paper by Brunsman-Johnson et al. (2011), contains data on information search strategies that are used by sighted as well as participants that are blind. The most common JAWS commands used in the present study are the primary search strategies listed in table 1. These are the commands that are favored and used first or most prominently in a website information seeking task. Insert F7 is a command that produces a pop-up box that lists the links on a website in the order they appear on the website. A user can read through all links but the most common method is to use a shortcut by typing in a letter that will jump the cursor to the links that start with that letter. All participants in the present study and the Shebilske et al. (2008) study used a shortcut when using the Insert F7 command. Basically, the user is selecting a keyword and using the first letter to see if the keyword is located at the start of a link on the webpage. Insert F6 works very similar to Insert F7 but the list consists of headers instead of links. Ctrl F is the virtual find and produces a pop-up box with a text area to type a keyword and typically just searches the contents of the present webpage. For sighted users this command will initiate the browser to highlight each keyword found on the webpage one at a time as prompted by the user. For the user that is blind, this function can read the first match and a previous match but must be completed again to further search the rest of the webpage. A site search refers to the search text box that is present on a webpage that allows the user to search the entire website and is maintained by the website owner.

Table B-1: Primary Search Strategies

| Blind | Sighted |
|---|---|
| Ctrl F -Virtual Find<br>Insert F7 -Links list<br>Insert F6<br>Site Search<br>Google | Ctrl F -Virtual Find<br>Site Search<br>Google<br>Visual Scan |

It was also observed that there was a favored primary search strategy by the participants who were blind. Insert F7, the command to list the links on the webpage, was used first by 64% of the time a user performed an information searches using a primary search strategy.

Users who are blind used the primary search strategies 68% of the time as their first command on entering a website regardless of whether the task is considered orienting or not. By separating out the commands that were general orienting, 92% of the time primary search strategies were used first. This suggests that the primary search strategies are commonly used upon entering a website.

This pilot study illustrated two future research objectives for information seeking for users with and without sight. The first object for future research involves creating a framework to assist users with keyword strategies and the second objective is enhancing the model of web-based information seeking for both groups.

**Null Hypothesis:**

**The efficiency of screen reader without the aid performs the same as the screen reader with the aid.**

**Procedures:**

The project will begin with each participant being interviewed. These interviews may be administered using several different methods including the telephone, self-administered survey and face to face interview. The users will be asked to conduct four tasks that involve browsing a website to find information on one of two possible websites. The user will also be asked to complete these same tasks on the same website with the assistance software aid. The websites used will be commonly used sites such as Wright State University's and Wright-Patt Credit Unions website. These tasks will be observed, videotaped and screen captured for documentation. The tasks will include common tasks performed on these websites.

**Risks:**

Minimal risks will be involved in this research. The tasks that the participants are asked to conduct on computer are assumed to be tasks they are familiar conducting. These tasks will be observed and videotaped for documentation. A possible risk would be if the security was breached and the videotaped information was viewed.

**Confidentiality:**

All data collected will be kept confidential in a locked file cabinet in an office located at Russ Engineering Building at Wright State University. Participants will only be addressed by subject identification number. No connection will be made between subject identification number and subject name on research materials.

**Potential Benefits:**

As a group, the participants will aid the research in optimizing accessibility in the Internet. The main benefit to them would be to potentially see progress in this area by the publication of this research. There are no direct benefits to the participant for their participation.

**Inclusion and Exclusion Criteria:**

All participants considered for this study will need to have some experience using computers and browsing websites. Level of expertise for the screen reader is important for this study. The software aid is being compared to the performance of participants that blind. Sighted participants are being used as a base comparison. All participants will be adults, over that age of eighteen.

**Consent:**

The next section contains a sample of participant's consent form. This form will be presented to the subject prior to any test. The subject will be read the consent and asked sign it. After the subject has signed the consent form, the principal investigator will sign and date as a witness.

**Survey consent letter:**

Date: 5/17/2010

Subject: Participant cover letter for "Development and Evaluation of an Interface Aid to Support Web Based Information Seeking for the Blind Research Study"

Dear Participant:

My name is Carissa Johnson and I am conducting a research project called "Development and Evaluation of an Interface Aid to Support Web Based Information Seeking for the Blind Research Study." I am inviting you to participate in this research project. I am a Ph.D. Candidate at Wright State University studying the effectiveness of an assistive interface used by people who are blind to search for information. This survey will ask you about words you expect to be present on a website when you are performing a few basic tasks.

Participation in this research projects is voluntary and your confidentiality will be maintained. No personal information is gathered in the survey that will identify you. You are free at any time to terminate your participation. You may terminate your participation by not completing the survey. Completion of the survey implies consent to participate in the research project.

This project will take approximately 5 minutes to complete. There are no risks to participating in the research. There are no direct benefits to participating.

If you have any questions or concerns about the research, I can be contacted by calling 750-7946 or emailing Brunsman.3@wright.edu or my faculty advisor, Dr. S. Narayanan. Dr. S. Narayanan can be reached by email at s.narayanan@wright.eduor by telephone at 937-775-5009. If you have general questions about giving consent or your rights as a research participant in this research study, you can call Wright State University's Institutional Review Board at (937) 775-4462.

Sincerely,

Principal Investigator: Carissa B. Johnson

Faculty Advisor: Dr. S. Narayanan
Email: s.narayanan@wright.edu
Principal Investigator and Advisor are located at
Wright State University
207 Russ Engineering Center
telephone number 937-775-5009

Date: 10/31/2010

Subject: Participant cover letter for "Development and Evaluation of an Interface Aid to Support Web Based Information Seeking for the Blind Research Study"

Dear Participant:

This cover letter will be read to all participants to describe the research project they are being asked to participate.

My name is Carissa Brunsman-Johnson and I am conducting a research project called "Development and Evaluation of an Interface Aid to Support Web Based Information Seeking for the Blind Research Study." I am inviting you to participate in this research project. I am a Ph.D. Candidate at Wright State University studying the effectiveness of an assistive interface used by people who are blind to search for information. There are two parts to this research project. First, I will ask you to answer some basic questions in a survey about your Internet use and then I will train you on the NVDA screen reader and the aid that was designed. Once this is complete you will be asked to conduct a few information searching tasks that I may observe and ask questions regarding these tasks. I will ask you to assess the workload for each task and then end with some final thoughts. Your participation in this research will enable me to learn more about the strategies and potential problems you face with website browsing. It will also allow me to test an information seeking aid and determine if it is helpful.

Participation in this research projects is voluntary and all participants' confidentiality will be observed. As a precaution, a code will be associated with your information on all research documentation. During the research, your keystrokes, screen movements and video will be recorded for later evaluation. These videotapes will be used to document the commands and screen movements you made while completing the tasks. Once the study is documented and completed, all tapes will be deleted and destroyed. You are free at any time to terminate your participation without any penalties or loss of benefits.

This project will take approximately 90 minutes and participants will be paid $20/hr for their time. Since the survey is conducted in person, the possible risk to participating in the research project is a breach in confidentiality. There are no direct benefits to participating.

I would be happy to send you a copy of the summary of results that should be completed by January, 2011.

If you have any questions or concerns about the research, I can be contacted emailing Brunsman.3@wright.edu or my faculty advisor, Dr. S. Narayanan. Dr. S. Narayanan can be reached by email at s.narayanan@wright.edu or by telephone at 937-775-5009. If you have general questions about giving consent or your rights as a research participant in this research study, you can call Wright State University's Institutional Review Board at (937) 775-4462.

Sincerely,

Principal Investigator:  Carissa Brunsman-Johnson
Faculty Advisor: Dr. S. Narayanan
Email: s.narayanan@wright.edu
Principal Investigator and Advisor are located at Wright State University
207 Russ Engineering Center
Telephone number 937-775-5009

______________________________________________

Participant Consent Signature

______________________________________________

Participant Name                                        Date

## APPENDIX C -Survey Questions

**User:_______________ Sighted or Blind Age: _________ Date:_____________**

1. When were you diagnosed as blind?
   □ Birth □ 0-5 years □ 6-10 years □ 11-20 years □ Later

2. How often use Internet?
   □ Daily □ Once a week □ Seldom

3. How comfortable are you browsing the Internet?
   □ Very comfortable □ Comfortable □ Not very comfortable

4. What screen reader do you use?___________________

5. How comfortable are you browsing that screen reader?
   □ Very comfortable □ Comfortable □ Not very comfortable

6. Are you familiar with NVDA screen reader? If yes, how familiar?
   □ Very familiar- I use it often
   □ Familiar- tried it out
   □ Not used it or heard of it

7. How do you use the Internet? (select all that apply)
   □ Research
   □ Shop
   □ Browse
   □ Email
   □Downloading files
   □ Games
   □ Training or education
   □ Web developing
   □ Networking or chat groups
   □ News

8. How would you describe the effort level for searching for items on a website?
   □ Very Easy □ Somewhat easy □ Not very easy □ Difficult □ Very Difficult

9. Do you visit a banking website? □ Yes □ No
   If yes, how often (choose closest fit)?

□ Daily □ Once a week □ Once a month □ Less than once a month

10. Rate how familiar are you with the (WSU or WPCU) Website
    □ Very Familiar □ Somewhat Familiar □ Not very familiar □ Unfamiliar

11. Do you visit an academic website? □ Yes □ No
    If yes, how often (choose closest fit)?
    □ Daily □ Once a week □ Once a month □ Less than once a month

## APPENDIX D – Final Questions

1. Rank you overall opinion of the website with the aid
   □ Very Easy □Somewhat easy □ Not very easy □Difficult □ Very Difficult

2. Rank you overall opinion of the website without the aid
   □ Very Easy □Somewhat easy □ Not very easy □Difficult □ Very Difficult

3. How do you feel the aid changed the way you found information?

4. Any other comments:

## APPENDIX E- Comparison of time of blindness

Table E-1 Comparisons of means for participants blind at birth and blind after age 5

| AID<br>KEYS | Number of tasks | TLX | Frustration | Time |
|---|---|---|---|---|
| Blind at birth | 28 | 46.32 | 30.25 | 298.1 |
| Blind after age of 5yrs | 16 | 53.65 | 48.44 | 297.4 |
| No KEYS | | | | |
| Blind at birth | 28 | 56.82 | 56.71 | 553.7 |
| Blind after age of 5yrs | 16 | 63.00 | 61.75 | 505.1 |

No significance was found.

## APPENDIX F- Age group comparisons for participants that are blind

These comparisons do not adjust for inflation of the Type 1 error for measuring multiple effects since few were found to be significant. Therefore, no significance can be placed on the factors that showed p values slightly under .05. Variance equality tests were conducted to determine if Pooled or Satterthwaite values were used.

**20's and 30's Comparison**

**Table F-1: Comparison of age groups 20's and 30's with and without KEYS for all TLX scores and subscales**

| KEYS | TLX | Mental | Physical | Temporal | Performance | Effort | Frustration | Command | Time |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 48.27 | 34.25 | 24.75 | 34.61 | 73.61 | 33.61 | 24.50 | 3.94 | 337.1 |
| 30 | 41.26 | 34.50 | 25.38 | 38.08 | 73.50 | 39.83 | 23.50 | 3.92 | 276.8 |
| No KEYS | | | | | | | | | |
| 20 | 59.50 | 63.00 | 27.67 | 45.33 | 59.00 | 58.17 | 61.75 | 8.33 | 554.4 |
| 30 | 58.90 | 56.38 | 39.63 | 55.00 | 47.75 | 71.75 | 58.75 | 9.88 | 465.1 |

*Indicate significant difference in p<.05.

**20's and 40's Comparison**

**Table F-2: Comparison of groups 20's and 40's with and without KEYS for all TLX scores and subscales**

| KEYS | TLX | Mental | Physical | Temporal | Performance | Effort | Frustration | Command | Time |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 50.36 | 34.25 | 24.75 | 40.25 | 71.25 | 38.83 | 27.25* | 4.67 | 337.1 |
| 40 | 50.40 | 34.63 | 15.04 | 40.21 | 74.92 | 38.17 | 45.71* | 4.38 | 285.3 |
| No KEYS | | | | | | | | | |
| 20 | 59.50 | 63.00 | 27.67 | 45.33 | 59.00 | 58.17 | 61.75 | 8.33 | 554.4 |
| 40 | 58.91 | 54.71 | 20.04 | 55.04 | 51.83 | 64.96 | 56.88 | 12.92 | 550.5 |

*Indicate significant difference in p<.05.

A significant difference is found between age group 20's and age group 40 and over for frustration with the KEYS prototype.

**30's and 40's Comparison**

**Table F-3: Comparison of age groups 30's and 40's with and without KEYS for all TLX scores and subscales.**

| KEYS | TLX | Mental | Physical | Temporal | Performance | Effort | Frustration | Command | Time |
|---|---|---|---|---|---|---|---|---|---|
| 30 | 42.68 | 34.50 | 25.38 | 37.88 | 74.88 | 40.00 | 24.75* | 4.5 | 276.8 |
| 40 | 50.40 | 34.63 | 15.04 | 40.1 | 74.92 | 38.17 | 45.71* | 4.38 | 285.3 |
| No KEYS | | | | | | | | | |
| 30 | 58.91 | 56.38 | 39.63* | 55.00 | 47.75 | 71.75 | 58.75 | 9.88 | 465.1 |
| 40 | 58.91 | 54.71 | 20.04* | 55.04 | 51.83 | 64.96 | 56.88 | 12.92 | 550.5 |

*Indicate significant difference in p<.05.

**APPENDIX G** –More comparisons of all three KEYS levels (blind no KEYS, blind with KEYS, sighted no KEYS).

These comparisons do not adjust for inflation of the Type 1 error for measuring multiple effects since few were found to be significant.

## Mental Demand

Table G-1: Sample size and means for mental demand compare all

| AID | Sample Size | Mean |
|---|---|---|
| Blind no KEYS | 44 | 57.27 |
| Blind with KEYS | 44 | 34.50 |
| Sighted no KEYS | 64 | 22.70 |

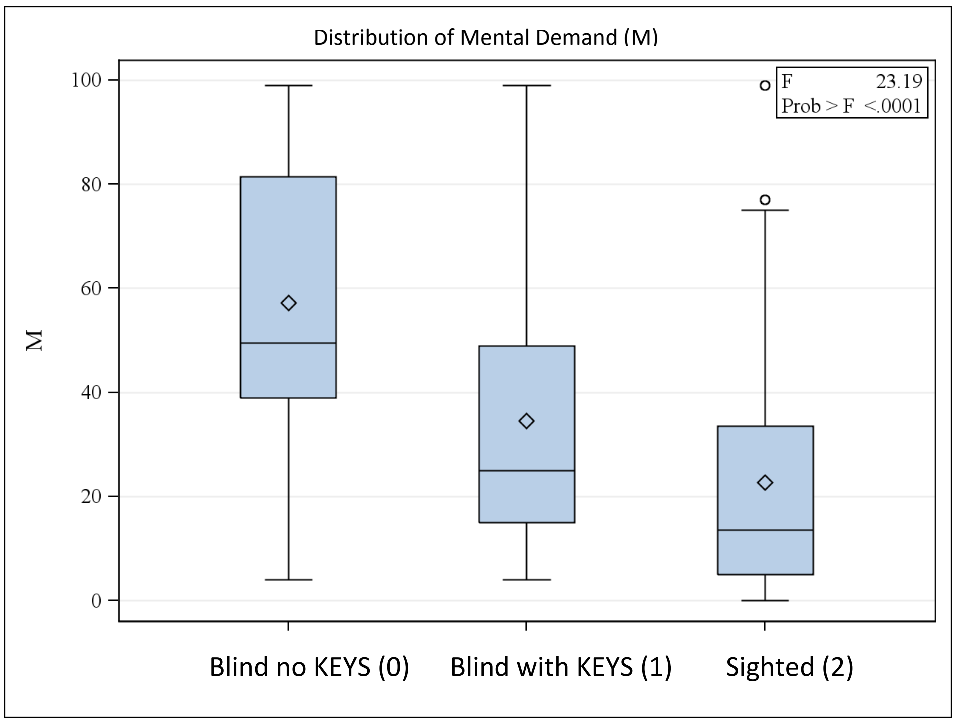



Figure G-1. ANOVA results for comparisons for all groups with number of commands.

Table G-2: Two way comparison mental demand score for all groups

| AID Comparison | Description | Significance at p<.05 |
|---|---|---|
| **0 - 1** | Blind without KEYS compared to blind with KEYS | Yes |
| **0 - 2** | Blind without KEYS compared to Sighted | Yes |
| **1 - 2** | Blind with KEYS compared to sighted | No |

## Physical Demand

To meet model assumptions, physical demand values needed to be transformed by adding 1 to the physical demand score and taking the logarithmic transform (plus one for values of frustration that were 0).

**Table G-3: Sample size and means for physical demand compare all**

| AID | Sample Size | Mean |
|---|---|---|
| Blind no KEYS | 44 | 25.68 |
| Blind with KEYS | 44 | 24.54 |
| Sighted no KEYS | 64 | 10.93 |

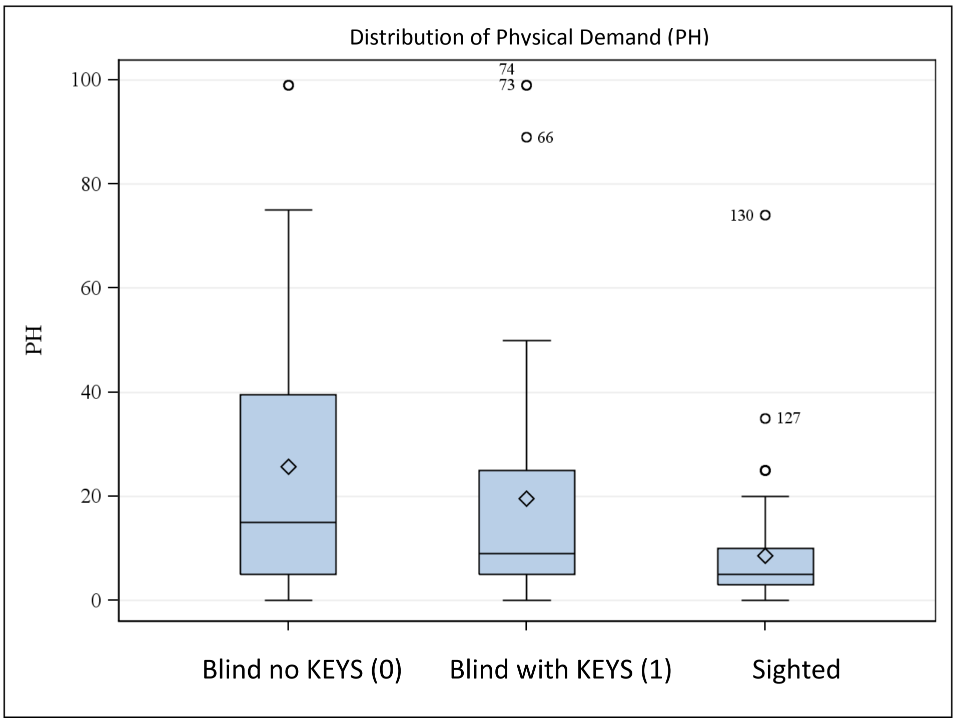



**Figure G-2. ANOVA results** for comparisons for all groups with physical demand.

**Table G-4: Two way comparison physical demand score for all groups**

| AID Comparison | Description | Significance at p<.05 |
|---|---|---|
| **0 - 1** | Blind without KEYS compared to blind with KEYS | No |
| **0 - 2** | Blind without KEYS compared to Sighted | Yes |
| **1 - 2** | Blind with KEYS compared to sighted | Yes |

## Temporal Demand

To meet model assumptions, temporal demand values needed to be transformed by adding 1 to the temporal demand score and taking the reciprocal (plus one for values of temporal demand that were 0).

**Table G-5: Sample size and means for physical demand compare all**

| AID | Sample Size | Mean |
|---|---|---|
| Blind no KEYS | 44 | 52.39 |
| Blind with KEYS | 44 | 39.80 |
| Sighted no KEYS | 64 | 18.47 |

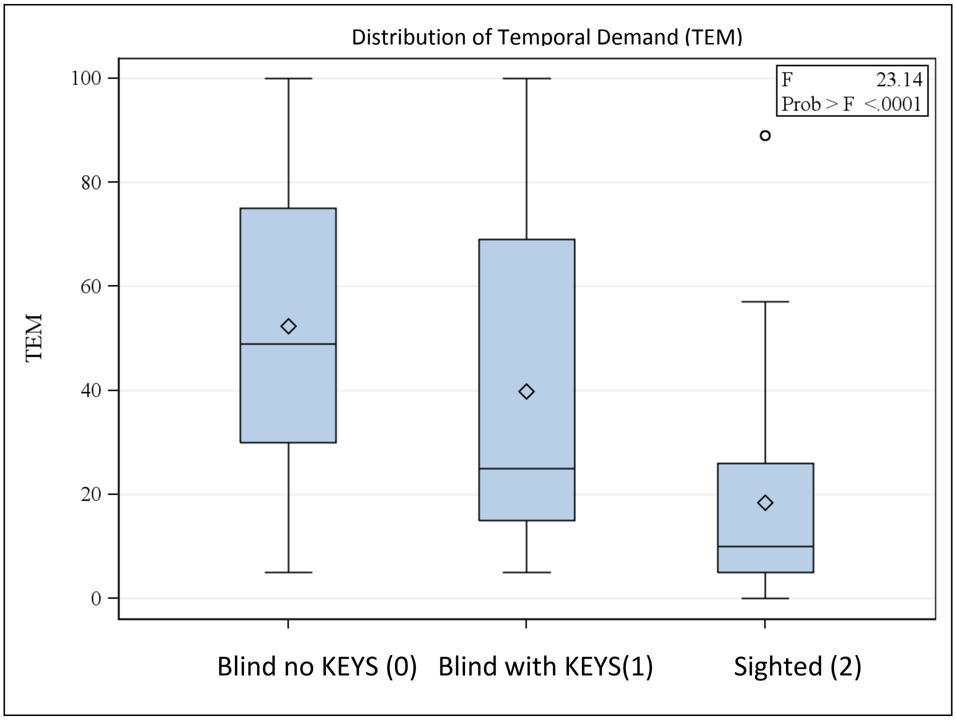



**Figure G- 3. ANOVA results for** comparisons for all groups for temporal demand.

**Table G-6: Two way comparison temporal demand score for all groups**

| AID Comparison | Description | Significance at p<.05 |
|---|---|---|
| **0 - 1** | Blind without KEYS compared to blind with KEYS | NO |
| **0 - 2** | Blind without KEYS compared to Sighted | YES |
| **1 - 2** | Blind with KEYS compared to sighted | YES |

## Performance

To meet model assumptions, performance values needed to be transformed by adding 1 to the physical demand score and taking the reciprocal (plus one for values of performance that were 0).

Table G-7: Sample size and means for physical demand compare all

| AID | Sample Size | Mean |
|---|---|---|
| Blind no KEYS | 44 | 53.04 |
| Blind with KEYS | 44 | 73.91 |
| Sighted no KEYS | 64 | 91.12 |

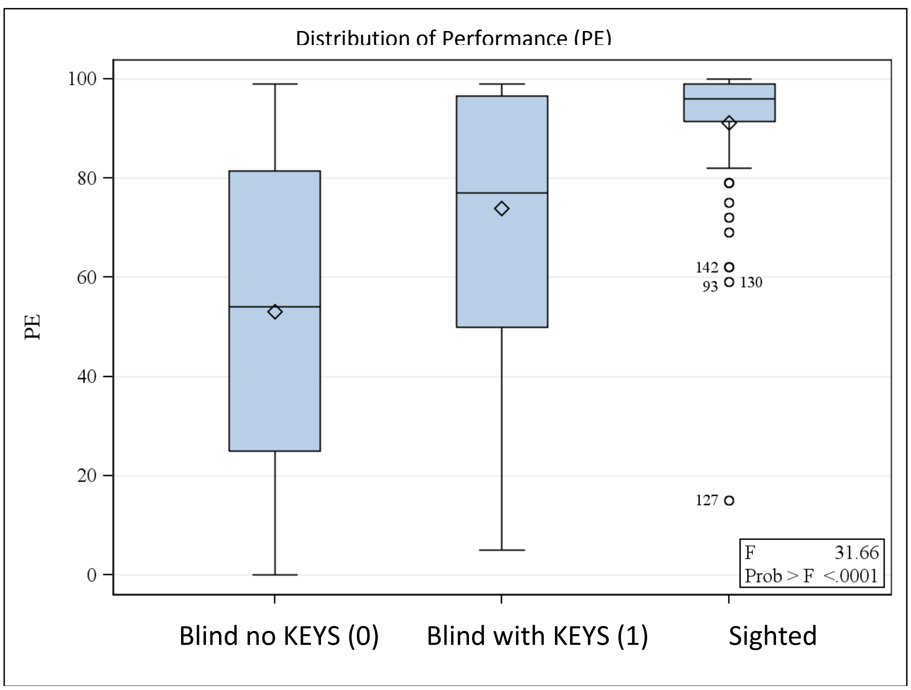



**Figure G-4. ANOVA results for** comparisons for all groups for Performance.

**Table G-8: Two way comparison performance score**

| AID Comparison | Description | Significance at p<.05 |
|---|---|---|
| **0 - 1** | Blind without KEYS compared to blind with KEYS | Yes |
| **0 - 2** | Blind without KEYS compared to Sighted | Yes |
| **1 - 2** | Blind with KEYS compared to sighted | Yes |

# References


Bennett, K.B. & Flach, J.M. (2011, in press). Display and interface design: Subtle science, Exact Art. London: Taylor & Francis.

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. *ASSETS'07,* Tempe, Arizona.

Card, S., Pirolli, P., Van Der Wege, M., Morrison J., Reeder P., Schraedley, P., Boshart, J. (2001). Information scent as a driver of web behavior graphs: Results of a protocol analysis method for web usability. *SIGCHI'01*, March 31- April 2, Washington. Seattle, 498-505.

Carroll, J. M., & Olson, J. R. (Eds.). (1987). *Mental models in human-computer interaction: Research issues about what the user of software knows*. Washington, D.C.: National Academy Press.

Craven, J. (July 2003). Access to electronic resources by visually impaired people. *Information Research, 8*(4), June 25, 2008. Retrieved from http://informationr.net/ir/8-4/paper156.html

Donker, H., Klante, P., & Gorny, P. (2002). The design of auditory user interfaces for blind users. *NoriCHI,* Arhus, Denmark.

Drori, O., & Alon, N. (2003). Using document classification for displaying search results lists. *Journal of Information Science, 29*(2), 97-106.

Flemming, L. (2008). *Reading for thinking* (2nd ed.) Wadsworth Publishing.

Goble, C., Harper, S., & Stevens, R. (2000).The travails of visually impaired web travellers. *Hypertext 2000,* San Antonio, TX.1-10.

Harper, S., Stevens, R., & Goble, C. (1999). Towel: Real world mobility on the web. In J. Vanderdonckt, & A. Puerta (Eds.), *Computer-aided design of user interfaces II*, pp. 305-314, Kluwer Academic.

Harper, S., & Bechhofer, S. (2005).Semantic triage for increased web accessibility. *IBM Systems Journal, 44*(3), 637-648.

Hillen, H., & Evers, V. (2007).Website navigation for blind users. In Y. Sharp, H. Rogers & J. Preece (Eds.), *Interaction design: Beyond human-computer interaction* (2nd ed.), Wiley Publishers, Chichester, UK.

Jacobson, R. D. (1998). Cognitive mapping without sight: Four preliminary studies of spatial learning. *Journal of Environmental Psychology, 18*, 289-305.

Juvina, I., & van Oostendorp, H. (2008). Modeling semantic and structural knowledge in web navigation. *Discourse Processes, 45*, 346-364.

Kuber, R., Yu, W., & McAllister, G. (2007). Towards developing assistive haptic feedback for visually impaired internet users. *CHI 2007,* San Jose, California.1525-1534.

Kurniawan, S. H., Sutcliffe, A. G., Blenkhorn, P. L., & Shin, J. (2003). Investigating the usability of a screen reader and mental models of blind users in the windows environment. *International Journal of Rehabilitation, 26*, 145-147.

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.

Liu, Z. (2005). Reading behavior in the digital environment changes in reading behavior over the past ten years. *Journal of Documentation, 61*(6), 700-712.

Maeda, J., Fukuda, K., Takagi, H., & Asakawa, C. (September/November 2004). Web accessibility technology at the IBM Tokyo research laboratory. *IBM Journal Research & Development, 48*(5/6), 735-749.

Marchionini, G. (1998). *Information seeking in electronic environments*. New York, NY: Cambridge University Press.

Moskovitch, R., & Shahar, Y. (2009).Vaidurya: A multiple-ontology, concept-based, context-sensitive clinical-guideline search engine. *Journal of Biomedical Informatics, 42*, 11-21.

Murphy, E., Kuber, R., McAllister, G., Strain, P., & Yu, W. (2008).An empirical investigation into the difficulties experienced by visually impaired internet users. *Univ Access InfSoc, 7*, 79-91.

Narayanan, S., Ruff, H. A., Edala, N. R., Geist, J. A., Patchigolla, K. K., Draper, M., et al. (2000).Human-integrated supervisory control of uninhabited combat aerial vehicles. *Journal of Robotics and Mechatronics, 12*(6), 628-639.

Nielsen, J. (2005). *Mental models for search are getting firmer.* Retrieved September 10, 2008, from http://www.useit.com/alertbox/20050509.html

Nielsen, J. (2006). *F-shaped pattern for reading web content.* Retrieved 9/8, 2008, from http://www.useit.com/alertbox/reading_pattern.html

Nielsen, J., & Tahir, M. (2001).*Homepage usability: 50 websites deconstructed*. Indianapolis: New Riders Publishing.

NV Access. *NVDA.* Retrieved 2010, from www.nvda-project.org

Passini, R., & Proulx, G. (March 1988). Wayfinding without vision an experiment with congenitally totally blind people. *Environment and Behavior, 20*(2), 227-252.

Passini, R., Proulx, G., & Rainville, C. (1990).The spatio-cognitive abilities of the visually impaired population. *Environment and Behavior, 22*(1), 91-118.

Princeton University. *AboutWordNet.*, 2010, from http://wordnet.princeton.edu

Rotard, M., Taras, C., & Ertl, T. (2008).Tactile web browsing for blind people. *Mulimed Tools Appl, 37*, 53-69.

Roth, P., Petrucci, L.S., Assimacopoulos, A. & Pun, T. (2000). *Audio-Haptic internet browser and associated tools for blind and visually impaired computer users*. Retrieved 7/29/2008, from citeseer.ist.psu.edu/roth00audiohaptic.html.

Rothrock, L., Barron, K., Simpson, T. W., Frecker, M., & Ligetti, C. (2006). Applying the proximity compatibility and the control-display compatibility principles to engineering design interfaces. *Human Factors and Ergonomics in Manufacturing, 16*(1), 61-81.

Salampasis, M., Kouroupetroglou, C., & Manitsaris, A. (2005).Semantically enhanced browsing for blind people in the WWW.*HT '05,* Salzburg, Austria. 32-34.

Shebilske, W., Narakesari, S., Alakke, G., Douglass, R., & Faulkner, E. (2009). Web usability and screen readers. *Paper Presented at the 24th Annual International Technology and Persons with Disabilities CSUN Conference,* Los Angeles, CA.

Shebilske, W., Ganesh, A., & Narakesari, S. (2008) *Nationwide & Wright State University accessibility project.* Unpublished manuscript.

Shneiderman, B., & Plaisant, C. (2005).*Designing the user interface: Strategies for effective human-computer interaction* (4th ed.). USA: Pearson Education, Inc.

Song, D., & Bruza, P. D. (2003).Towards context sensitive information inference. *Journal of American Society for Information Science and Technology, 54*(4), 321-334.

Takagi, H., Saito, S., Fukuda, K., & Asakawa, C. (September 2007). Analysis of navigability of web applications for improving blind usability. *ACM Transactions on Computer-Human Interaction, 14*(3), Article 13.

Tan, G. W., & Wei, K. K. (2006). An empirical study of web browsing behavior: Towards an effective website design. *Electronic Commerce Research and Applications, 5*, 261-271.

Thissen, F. (2004). *Screen design manual. Communicating effectively through multimedia* (3rd ed.). Germany: Springer-Verlag Berlin Heidelberg.

Walshe, E., & McMullin, B. (2006). Browsing web based documents through an alternative tree interface: The WebTree browser. *Computers Helping People with Special Needs 10th International Conference ICCHP 2006,* Linz, Austria. 106-113.

Yesilada, Y., Stevens, R., Harper, S., & Goble, C. (September 2007). Evaluating DANTE: Semantic transcoding for visually disabled users. *ACM Transactions on Computer-Human Interaction, 14*(3), Article 14.

Yu, W., Kuber, R., Murphy, E., Strain, P., & McAllister, G. (2006). A novel multimodal interface for improving visually impaired people's web accessibility. *Virtual Reality, 9*, 133-148.

Zhang, Y. (2008). Undergraduate students' mental models of the web as an information retrieval system. *Journal of the American Society for Information Science and Technology, 59*(13), 2087-2098.

## Curriculum Vitae

Wright State University, Dayton, Ohio • (937) 775-5153 • brunsman.3@wright.edu

# Carissa Brunsman-Johnson

### Education

Doctor of Philosophy, Engineering, Wright State University Dayton, OH., 2011

Master of Science, Human Factors Engineering, Wright State University, Dayton, OH., 2006

Bachelor of Science, Computer Information Systems from the College of Engineering, The Ohio State University, Columbus, OH, 1993

### Industry Experience

2010-present SAIC, Sr. Scientist
2001–2005 Independent bookkeeper
1999–2000 SAIC, Web and Database Programmer
1998-2000 YSI, Inc., Electronic Business Team Leader
1996-1998 UES, Inc., Manager of NetPage Integration Services
1993-1996 Ernst & Young LLP, Senior Computer Consultant

### Research Experience

2005–2007 Graduate Research Assistant-
-Eaagles Simulation Software funded by the US Air Force and the Wright Brothers Institute
-Network Centric Warfare funded by the Human Effectiveness Directorate at the US Air Force Research Lab at WPAFB

Volunteering
2008 -Disability Services Technology Center at Wright State University
2009 -Goodwill EasterSeals

Publications

Brunsman-Johnson, C., **Narayanan, S., Shebilske, W., Alakke, G., Narakesari, S. (accepted) Modeling Web-Based Information Seeking by Users who are blind.** *TIDT Disability and Rehabilitation: Assistive Technology.*

Johnson, C., Stieger, M., Narayanan, S., Haas, M., Urling, S. (Summer 2006). Modeling a Notional Network-Centric Warfare Command Center for Human-Centered Decision Aiding. *Information Age Warfare Quarterly*, I(2), 5-16.

Rao, D. M., Hodson, D. D., Stieger Jr., M., Johnson, C. B., Kidambi, P., & Narayanan, S. (2008). ***Design and implementation of virtual and constructive simulations using OPENEAAGLES***. Deer Park, NY: Linus Publishing.

### Presentations

**"**Development and Evaluation of an Interface Aid to Support Web Based Information Seeking for the Blind Research Study," 2010 IGERT Winter Intersession Conference, Dayton, Ohio
"Glucose Monitoring Devices," *2007 Annual Dayton Engineering Sciences Symposium* , Dayton, OH

## Teaching Experience

WSU- ISE 451/ HFE 651 Human Factors Engineering in Computer Systems Design Spring 2008
WSU- Guest lecturer on Universal Design and Accessibility in ISE451/HFE651 Spring 2009

## Awards and Honors

President of HFES WSU chapter- awarded Bronze Award 2010
Awarded IGERT 3 year Fellowship 2007
Member of Phi Kappa Phi Honor Society 2006
Member of Phi Kappa Delta Honor Society 2006
Member of the Society of Women Engineers, Secretary 1991-1992
Dedication award from Women in Engineering 1992