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Impact of shortcut key and design content for navigation in the context of an e-commerce website for visually impaired people

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Preface

This thesis is an accomplishment of the curriculum of master's degree in Universal Design of ICT under the department of computer science, Oslo Metropolitan University situated in Oslo, Norway.

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Abstract

This research has been conducted to find out the impact of using shortcut key and reducing the design content in an e-commerce webpage for screen reader users / visually impaired users. The purpose of this study is to address the changes that should be required to make in new webpages for screen reader users and make them more usable and accessible. The study was based upon a hypothesis that using the shortcut key in webpages for navigation could lessen the frustration and workload of screen reader users. A group of sighted participants were blindfolded during the experiment and were asked to complete the given task. NASA-TLX method of measuring the workload has been used for the statistical workload data followed by a survey of the participants to explore their psychological and social behavior regarding their experience. The collected data were then analyzed using one tailed paired t-test, and descriptive analytical method and the result were generated. The result shows that using the shortcut key and reducing the design content in webpages for the navigation for screen reader users reduces workload and enhance the usability of webpages.

Keywords

Screen reader; Visually impaired people; Navigation; Design content; NASA-TLX; Keyboard

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Abbreviations

WHO: World Health Orgranization

HTML: Hyper Text Mark-up Language

NASA: National Aeronautics and Space Administration

TLX: Task Load Index

PDF: Portable Document Form

IVRS: Interactive Voice Response System

WCAG: Web Content Accessibility Guidelines

NoSQL: Non Structured Query Language

JSON: Java Script Object Notation

SDLC: Software Development Life Cycle

NVDA: Non-Visual Desktop Access

IDE: Intergrated Development Environment

Js: Java Script

CSS: Cascading Style Sheet

CLI: Command Line Interface

HTTP: Hyper Text Transfer Protocol

APIs: Application Programming Interfaces

RAM: Random Access Memory

RTLX: Raw Task Load Index

HCI: Human Computer Interface

SPSS: Statistical Package for Social Science

IBM: Internation Business Machine

CONTENTS

1 Introduction

The internet has become a crucial part of every individual's life. A portion of them considers it as a vital necessity in daily life (Widyanto & McMurran, 2004). The Internet has integrated in such a way that a person searches on Google about the symptoms before visiting the doctor (Van Riel, Auwerx, Debbaut, Van Hees, & Schoenmakers, 2017). People who rely on the internet include visual impairment people also. It was assumed that around 285 million people throughout the world are visually impaired out of which 39 million of them are entirely blind (WHO, 2010). There is a significant need for designing and developing the websites which are accessible for visually impaired people as they also occupy a space of worldwide internet users. The challenge counts more for designers as visual impairments are of many types. Designers and developers are responsible for designing websites which are accessible for all kind of users and overcome the challenges.

Sighted users have various means of webpages navigating such as a mouse, trackpad, keyboard, and many others. Unfortunately, visually impaired people mostly rely on the keyboard to interact and browse the webpages (Manohar & Parthasarathy, 2009). The easiness of navigation for these users depends upon how competently the content of webpages is structured (Oyewole, 2019). Most of the browsers have their default function to navigate the links in the webpages. Users can press the tab key to navigate to the links on a page. The screen reader reads the content of the link, and along with the use of entering key, the users can visit the desired link (Pontelli et al., 2002). There are various modes of interaction in a screen reader, which produces different results. The mode of interactions are using a tab key to read the upcoming contents, a next heading key to read the content of next heading, a touch to read the content of an area where the users touch on the screen or mobile devices (Powermapper, 2019). These are the basic interacting ways in the web using a screen reader. This research study holds a hypothesis that using this built-in interaction mode provided in screen readers for navigation creates frustration in the users during navigation. The research also hypothesizes that these kinds of frustrations can be reduced or eliminated if shortcut keys were provided for the screen reader users, which will help them to navigate the link or content in a web of their choice in shortcut and efficient way. This study also hypothesizes that reducing the complex structure in web could also help to eliminate the frustrations in screen reader users.

Screen readers are the most popular assistive technology used for blind people to visit the web (Yesilada, Harper, Goble, & Stevens, 2004). The aim proposed in this paper will be empowering every individual who is visually impaired and assist them in ordering products online independently. The main theme of this research is to increase the functionality of an e-commerce website by focusing on several functional parts in the website itself. This research study focused on several functional parts of the web to reduce the mental workload for visually impaired people whenever they are surfing through webpages. The first one is the use of shortcut keys so that the visually impaired people could traverse to the core component of the web using the keyboard only. The shortcut refers to the navigation to the HTML element with the use of keys in keyboard.

On the other hand, the author has also engrossed about reducing the content of the web as far as possible and have proposed the way of a descriptive approach of describing the product in the site whenever the user visits it. The author believes that these changes will have a positive effect in terms of workload for the visually impaired people and if applied in modern web technologies could be a beneficial part of the universal design of web products and their usability. The proposed project will be a template design of web technology mainly in front end using Angular and typescript, which can be used by the available online shopping site. The developed application is accessible and comprised of usability.

The NASA Task Load Index (TLX) has been used as an experimental tool in this research procedure. It is one of the efficient methods of measuring the workload in terms of six different factors, including mental, physical, temporal, performance, effort, and frustration (Hart, 2006). The sighted participants were blindfolded and were asked to complete a list of tasks on two different prototypes. The reason behind selecting two different prototypes is to make a valid selection of the e-commerce website, which consists of a design problem. The problem addressed in the old existing prototype was eliminated, and a new prototype along with the use of shortcut keys was designed. The completion of the task was followed by the NASA-TLX experiment and interview of participants so that both psychological and social behavior of participants could be gathered. The collected data were later analyzed using the one-tailed paired t-test. Similarly, the interview data were also analyzed in a descriptive analytical form. The result obtained was then used for measuring the acceptance and rejection of the hypothesis that was generated at the initiation of the research process.

1.1 Problem Statement

Many standard guidelines for the webpage designing have been introduced to make more accessible and usable. Similarly, many types of research have been conducted to make the web accessible and usable for every kind of disabilities, including visual impairments. The development of a screen reader has been a boon for visually impaired peoples. However, there are many factors which frustrates the visually impaired people while using the screen reader. Lazar, Allen, Kleinman, and Malarkey (2007) conduct a research study and find out several factors which frustrate the screen reader users. These factors were a conflict between application and screen reader, the layout of the webpage which confuses feedback of a screen reader, unlabeled and poorly designed/developed forms, missing of alt text, tie between unreachable PDF, ambiguous links, the crash of screen readers (Ibid.).

Along with these factors, navigation for visually impaired people using a screen reader is also one of the substantial obstacles to interact with webpages and its content (Craven, 2003). Screen readers are the software which synthesizes text into speech and reads the content of websites for visually impaired users. Visually impaired people cannot surf the webpages and internet as sighted users do. Hence, visually impaired people must rely on screen readers to visit the webpages or use the computer even. The users use the traditional approach to interact with the web contents, which could bring the frustrations among them when the screen reader traverse along with each content of the web. The users must go through each content out of their concern to reach the content of their desire, which is time consuming (Lai, 2011). Hence, the lack of a straightforward navigation approach and use of complex design content could increase the workload of the users and reduces the usability of the webpages. Proper research was needed to be carried out to address these issues and find out its remedy.

1.2 Research gap

From a review of past research, we found that the number of researches has been done for online shopping for visually impaired users in previous decades. The researcher has introduced navigation using the screen recorder consists of lots of challenges and problems. Similarly, some researcher has pointed out the issues of content of information in digital data could decrease the performance of the visually impaired people who use assistive technologies to interact. More advanced research is being carried out till now, to deliver the universal design of webpages and make it more usable and accessible. However, very less research has found to be carried out in the context of navigation using a screen reader by people with visual impairments in the context of an e-commerce website.

This research aims to design a feasible solution for the problem that has been seen in the previous research modules. The use of shortcut key and reducing the design content of the web, including the essential content only, could make visually impaired people navigate and interact in e-commerce webpages with less workload and frustrations, which will increase the usability of e-commerce webpages and could be deployed in other webpages in near future days.

1.3 Research Hypothesis

The following hypothesis was made based on the assumptions mentioned above:

Hypothesis:

H_o: The proposed web prototype will be identical, functionally, and statistically, with the existing e-commerce websites, in the concern of usability. Even using the shortcut keys and reducing the design content on the web will not be able to reduce the workload and frustration for visually impaired people to navigate using a screen reader and interact with the webpage. There will be no significant difference between them.

H_1: The proposed web prototype will not be identical, functionally, and statistically, with the existing e-commerce websites, in the concern of usability. Using the shortcut keys and reducing the design content will address the problem seen in the old prototype and lessen the workload/frustration for visually impaired people who interact with webpages with the help of a screen reader. There will be a significant difference between them.

2 Literature Review

In the paper, the author has discussed interaction behaviors of blind users, screen reader and navigation issues, challenges & expectation with visual content over using the webpages and e-commerce websites.

2.1 Related work on e-commerce sites, screen readers and navigational approaches for blind users

Craven (2003) researched with the aim of further understanding of user experience and behavior with web-based resources, with a concern about the information retrieving procedure by visually impaired and blind people. In their research, they used 20 visually impaired people and 20 sighted people, who were asked to seek information using various electronic resources. Each step of the procedure was logged. Pre-task and post-tasks questions were catechizing to gather the data qualitatively. The outcome of the research discloses that the visually impaired users spend more time browsing and searching the web varying considerable ably relying on the design content of the site. Visually impaired users have taken more time to navigate around each page, predominantly if, the webpage contains excessive information or has many navigation links. The result also reveals that people who have more experience with assistive technology performs better and were successful with the task. Designers may have as assumed that every single user has access to the modern version of assistive technology, which is not the always case. The researcher has coined that designers will have to take these actualities into account.

Webpages are visually interactive. It is challenging to travel along with the web for visually impaired people (Goble, Harper, & Stevens, 2000). The screen reader is mostly used by visually impaired people to navigate through webpages and its content. At the same time, screen readers cannot perceive the complete constructional and route-finding information, like sighted users, linked within the visual description of web pages. Goble et al. (2000) have approached the remedy for this problem by annotating pages using ontology. This travel ontology enriches constructional, structural and navigational knowledge about these objects. Such information is made computational and conspicuously accessible using semantic web tools and technologies. Semi self-service tool named Dante could recognize the travel objects, which interprets these objects and uses it to convert the web pages and enrich the travel support with the help of Travel Ontology.

Lazar et al. (2007) has enlisted significant causes for frustration, as their research outcome, for blind people using screen readers. The reasons are (i) layout of a page which confuses the screen reader for the proper feedback; (ii) dissension between an application and a screen reader; (iii) dismally unlabeled/designed forms; (iv) no use of alternative text for images and pictures; and (v) ties between inaccessible PDF, misleading links, and screen reader crash. Researchers have also pointed out that most of the causes like designing of inappropriate graphics labels and forms, misleading page layout, and design content could be solved easily if the web engineers effectively focus on these issues. Technical challenges such as screen reader conflicts and crashes are required to be addressed by screen reader engineers. Blind people were presumably attempting to resolve a frustration in this research where the researcher reports that on an average, around 30.4% of the time is taken more due to these frustrations and its situations.

Leporini and Paternò (2004) in their research, proposed a set of standards which could improvise the accessibility and usability of websites for visually impaired people. Their set of criteria was determined via experimental feedback from where potential issues were found. A systematic approach was deployed based upon these issues, which results in the classification of these standards into usability aspects. In these categories of usability aspects, researchers have included using the shortcut keys for navigation for the people rely upon a keyboard to interact in their web. They have suggested designers add a link or a section which includes all the information about the hotkeys and its uses. They also emphasized that the method the hotkeys should start with the initial letter of the word so that users don't need to memorize all the content and would be more comfortable for them to navigate.

Guercio, Stirbens, Williams, and Haiber (2011) researched to find out the challenges for visually impaired people while interacting with web content. They found that sighted users can filter the information provided in the web smoothly, but it was challenging for the visually impaired people. To address this problem, the researcher proposed prototype WAVES. It was a system which restructures the content or page of webpages and analyzed webpages, finds out the essential constituent from webpages, uses their visual cues and semantic information to find out its importance, arrange them accordingly to their importance and restructure these contents into the original form so that users could read them in incisive format. They conducted a user testing of their prototype to check its performance and found out that WAVES prototype helps to increase the accuracy and speed of readers while interacting with webpages.

Easiness of navigation is one of the critical factors of usability for visually impaired people, more important for complex webpages which are used in e-commerce and online portals (Takagi, Saito, Fukuda, & Asakawa, 2007). But it is complicated for the automated inspecting tools to assess navigation functionalities even in a single page application. Hence, it is far more challenging to find out the navigational issues and beyond the limit when it comes to a complete web application. Takagi et al. (2007) conducted a quantitative experiment to measure the accessibility state of real-world applications and webpages. They analyzed real world users' experience and behavior in such web contents. At first, they prevailed in the automatic analytical procedure for navigation in webpages and surveyed around 30 global e-commerce shopping websites using this method. In their second study, they focused on the pulverized analysis of real-world users' experience and behavior among several of these e-commerce websites. They amended a voice browser to capture users' behavior and information gained by the user. They conduct user testing on current sites with the help of that tool. They introduced an analytical and envisaging mechanism for those noted data. In their result, they found that users immensely rely on scanning navigation rather than logical navigation. They proposed landmark-oriented navigation based on their achievement.

Lai (2011) addressed the problem of interaction with the web for blind people in their research. They point out that visually impaired people could access the internet and its content with the help of a screen reader which readout the complete webpage, which take more time for users to go the content of their choice. The researcher in this study proposed a solution to categorize the content of webpage into various logical sections, which will contain a descriptive heading along with number so that the screen reader users could enter the number to get the detail content of that section. Their idea was based upon transforming the web portal into an Interactive Voice Response System (IVRS), which makes easier for blind people to interact with webpages by using cellphones. The users could listen to the index page and get the details of the content by entering the corresponding number on the keyboard.

Only sighted users interact with the web with multiple interacting devices such as a mouse, a keyboard, a trackpad, and others. Hence, it becomes easier for them even to interact with the inaccessible content of webpages. Screen reader users encounter these kinds of usability problems and challenges when designers only undermine the design content for sighted users (Hillen & Evers, 2007). Borodin, Bigham, Dausch, and Ramakrishnan (2010) overviewed strategies of browsing webpages and found that screen-reader users faced challenges in various complex and unfamiliar websites along with dynamic webpages with auto-refreshing elements. They have addressed that better exploration of browsing strategies could enhance the designers for designing accessible and usable websites, development of new technique and tools which sharpens the experience real world users more smoothly and effectively and help to overwhelm the starting learning idea for users who are not aware of intuitive browsing strategies.

The sophisticated design content and layouts of e-commerce websites create difficulties for screen reader users to navigate using a screen reader (Buzzi, Buzzi, Leporini, & Akhter, 2009). Moreover, security becomes the primary concern for this kind of customers (Ibid.). Buzzi et al. (2009) investigated about interaction behavior of blind users in eBay, one of the most popular online shopping websites, focused on its usability and accessibility aspect along with security concerns when navigating through a screen reader. In their paper, they pointed major issues while interacting through a screen reader in one of the popular e-commerce websites, including overloading of information, lack of contextual elements, lack of proper user interface and structure, an odd mixture of structure and content, tables, form elements and difficulties in accessing multimedia elements.

It was found from many types of research that blind people face more difficulties than other kinds of disabilities such as hearing, low vision or motor impairment while performing any task (Craven & Brophy, 2003). Petrie, Hamilton, and King (2004) conducted accessibility testing of around 100 web applications for perceptual, visual, and motor impaired people. They found out that those websites which are accessible by differently abled people are visually appealing. One hundred sites covering five different areas were examined with an automated validation tool and user testing approach, including 51 disabled users out of which 10 of them were utterly blind users. The outcome of research shows that the average completion rate of task drops from 76% to 53%, where the lowest score was of blind users. They found that blind users face more difficulties than the other kind of disabled users' group (4.2 out of 1-7 Likert Scale value, lowest among all other scores).

Similarly, the research group of Manchester Metropolitan University, (Craven & Brophy, 2003) researched non-visual access behavior of visually impaired and blind users who carry out information finding tasks which includes the usage of search engines. Visually impaired peoples took 2.5 times longer time than sighted users to search for information. This gap was further explored by Ivory, Yu, and Gronemyer (2004); when a set of the task was given to blind users' group, they prolonged twice more than sighted users to find out the search outcomes, and thrice more to find out similar websites.

E-commerce websites consist more problems and challenges than other webpages as its user interface includes of the contents in which many features are active, and even offer critical functions likewise secured transaction. Norbert (2000) highlighted that concern for usability should be given of high importance while designing an online shopping site.

Various research has been carried out in the field of online shopping sites along with the concern of usability and accessibility, but distinctly less researcher has given importance for entirely blind people (Brudvik, Bigham, Cavender, & Ladner, 2008; Gladstone, Rundle, & Alexander, 2002; Petrie, Badani, & Bhalla, 2005).

Petrie et al. (2005) explored accessibility standard logs of a couple of online shopping and commercial sites and found that level of a standard guideline of Web Accessibility Guidelines (WCAG) 1.0 was overvalued in more than 30% analyzed webpages. Structuring of web contents into the relevant section increases navigational smoothness for blind people in two different ways: it allows to jump into logical sections of material from one to another and provides a layout of the page. Precisely, a division of headings helps easy navigation as there are various shortcuts available in default screen readers (Ibid.). Gladstone et al. (2002) investigated the sighted user's behavior and experience related to headings while interacting with a webpage. They observed different results, such as the hierarchical structure of webpages, the acts of users for identifying sections and many more.

Moreover, the author implicated multiple tools and techniques of information retrieval. They developed a system which infers the context (color, font, size, text, etc.) to find out if the phrase works semantically when used as a heading, and eventually affix level of headings with the help of JavaScript. The human-labeled headings were collected and evaluated in the system named "HeadingHunter" and found a high degree of precision (0.92 out of 1). Usability factors in many web applications meet the business objective and have an astounding user experience. Hence, accessibility is a challenge more than a restriction for designers and developers.

The effective interaction with online shopping sites depends upon the experience and knowledge of users (Buzzi et al., 2009). The enormous scale of a crucial user's data needs to be communicated and warehoused in various places, which causes critical privacy issues. There have been numerous studies in the area of privacy and security issues (Chong, Yang, & Wong, 2003; Egger, 2000; Friedman, Khan Jr, & Howe, 2000; Wang & Emurian, 2005).

Some of the online consumers are not entirely comfortable when it comes to security issues in online shopping sites during an economic transaction (Runyan, Smith, &

Smith, 2008). Online consumers have mostly doubt about the payment through online purchases (Wang & Emurian, 2005) and insecure about the product bought as they don't have any choice for physical examination of the product (Ye, Li, Kiang, & Wu, 2009). Online consumers must bear a considerable risk due to trust issues which could result for them to loss the money and privacy (Friedman et al., 2000; Wang & Emurian, 2005). For example, phishing causes a flood of electronic frauds and even damage the semi-skilled or unskilled consumers, which could result in the inducement of online users to use e-commerce websites.

Trust issues have been acknowledged as one of a significant blockades in the growth of e-commerce applications (Brudvik et al., 2008; Gladstone et al., 2002; Petrie et al., 2005) , which strikes more when it comes to blind users who rely on a screen reader to interact with webpages as they cannot see the screen. They require more cognitive and physical effort while interacting with e-commerce applications. Hence, the assurance of trust and security is one of the fundamental criteria that need to be followed while designing e-commerce applications.

Accessibility is the vital requirement which allows users to access the web contents. On the other hand, usability concerns with providing users easy, smooth, and efficient interaction and navigation (Buzzi et al., 2009). Navigation is the critical issues for people with special-needs, specifically for blind users, as they need to be aware of their current location of web content, travel to their desired location or return to the initial or beginning element (Debevc, Verlič, Kosec, & Stjepanovič, 2007).

2.2 Web Accessibility

The information is visually presented in modern e-commerce application using latest design tools such as JavaScript, HTML 5, Flash based content. Accessibility plays a critical role in applications. However, people with disabilities face a problem of accessibility in these modern tools (Sohaib & Kang, 2017). These researchers conducted a test on several web pages following the guideline version 2.0 of WCAG. A checker[1] is an online web service developed by several the researcher of the University of Toronto. Three types of problems are identified by this service that is

- KP (Known Problems)
- LP (Likely Problems)
- PP (Potential Problems)

The experiments were conducted on several Australian e-commerce web sites. It was found that not level A was obtained for web content accessibility guideline for an e-commerce web application. The problems that B2C (business to consumer) e-commerce application found are described below:

- Missing text element's label and input assistance, which was found to be 65%.
- The color contrast was not smooth. It was one of the problems.
- Correct mistakes and help users avoid 73%.
- The issue with visually impaired users for hearing contents were 68%.

2.3 Web Usability

There have been several definitions which extend to a standard definition of usability that is the user should find information or data easily when they interact with the web application. Krug (2014) defined that a typical person with average experience and ability must be able to figure out how to do the task efficiently. Nielsen (1999) described usability in-depth, stating the following five qualities that must be included in a web application and make it entirely usable. They are:

- Efficiency
- Learnability
- Memorability
- Satisfaction

1. A checker, *"web accessibility checker",* https://achecker.ca/checker/index.php, (accessed May 15, 2019)

- Error

The usability of a webpage plays a significant role in websites in users experience. The usability flaws were discovered using several experiments. A research was conducted by (Pokki, 2016) to test the usability of four web applications. The following problems were found such as issue in finding relevant contents, functions of applications not working correctly, the difficulty in readability, and arrangements of web application contents.

2.4 Summary

From previous research studies, it was found that lots of research has been carried out in the field of navigational issues and approaches for screen reader users. Similarly, lots of problems and challenges were discussed by many scholars in their research and provide their substantial solutions and findings. The factors of frustration for screen reader users, the complex structure of e-commerce website, use of shortcut key as a standard guideline of usability, retrival of information by visually impaired users have been clearly explained in previous research.

This research further explores the methods of reducing the frustration in screen reader users while navigating in an e-commerce website. The researcher investigates the impact of using shortcut key while using the screen reader. Similarly, in this research study, the researcher has hypothesized that the complex structure of e-commerce websites should be eliminated to simple and easy so that the visually impaired people could interact the content easily.

3 Methodology

This chapter includes all the steps of protype design, conduction of experiment, and data collection procedures. A control experiment was designed where the sighted users were blindfolded, and user testing was performed. The user testing was conducted in the old e-commerce website and new proposed e-commerce prototype. A list of tasks was assigned during user testing, and the participants were asked to complete the task. NASA TLX experimental method has been used for the generation of workload data. The user was asked to complete the NASA TLX questionnaire, and the data were collected, which were further analyzed using one-tailed pair t-test. The one-tailed pair t-test was to find out the impact of using shortcut keys and eliminating the complex structure of the ecommerce website. An interview was also conducted to analyze the social behavior and experience of the participants. It was also necessary to find out the degree of influence (positive or negative impact) of using shortcut keys and functional changes. The data gathered from NASA TLX and interview were analyzed further and used for the acceptance or rejection of the hypothesis.

3.1 Prototype design

As the research hypothesis suggests, the author has designed a prototype, an e-commerce website along with the use of functional / a shortcut key so that users could traverse to the HTML element with the help of a keyboard. Similarly, the complex content of e-commerce webpages was also reduced so that users interacting with webpages using screen recorder could do it with less effort and frustration. The author has also included a description of the product clearly so that the screen reader would read the content and description of the product clearly and help to inform the users in a well descriptive manner.

On the other hand, the researcher has picked up the existing e-commerce webpage www.sears.com as an old prototype. The reason behind to choose was simple as it does not consist of any functional or shortcut key. Similarly, this e-commerce webpage has lots of complex design contents which if accessed through the screen reader increase a workload for the users to traverse through it. The description of the product was also not so descriptive, and screen reader had to cross through much mid content HTML element to access the description of the product.

The user-centric design approach was taken into consideration. The process of designing and developing a prototype consisted of two phases. Database designing plays a vital role in arranging all the information about products, orders, customers, etc. The NoSQL database was chosen after thorough analysis, which was in JSON format. The wireframes were designed in a structured manner which was accessible and user-friendly. The color, fonts, design, and pages were significant in wireframe.

The software development lifecycle section consisted of two phases, where the agile model for SDLC was followed. A working prototype was delivered after each cycle along with testing results. The requirement and documents were done on the starting phase of SDLC. The development and testing phases were done simultaneously

After the prototype was ready, the author collected 20 participants for the control experiment of the research process. User testing approach was followed as a control experiment environment where the participants were asked to complete a specific task in a blindfolded manner with the help of a screen reader. Due to the time limitation and other limited resources, it was difficult to involve the real blind user in the actual experiment, which is one of the limitations of this research process. Hence, sighted users were blindfolded and were involved in the experimental design procedure. NVDA screen reader was used in this research process as it is an open source and free. It is simple, fast, functional, intuitive, ethical, portable, international, and peace of mind with compare to another high-cost screen reader (NVAccess Limited, 2019). Each participant was asked to complete the task. The task was randomized so that the different user experience could be achieved, and the experimental data would be variance. After the completion of user testing, users were introduced with the NASA-TLX workload experiment followed by the interview process. The users were blind folded only during the task assignment. Since the participants were not familiar with the blindfolded experience, the proper assessment was provided to the participant, including opening the link, providing initial training to use a keyboard and other small issues. The participants were informed about why the test was conducted. Similarly, there were also informed about what kind of data is being extracted from the NASA-TLX workload experiment and interview. The information that was gained from the test were collected in a sheet for further data analysis procedure.

3.1.1 User-Centric Design of prototype

The design of the page was kept consistent and straightforward. Clear, consistent, and simple were three primary things considered in the design of the site. Minimum graphics were used throughout the site. Simple sitemap or text index was used to take the user to the required page. Images and other optical stuff contained alternative text, so that text should describe the picture in a few simple sentences (short). All the links were divided into simple lines as some devices take a group of links as only one link, which may create difficulty (Norman, 1986). The visually impaired person wants to know what's going on a screen. For these pages design, the solid color was always considered the best for the background and contrasting color for the font (Harris, 1991). Different users have different preferences. The page was flexibility for font size; it was not too large or too small. The user had an option to reduce or increase the font size of the page when required using browser settings. Writing the first letter as capital may cause difficulty in reading, and it's better to avoid capitalization. Frames make access to information complicated various devices, which implies that some tools can't read the information on structures, so the alternate text was provided for all the structures in the page (Barkan, 1991). Avoiding the structures on the homepage was very efficient. Special care was provided for the tabulation since some devices may read a table from line to line, which may make understanding difficult for users. Web Content Accessibility Guidelines (WCAG) was followed as it is the crucial part of accessible web development methodologies.

3.1.2 The process of design and development of a prototype

3.1.2.1 Phase 0

In phase 0, the prototype of the web application was developed using agile methodology. The application included all the features for online shopping for visually impaired people. The phase 0 followed all the software development life cycle with each element being added. The testing and a necessary change were made in every period.

The phase 0 involved information gathering and preparing to develop a prototype application. Analyzing the application developed was critical in this phase.

3.1.2.2 Phase 1

This phase doesn’t require much information gathering processes; instead, it involved fixing bugs and making changes after a thorough analysis. It included all the steps of the software development lifecycle. The black box and white box testing were the most important final step in this phase. It also contained the releasing and maintenance approach at the end.

3.2 Design

This section contained all the plans for the proposed project. The model included wireframes and database design for a web application. It was the essential part of an application which interacts with user and store information. They were explained and discussed clearly.

3.2.1 JSON APIS design of the prototype

The detailed JSON data model was presented for an online shopping application for visually impaired customers. The database that was used for the application was in JSON format, which is also used by the NoSQL database, which is the most effective solution for managing extensive data and provide consistent speed. The next generation application was being supported by NoSQL’s use. The simple reading and writing operation was performed for data storage, which also includes performance and scalability to applications (Grolinger, 2013).

The modeling of the database was created accordingly with online shopping and one dimension easy to use the application of visually impaired people. The business requirement provides all the data model that is required for the application. The critical value pair was one the most effective approach where the structure of data changed as per requirement. The document stores key-value pair data where the key is the name and value are the data (Grolinger, 2013).

The database needs to hold the following data that are given below:

1. Customer:

Customer Name, Age, Address, Customer type, Zip code, Number, Email id, Username, Password and Pin code.

2. Product:

Product Name, Category, Unit Price, Quantity, Images, etc.

3. Shopping carts:

Customer Name, Age, Address, Number, Email id, Username, Password, Pin code, Product Name, Category, Unit Price, Quantity, Images, etc.

3.2.2 Wireframes of prototype

The wireframe provides structure to the user interface, which communicates with the customers. The web page layout was presented in this section of the prototype, where all the necessary elements are being added. Online two details were performed on the header of the page, and they are the website’s name and a search option (Norman, 1986). The search operation could be used by speech recognition in future work. The main menu consists of only a few options to choose using keyboard and speech. The main page of the prototype as per wireframe design is given below.

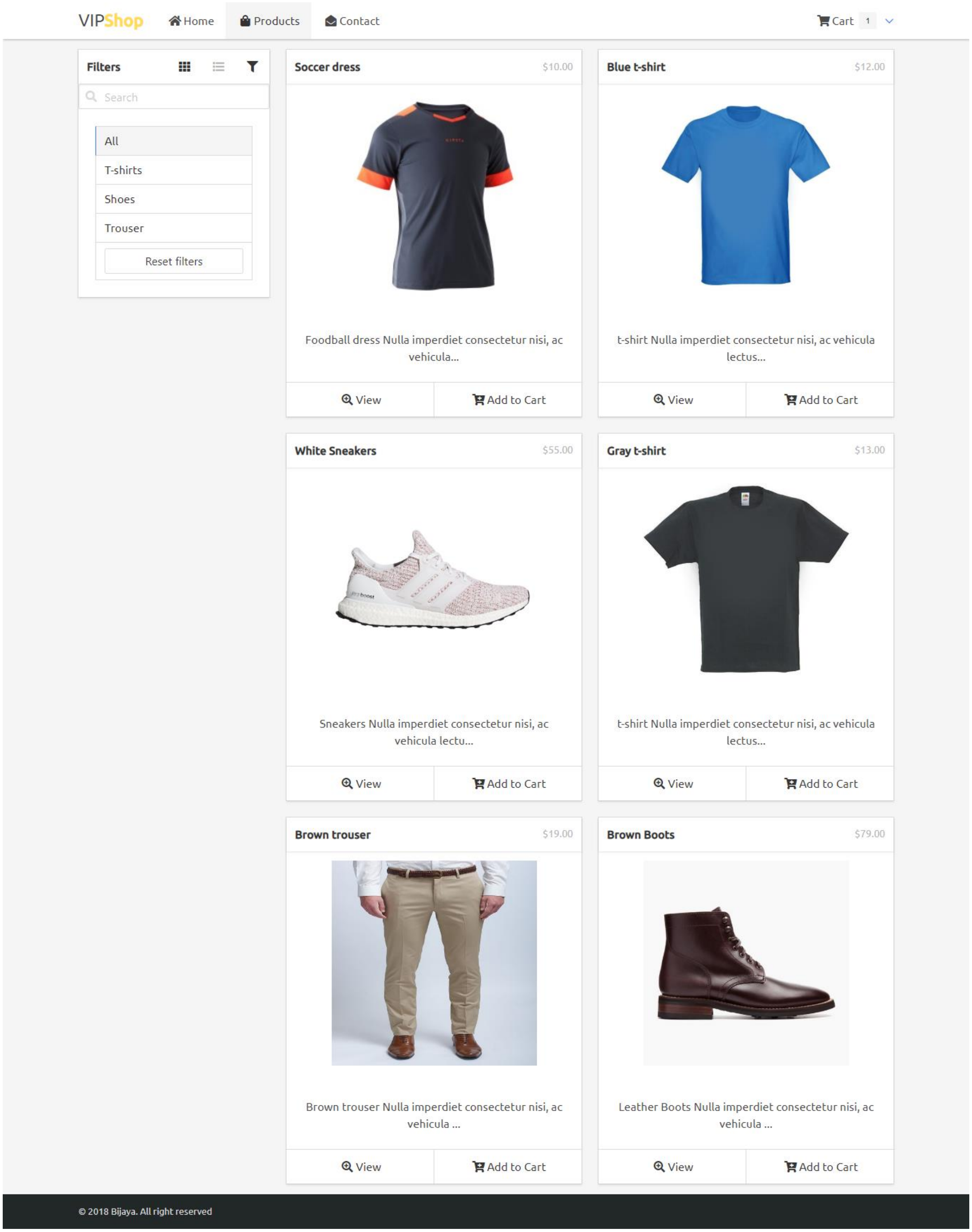


Figure 3.1: Home page

The product section in the web application consists of an image with all the necessary details for visually impaired people in other texts. The category section was chosen using the keyboard tab button. The shopping cart section was presented on the right-hand side, and when pressing a key in the keyboard, it will be selected. A simple design was shown in the wireframe, which was modified when a better approach was encountered.

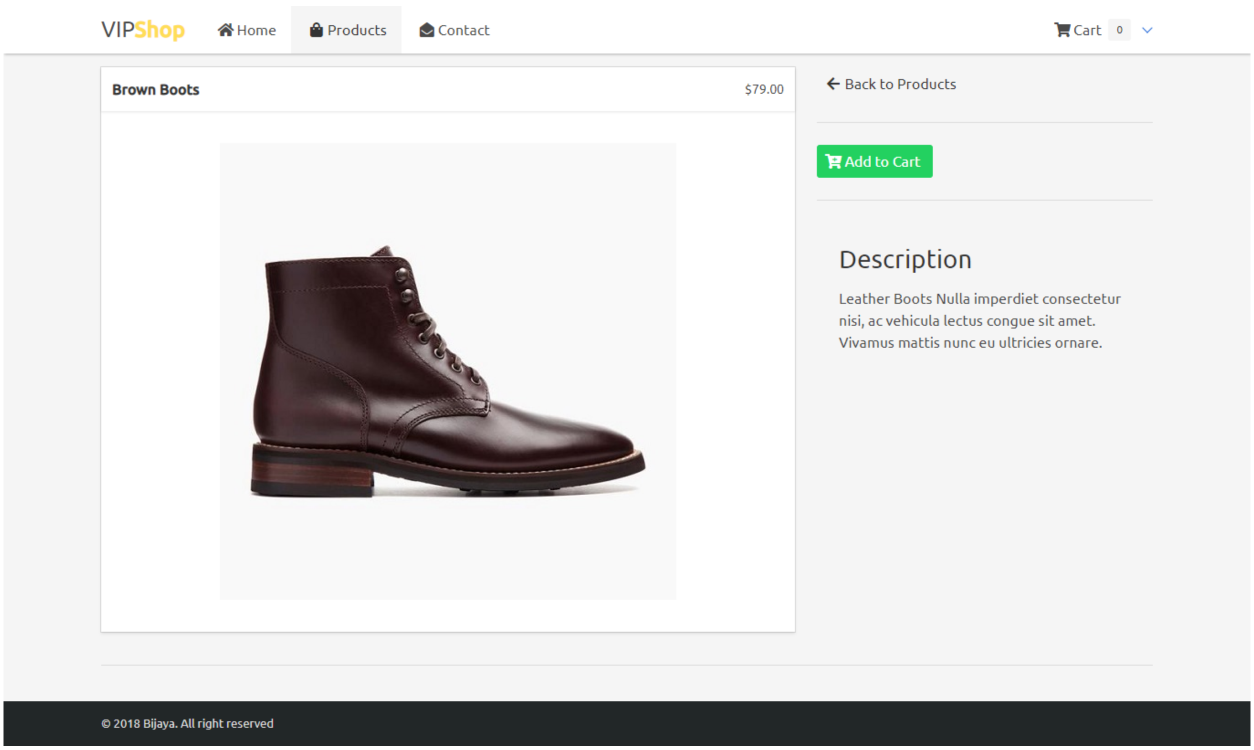


Figure 3.2: Product detail page of the proposed prototype

The product detail page payout is shown above, which contains all the necessary information about the product. There are two sections inside a section with images on left and details on the right. The pictures are presented with audible detail about the product like its color, size, shape, and other information. The delivery address is confirmed by a call from customer service after the other is placed, which makes it easy to order and find more about the delivery. Users can traverse to the respective HTML element using the shortcut keys. In this prototype, we have used the shortcut key to cross to the navigation bar. For example: if the user wants to go to Home of the webpage, they could press CTRL+ALT+H.

Similarly, to travel to products, contacts, cart the user could use CTRL+ALT+P, CTRL+ALT+C, CTRL+C respectively. The participants were well informed about these hotkeys and where they can use if necessary. These hotkeys were introduced to the design so that the user doesn't need to press the tab key continuously to reach the desired element and save the time of the users.

The use of shortcut keys was the most significant challenge in this research process because participants have never experienced using a keyboard in a blindfolded manner even though most of them have a good typing speed and experience. The use of braille keyboard on real was supposed to be costly due to a limited resource. Hence, an alternative method of making a regular keyboard into a braille keyboard was followed. A braille keyboard sticker was used instead so that blindfolded participants could recognize the keyboard correctly. Since there were only several keywords that were used in the new prototype, only the corresponding keywords were peel-and-stick during the experiment so that there will be no confusion for the participants to recognize the correct keyword. It was a very economical option for creating the multilingual braille keyboard. They were not dry out, ooze adhesive, or did any physical damage for the user or manual. However, basic training was required for every participant of these braille formats and their respective representation of the keyboard's letter.

Figure 3.3: Braille keyboard stickers (Datacal, 2019)

The profile section and other pages were designed as any other web applications.

3.2.3 Software Technology

- Online Wireframe application was used to design the layout of the prototype, which was described in the section above. The web application design was carefully analyzed for user-centric design.
- Visual studio code: The IDE used for developing a prototype application was chosen from the product of Microsoft. It is defined as a source code editor which is an open source and provides a wide range of programming language compatibility. The latest version of visual studio code, i.e., version 1.29, was used. It offers several the plugin which helps to programme easy and save time. The tslint plugin helps to find bugs in the application while it is being developed.

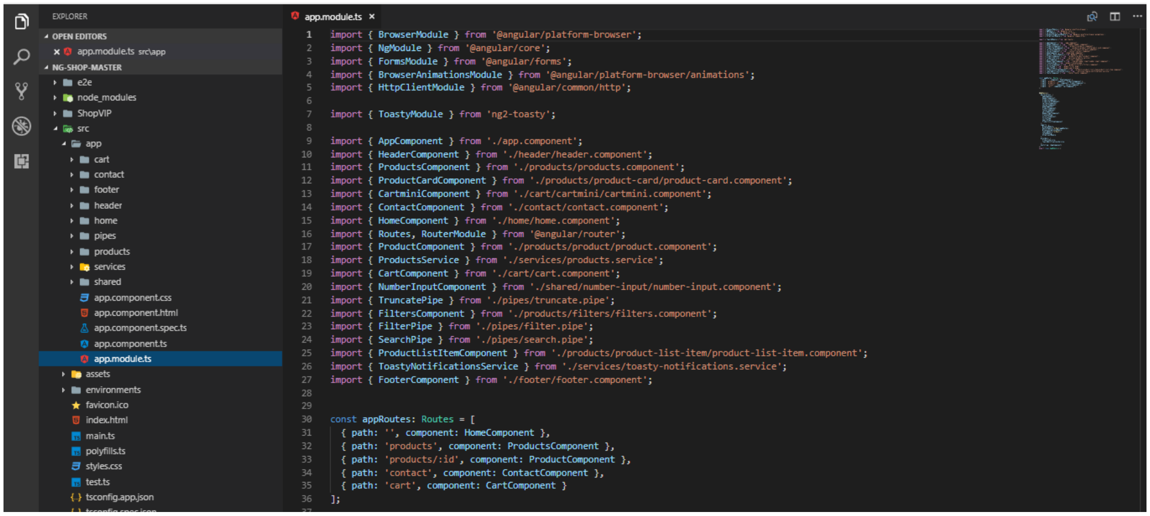


Figure 3.4: Visual Studio Code

- CSS: It is used to design the presentation of the web application. The contents which are in HTML is made to present using CSS example layout, colors, fonts, effects, etc. It also provides responsiveness to the web application for different size of devices. The CSS is wholly depended on HTML code.

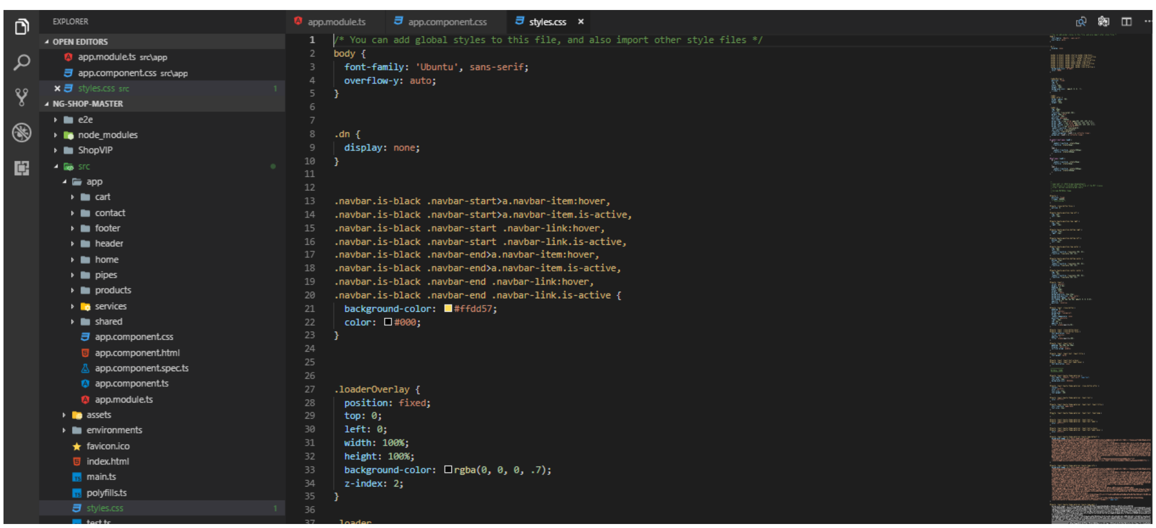


Figure 3.5: CSS Snippet

- HTML: Hypertext markup language is used to develop the structure of websites. It defines the structure of a web application. Tags represent it. The prototype is developed using HTML for providing structure to the web application.

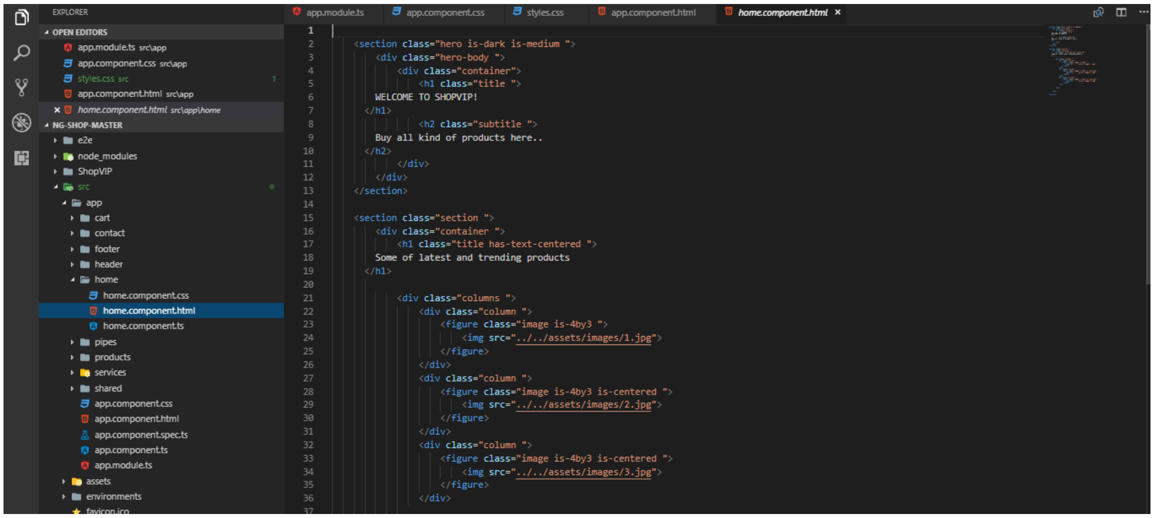


Figure 3.6: HTML snippet

- Node Js: One of the most used open source JavaScript cross-platform runtime environment is node.js. It follows event-driven architecture which can perform asynchronous input-output. This approach provides maximum optimization and scalability in a web application. It is governed by node.js and facilitated by linux. Ryan Dahl wrote node.js in 2009. The main reason to choose node.js for prototype design is that it can create web servers by itself, which contains modules. These modules are facilitated by file input/output network like TLS, HTTP, and TCP. Most highly scalable servers can be created even without creating threading. Today, there are several libraries for node.js for performing different features.
- Angular 5: It is a typescript based front-end web application programming language. It is made open source and is led by the Google team. The web application development has been made easy with angular providing number of features to make web application reactive to use. Angular is faster, more comfortable, and smaller (Green & Seshadri, 2013). It provides continuous web application support. It contains built-in optimizer for deployment. The angular runs on the node.js environment and uses Angular CLI to perform different operations. The command [Ng new projectName] is used to create a new project with the name of the project. The command [ng serve] is used to run the web angular web

application which runs on localhost 4200 port. The folder structure of the Angular 5 application is being given below:

- E2e: This is used for end to end testing.
- Node modules: It contains all the packages that are required to run the angular project. On running npm install creates this folder and downloads all the packages from the internet.
- Angular-cli.json: This contains all the information about the project, its cli versions.
- Package.json: This contains all the information about the packages and libraries that are used for the project.
- Src: This folder contains all the codes for an angular application. Inside the src folder, there is several subfolders and files.
- Module.ts: this file contains information about a module of the application. It provides and lets the application know that servers are being used and which packages are being imported.

Component: The component in an angular application is its main building block. It contains CSS, HTML, metadata for animations, input-output, and imports.

3.2.4 Prototype contents

The prototype developed is a single page application which acts as multipage. Once the application is open in the browser, it doesn’t need to load again. The component which is small segments in the application access APIs and makes the web application work. This feature is found to be reactive and mostly used by several companies all around the world. There are several components of the prototype, which is divided into pages. Each page is in the components like a home page, product page, cart page, etc. A fake json server was created to work with APIs form angular prototype. It contains data in JSON format.

The web application uses HTTP client to access the JSON data from the server. The use of getting, post, update, put APIs calls done in the service file in the angular application.

3.3 Software development lifecycle

Software development life cycle plays an essential role in the planning and development of the application. The proposed project follows the agile software development life cycle in two phases, as discussed in the above section (Pendharkara, Rodgerb, & Subramanian, 2008). The agile model for software development is chosen as it has many advantages over other SDLCs as it follows rapid delivery of developing the product. The working product is delivered after each cycle. The methods and phases that are in this software development life cycle are as given below:

1. Requirement analysis
2. Design and documentation
3. Development
4. Quality assurance and testing
5. Deployment and maintenance

3.3.1 Requirement analysis:

Business goals and user needs were discussed in this phase of the software development lifecycle. The detailed analysis was required to develop a better solution which has been done in previous sections along with wireframe designs. The steps in this phase were to discuss and collection of required information. All the required data was collected and structured. Both the business requirement and functional requirement analysis were done. The hardware and software requirements were as given below:

Hardware requirement:

- 350GB Hard Disk
- 2GB RAM
- CPU Quad 2GHz

Software requirement:

- Chrome Browser

- Internet
- Visual studio code IDE (Angular, Nodejs)
- JSON SERVER

3.3.2 Design and documentation:

This phase deals with the design of web application and user interface. It also contains the design of a database and processes. The UML diagrams were presented and thoroughly discussed. The entire key features for the applications were:

1. Online order
2. Search feature
3. Shortcut key assistance for choosing products and ordering.
4. Fully supported screen reading.

3.3.3 Development:

This phase consists of coding using HTML, CSS, typescript, angular, and NoSql database. The development phase consists of designing web pages for all the device sizes. Responsive web pages development was required. The designing was done according to wireframes. The shortcut keys were added to function with the developed web application using typescript. MongoDB, the NoSQL database is used to store all the product details and order details.

3.3.4 Quality assurance and testing:

The quality assurance process was being followed along with the black box and white box testing. The web application was tested against responsive design.

3.4 Experimental design on the prototypes

Group of 20 participants was requested to volunteer for the experiment. Users of different age group and genders were taken under consideration. The sighted users were informed about the research process, why is being conducted, and what kind of experimental data was going to extract. They were also informed about the blindfolded process due to the limitation of resources. Participants were blindfolded during the assignment of the task. An eye mask was used to make them blindfolded. They were completely assisted so that none of the participants will feel any discomfort during the whole session. They were blindfolded during the assignment of task only. The eye mask was released for the rest of the experimental procedure, which includes data collection through the NASA-TLX process and interview of participants. Since all the participants were chosen with good web experience and conscience computer knowledge, they were all familiar with the screen reader and its application. However, none of them were the regular user of this software as they don't need this tool in their past computer interaction process. They were informed about the task that they must complete in the old prototype and a new prototype. At the same time, they were also informed about the use of shortcut key which is the crucial factor of our research design that could be used through a keyboard instead of pressing tab every time for navigation. An observation sheet was used to observe the user experience, to calculate the time required for the completion of the task, and whether the users were able to complete every task or not. After successful user testing procedure, on both prototypes, the user was introduced with the NASA-TLX experiment. They were informed about the NASA-TLX experiment and what kind of data it collects. The workload factors used to measure in the NASA-TLX experiment was clearly described to all the users. This experiment process was followed by an interview or survey with the users. In this interview, the investigator asked the users several questions related to their social behavior with the task and their experience. This interview was conducted as it could provide more evidence for the acceptance of alternative hypothesis based upon the user's real-time experience data.

3.4.1 Comparative study of prototypes

3.4.1.1 Design Content

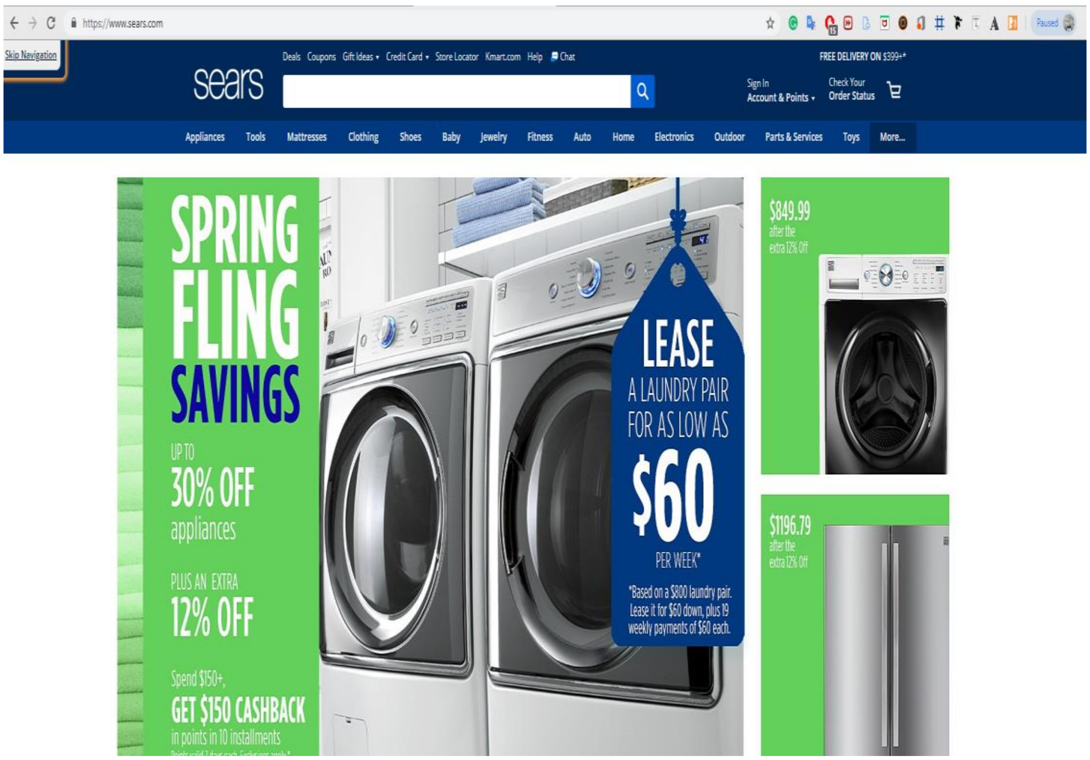


Figure 3.7: Homepage of the old prototype

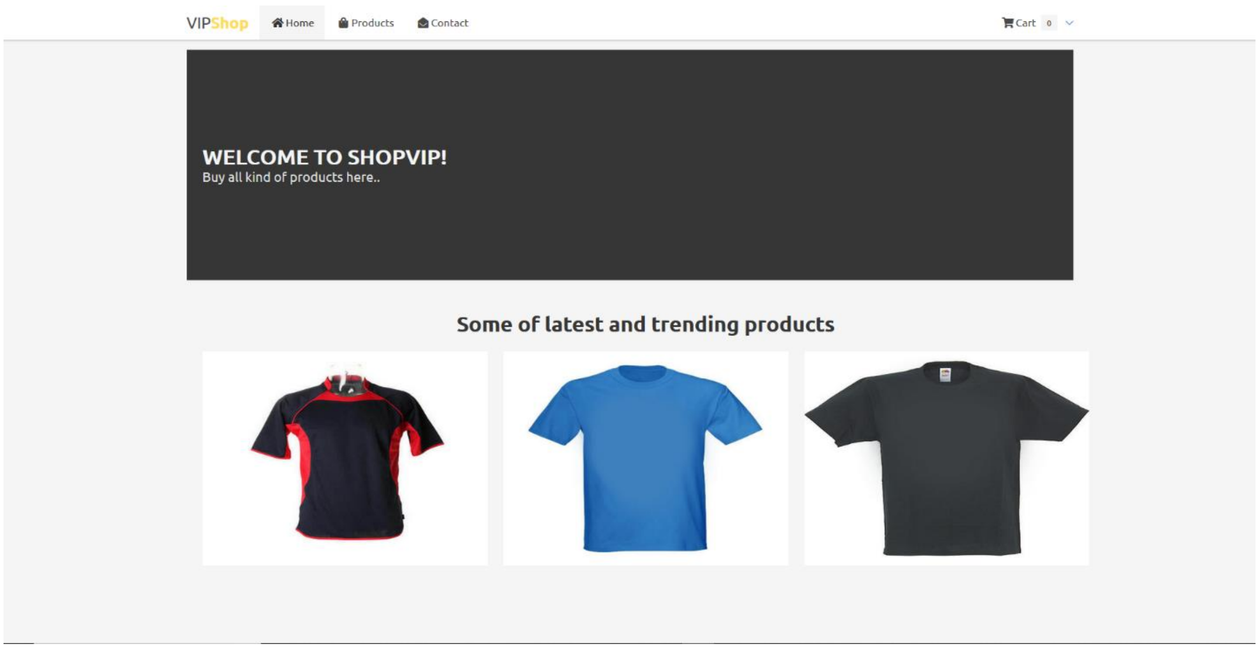


Figure 3.8: Home Page of New Prototype

The complications of design content in the old prototype and new prototype can be viewed above daigrams. The home page of early prototype consists of lots of information in along with many elements. There is no problem with these contents for the sighted users; however, for screen reader users, these lots of content could not be unnecessary. The users who rely upon the tab key to cross the element of webpages must go through all those unnecessary elements of the page which concern them very less.

On the other hand, it can be viewed that the design content of the new prototype is much simpler. Only the fundamental element has been well structured so that screen reader users could navigate to their desired element easily and timelier.

3.4.1.2 Use of shortcut key

In the old prototype, the screen reader users must rely upon the traditional approach of keyboard navigation. There is no shortcut to traverse to the desired element of the webpages using the keyboard. The research assumption was based on this issue. While navigating, the users could feel the frustration in this old prototype.

However, in the new prototype, the author has introduced the shortcut key to navigate the essential element of prototypes like home, products, contact, and cart.

3.4.1.3 Description of product

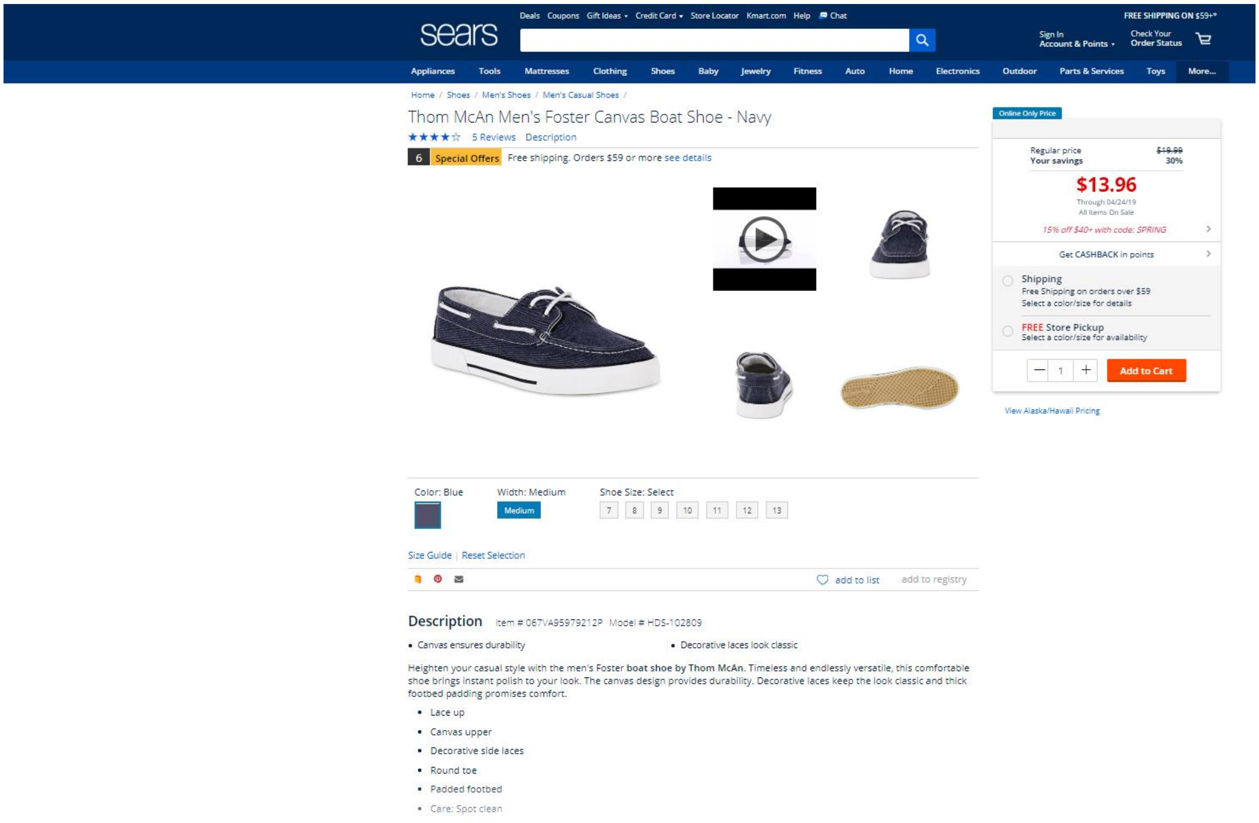


Figure 3.9: Screenshot of the product selected in Old Prototype

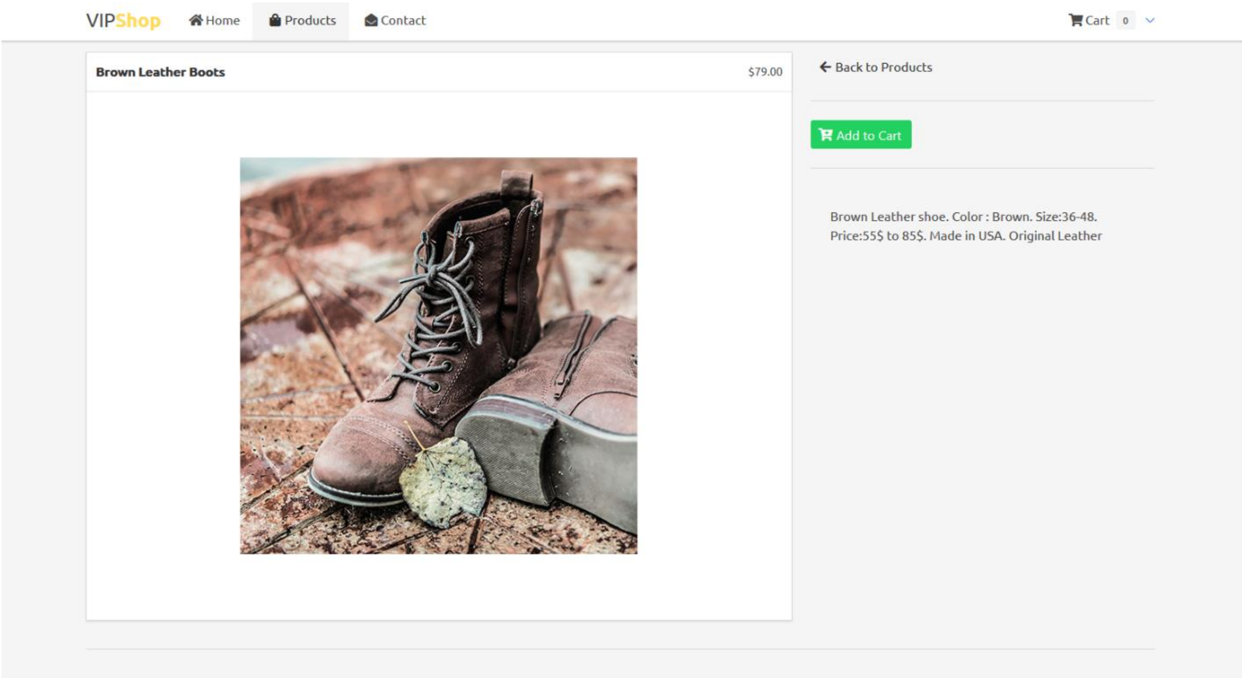


Figure 3.10: Screenshot of the product chosen in New Prototype

In the old prototype, the description of the product is available at the mid-section of the webpage. The screen reader users must traverse from the head, from all those unnecessary contents to reach to the description of the product. Similarly, if skipped the description content, the users must go through all those web content on the way to come back to the description content.

In the new proposed prototype, whenever the product has selected the image of the product was displayed on the left-hand side, and description of the product was provided in the right-hand side. All those unnecessary contents were eliminated, which are not necessary while reading the description of the product. Similarly, the description of the product was clearly stated so that the users, when chosen the product, would be able to take a picture of the product in their mind as far as possible with the real product.

3.4.2 User Testing on Old Prototype

The old existing e-commerce website was randomly sampled from the e-commerce websites available on the internet. The current e-commerce web application developed in angular version higher than two was chosen for the experiment. The current system chosen was https://www.sears.com/. The Sears web application is developed in Angular 4. The Sears company is based in the United States of America. It is a chain department store where all kind of products is available. The products are sold online, using web application.

Users interacting sears with screen reader should rely on tab buttons to traverse to the entire webpage element. There was no use of any hotkeys or shortcut key to traverse with the help of a keyboard to the desired webpage element. Moreover, the design content consists of lots of content which were not relevant to the users, and whenever the product was chosen, it does not provide complete information about the product for a screen reader which create difficulties for the users using a screen reader to find out the detail of the product. Hence, sears was chosen for the research project.

Tasks that were given to a participant were classified into several steps. During the experiment, the task was delivered with a voice assistant for each level from the investigator so that the participants do not need to memorize or do the task efficiently. The old prototype was assigned with code “A,” and the new prototype was assigned with code “B” for the easy representation during the study. Help was provided in both prototypes, including to open the link by the investigator and other supportive assessment. The task assigned are listed in an appendix below (See Appendix C). Few of the steps were the same for all the task to make participants feel comfortable to go through each step with some easy once. These tasks were given to the participants randomly, which is explained in the below section.

After completion of user testing, participants were given the NASA-TLX workload questionnaire where they filled up all the information and data that were asked in the form of Likert scale and 15 different pair of workload factors. At last, users were interviewed to analyze their personal experience and behavior. The data were gathered in the individual sheets and were used for further analysis in the data analysis phase.

3.4.3 User testing on the proposed / new prototype

The same experiment was conducted on a proposed prototype developed. The proposed prototype was a similar kind of business application which differs in design and accessibility, including functional keys and logical elimination of content as explained above. Similar kind of task was given as explained above in this prototype as well.

The answers were collected in an excel sheet from each of the users. These data from both the existing and proposed prototype was evaluated using SPSS and analyzed using the appropriate statistical tool. The NASA TLX methodology was used for measuring the mental workload was carried out after collecting answers from the participants at the end of this experiment.

3.4.4 Randomization

Randomization technique was chosen for the task to the participants to provide similar change to them for the experiment (Mitzenmacher & Upfal, 2017). The author, in an overview of randomization techniques, uses for an unbiased assessment of the outcome in research analysis (Suresh, 2011). It eliminates the bias for the evaluation. The task must be performed by the participants in for the job which is chosen randomly. The table below shows the task to be completed by the participants on the prototype.

Table 3.1: Randomization Table

Participant’s Id	Prototype	Task Id (A)	Task Id (B)
1 and 20	A / B	10 / 1	9 / 10
2 and 15	A / B	5 / 2	1 / 9
3 and 10	A / B	10 / 3	9 / 8
4 and 11	A / B	10 / 4	3 / 7
5 and 8	A / B	4 / 5	3 / 6
6 and 17	A / B	8 / 6	7 / 5
7 and 12	A / B	1 / 7	8 / 4
8 and 16	A / B	3 / 8	1 / 3
9 and 13	A / B	6 / 9	7 / 2
10 and 19	A / B	1 /10	8 / 1

3.4.5 NASA-TLX Experiment

The NASA-TLX is a multidimensional assessment tool used for conducting a control experiment to measure the workload in term of various factors (Hart & Staveland, 1988). The participants were implored to complete the task and ask to rate it in terms of need of mental demand, temporal demand, physical demand, frustration, and effort to complete it. The format of NASA-TLX given to the participants is below:

Participant ID: ______________

Task ID: _______________

NASA-Task Load Index (TLX)

There are six rating scales which are meant for evaluating your experience during the experiment. Please, evaluate the task by marking "X" on each of the six scales at the point which matches your experience. In each rating, scale ranges from "low" on the left to "high" on the right. Note that the Performance scale goes from "Good" on the left to "Poor" on the right.

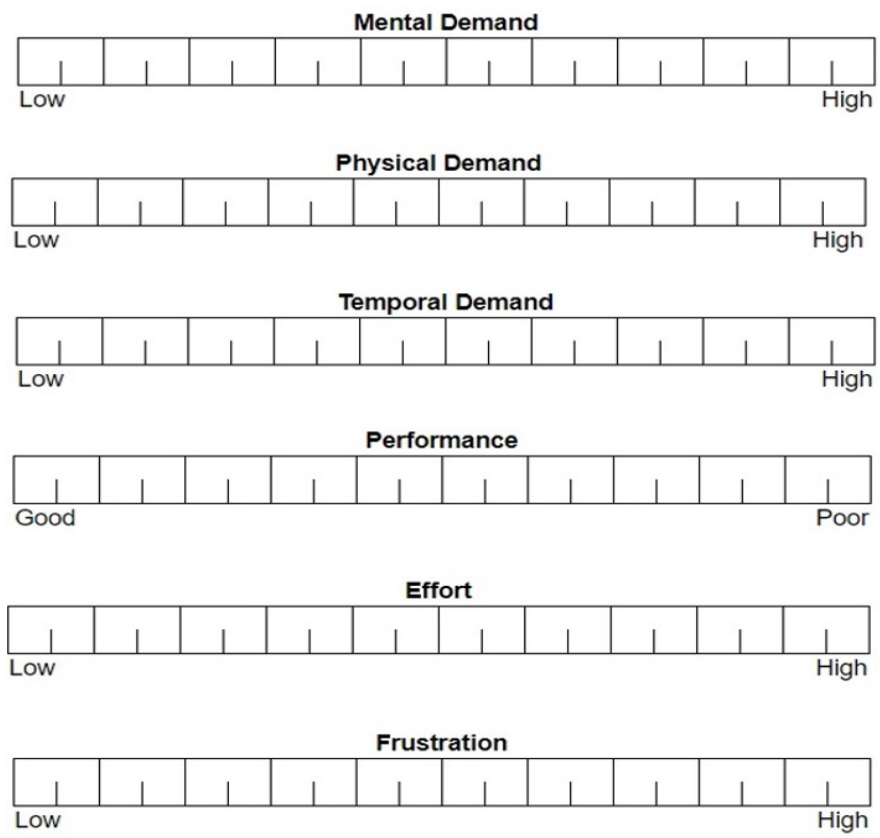


Figure 3.11: NASA-TLX rating scale of six different factors

Item	Endpoints	Description
Mental demand	1 - 10 Low / High	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical demand	1 - 10 Low / High	How much physical activity was required (e.g.. pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal demand	1 - 10 Low / High	How much time pressure did you feel due to the rate or pace at which the tasks occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	1 – 10 Good / Poor	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	1 - 10 Low / High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration level	1 - 10 Low / High	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Figure 3.12: NASA-TLX workload scale ratings and its definition (Memarian & Mitropoulos, 2011)

This experiment was also conducted on a developed prototype, and data were collected as explained for an existing web application. The collected data from both the web application were used for analysis, which is described in the analysis section.

The NASA-TLX experiment consists of two parts. In the first part, six workload factors are weighted using the Likert scale. The second part of NASA TLX is vital for increasing experimental validity (Bustamante & Spain, 2008). In this part, the subject workloads are compared in pairwise based on their importance to create an own weight of subscales. The users choose the measurement that is more relevant to the workload. The weighted score is the number of times each workload is determined (Rubio, Díaz, Martín, & Puente, 2004). This weighted score is then multiplied by scale score for every dimension, which is then divided by 15, which provides a workload score between 0 to 100, which is the overall index of the task load. Raw task load index (RTLX) data are crucial for further analysis. In many cases, the individual subscales could be dropped if they are not relevant to the task while using RTLX (Hart, 2006). But in this research process, the author has used the individual subscales score also to analyze the result at a personal level.

3.4.6 Experimental condition

The experimental condition was that all the participants were asked to perform a task on the developed prototype application. All the participants were blindfolded completely. All of them were provided with several different screen reader tools of their choice. They were restricted to ask any help from fellow participants.

3.4.7 Users and their types

The users were gathered from university colleagues. All the participants know the english language, and all of them know how to use a computer and the internet. Ten male and ten female users were considered for the experiment on the developed prototype. The users were of a different age group, and they were recruited based on their knowledge in online shopping. All the participants were blindfolded and provided with several tasks to be performed in the developed application. They were made free to use any tool which they feel could help them perform user testing being blindfolded.

3.4.8 Environment setup

The developed prototype application was hosted in a web server locally and was accessible over the internet within the network. Internet speed could be varied on different systems using tools. The experiment was conducted in a closed room where several methods were provided. One single prototype design was provided, which was developed from the proposed project.

The equipment of the prototype was well described in the requirement analysis section. The hardware and software being used were provided.

3.4.9 Experimental procedure and data collection

All the participants were acknowledged about the test condition ten days before and got confirmation from them. The experiment was conducted individually. The environment setup was comforting and noise free. The investigator and the participants were only allowed to stay in the room where laptop and computer were used along with report form. The participants filled a form containing basic questions about the user.

There were following segments for experiment setup.

1. The first section was of acknowledging the participants about the study, experiment, and risk while taking the experiment.
2. The second section was filling the form which contains necessary personal information about their education, age, gender, etc., and the participants were asked to answer them honestly. No answers will be made public, and it will remain private. Ten questions were summoned to the participants. The information that was related to the identity of the participants were excluded, such as name, their signature, or photos for the concern of privacy.
3. The third section was of providing and acknowledging the screen reader and other technologies that were used to experiment. The total of 20 participants was used for the experiment by blindfolding them. There was a single website link provided to the user and asked with a simple task to perform. Once the experiment starts, no help was provided to them by the investigator.
4. The fourth section was to measure the mental workload of users. The method used was NASA-TXL and contained the scaling of 0 to 100. These data were collected from each participant. The following question was presented to the participants.

- How much time pressure did the participant felt for the task?
    - Rate from 0 to 100.
- How much mental pressure was felt by the participants?
    - Rate from 0 to 100.
- How much physical pressure was felt by the participants?
    - Rate from 0 to 100.
- How satisfied are participants for their performance in completing the given task?
    - Rate from 0 to 100.
- How severe was the task?

- Rate from 0 to 100.

The NASA-TLX questionnaire was used to measure the mental workload overall. It can be regulated under the six dimensions which describe the mental workload, and they are:

- Mental Demand
- Physical Demand
- Temporal Demand
- Performance
- Effort &
- Frustration

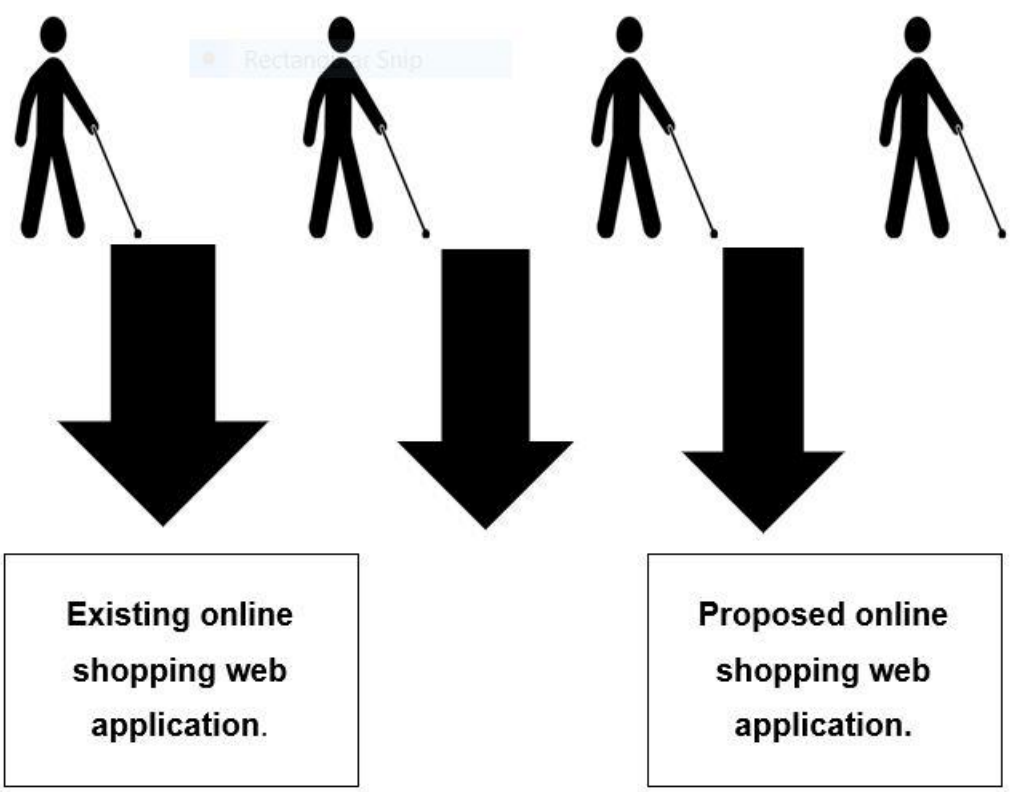


Figure 3.13: Experimental Procedure

Twenty-step bipolar scales were used to find a rating for all these magnitudes. Each scale consists of a score from 0-100. These scales were used to measure the weight, which requires a paired comparison task. After completion of the task given to the user, they were asked to rate the scale as a response to the question asked to measure each dimension of workload. These above questions were the sample questions that were summoned to the participants after the experiment. These data were then analyzed, and the result was provided. As already mentioned, the same procedure was also applied to both prototypes. After completion of an experiment in both web application, a comparative study of the data was done, analyzed, and find out whether the alternative hypothesis was accepted or rejected.

3.5 Pilot study

The pilot study is a study to test the procedure of research, sample, and data collection (Arain, Campbell, Cooper, & Lancaster, 2010). It is done before collecting any data using an experiment. It is a critical stage of project and research. A pilot study is done to find problems with research and the prototype alone with instruments used.

A pilot study is conducted among a couple of participants (Hulley, 2007), which is used to find possible project failure problems. It is also performed to see if the research project is too complicated or inappropriate. The main reasons to conduct this study are:

- To determine the problem for following research procedure.
- To gain access to the feasibility of a study on a research project.
- To collect preliminary data for the research project.

Before the real experiment, a pilot study was conducted with 2 participants. The NASA-TLX was done using pen and paper for each of the investigations. After the experiment, it was analyzed that it takes a tremendous amount of time of the participants to complete the task. It was also found that participants don’t feel comfortable being blindfolded for such a long time, which led to an incomplete job. Hence, enough time was allocated for every participant to experiment. Indeed, a day was assigned for each participant so that there will be an abundant amount of time. The users were a little confused about using the screen reader. Hence, every participant was informed clearly and was asked to use the screen reader for several minutes while they were sighted.

Similarly, in a real experiment, after every task, the participants were given a break for a few minutes so that we could keep them smooth and comfortable. Since the braille keyboard stickers were used for the economical replacement of braille keyboard; several pieces of training were required for every user to let them know the respective alphabet and keys that were required during the experiment. They were also informed about what they could shortcut keys so that whenever they need to navigate to the element in the navigation bar, they use the corresponding keywords. In the proposed prototype, only several keys like CTRL, ALT, H, C, P including tab keys were used, so there was not such an extreme overhead for participants to use them during the experiment. Several pieces of training were provided for every participant so that there would not be any confusion. The participants were also informed that they could ask for a break anytime whenever they feel some uneasy or uncomfortable during the experiment. None of the users were familiar with the NASA-TLX experiment; hence, it was little time consuming to inform about the application of the NASA-TLX data collection process and its procedure. All the ethical considerations were undermined while experimenting.

3.6 Ethical Consideration

All the personal information which could expose the identity of the participants were excluded for the matter of privacy concern. All the research ethics were strictly followed to make the research process cohere research norms and values. Human-computer interaction (HCI) research procedure foster new challengers in the inner ethical mandates of doing no anguish, maintain respect for participants in a research study, and contemplating the benefits and costs of research, making sure that they are distributed equitably over the population (Bruckman, 2014). All the crucial research ethics were strictly followed during the experimental design procedure. The author was aware of the participant’s age, language, or cultural background, socio-economic status, disability. The worth of their participants was highly respected, along with their dignity. The author was highly sensitive to the participant’s feelings. The author informed them clearly about what this research was all about and what kind of participation was needed from them.

Similarly, they were all acknowledged about what type of data and information were being collected from the experiment and where they will be used. After these acknowledgments, the researcher took permission from the user to use the data given by them for further data analysis. The collected data was wholly used for the aim that was stated or explained to users.

4 Data Collection

The participants were guided to the web-based NASA-TLX link, after completion of the experiment, to collect their response about their experience of user testing. Similarly, users were also surveyed or interviewed with several questions related to the experiment to find out their experience regarding user testing and procedure. Later, these collected data were organized in the survey sheet, and the web-based data were saved in the secured folder for further analysis.

4.1 NASA-RTLX (RAW INDEX)

The saved file contains raw TLX data, provided by an individual with a completed set of ratings. The table consists of 4 two headers for TLX workload determinant along with participants ID. All the data were systematically ordered under six various TLX sub-scale score, which was corresponding to the twenty participants into 6 by 20 matrix table cells. TLX sub-scale value range from 0 to 100 with an interval of the value of 5.

The mean of subscales values calculated this raw TLX score. The workload value was rounded off to the nearest workload scale indexes. Similarly, the average value of individual sub-scales among 20 participants was calculated as well. The average score of individual workload indexes among all participants was also approximated to the nearest TLX rating scale.

Table 4.1: NASA-TLX score of individual workload factor along with overall raw TLX index of the old prototype

NASA-TLX Factors	**Participants id**																				**Mean score**	**Approx. Score**
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T		
Mental Demand	55	45	55	55	55	85	65	50	50	60	55	60	50	55	40	40	55	50	50	80	55.5	56
Physical Demand	10	10	10	35	30	65	45	45	40	20	30	20	20	45	25	25	45	20	30	20	29.5	30
Temporal Demand	40	80	55	60	60	40	65	60	65	45	60	60	60	65	60	55	55	55	40	60	57	57
Physical Demand	10	45	65	65	55	35	75	50	35	50	60	50	50	65	10	45	65	55	35	50	48.5	49
Effort	45	35	75	50	60	85	80	50	45	60	60	55	50	50	45	50	60	45	35	50	54.25	54
Frustration	45	40	65	65	50	80	95	50	30	50	60	60	70	65	40	65	45	75	90	80	61	61
RTLX Score	26.66	36.33	52.33	52.33	77	24.33	12.33	60.33	35	55.66	37	48.33	69.33	25.33	47.33	41.66	25.66	51.33	35.33	51.33	43.24	43
Approx. RTLX	27	36	52	52	77	24	12	60	35	55	37	48	69	25	47	41	25	51	35	51	42.95	43

Table 4.2: NASA-TLX score of individual workload factor along with overall raw TLX index of new prototype

NASA-TLX Factors	Participants id																				Mean score	Approx. Score
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T		
Mental Demand	35	25	50	35	35	60	20	30	40	35	30	50	20	20	35	50	30	20	35	45	35	35
Physical Demand	10	10	35	40	20	45	40	45	20	25	30	20	45	25	25	45	20	25	25	20	28..5	39
Temporal Demand	45	30	40	30	25	45	20	25	30	40	40	40	25	35	35	25	40	40	30	25	33.25	33
Performance	15	20	20	25	25	60	15	30	25	30	30	50	35	35	40	35	50	30	30	25	31.25	31
Effort	30	15	35	30	50	25	20	30	40	35	35	45	30	25	25	30	45	35	20	25	31.25	31
Frustration	25	20	20	20	20	25	15	30	20	40	35	30	20	20	25	25	30	25	25	20	24.5	25
RTLX Score	15.93	56.66	57.66	56.33	64.66	17	16	71.66	51	28	26.33	25	34.33	28.66	41.66	38.66	14	21.33	31.33	32.33		
Approx. RTLX	16	57	58	56	65	17	16	72	51	28	26	25	34	29	42	39	14	21	31	32		

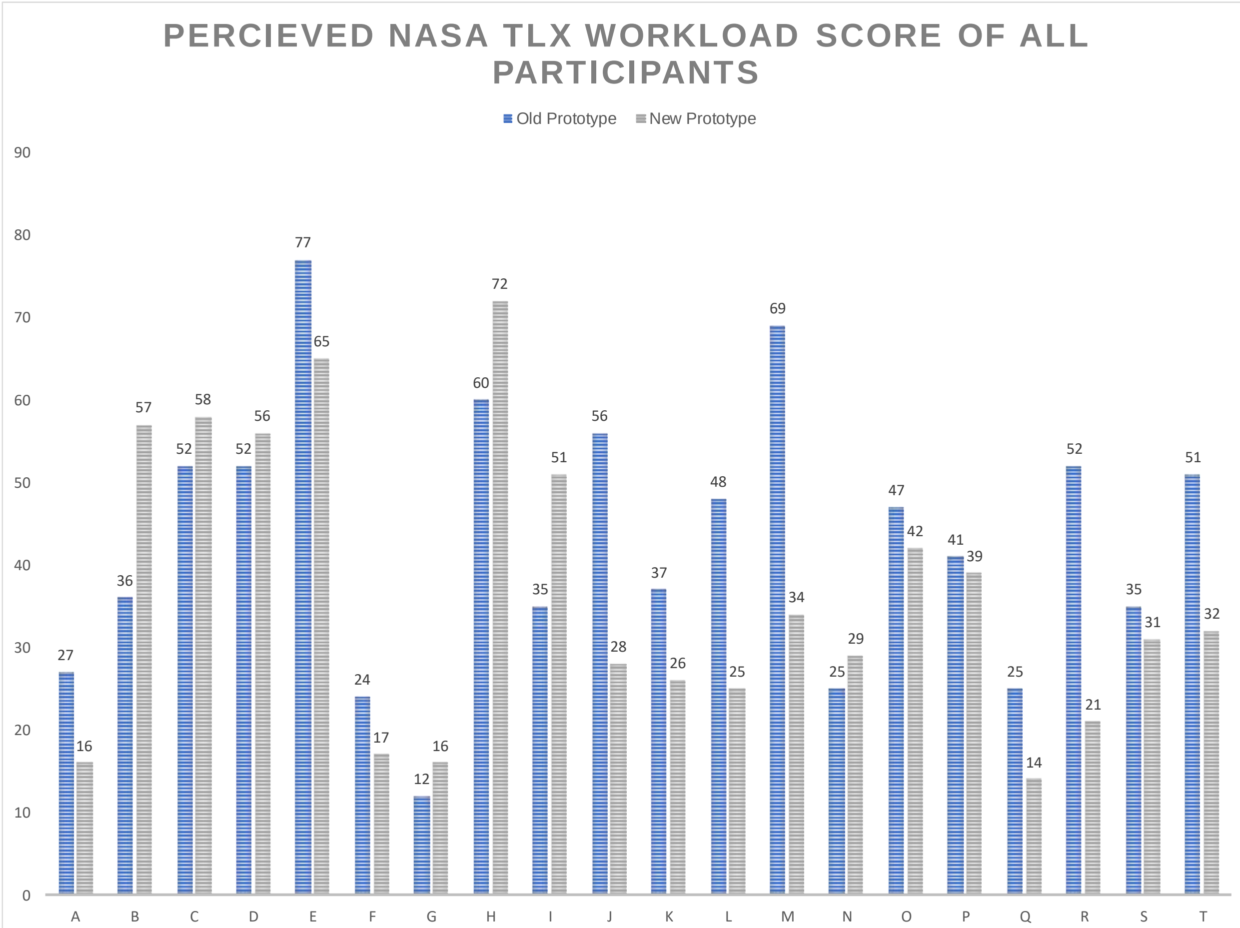


Figure 4.1: A composite diagram of overall workload score of all participants in both prototype

4.2 Observation Sheet

Participants	Accomplished		Unaccomplished		Misunderstood	
	Old Prototype	New Prototype	Old Prototype	New Prototype	Old Prototype	New Prototype
A	3	3	1	1	0	0
B	4	3	0	1	0	0
C	4	4	0	0	0	0
D	2	4	2	0	0	0
E	3	4	1	0	0	0
F	4	4	0	0	0	0
G	2	4	2	0	0	0
H	1	3	3	1	0	0
I	4	4	0	0	0	0
J	3	3	1	1	0	0
K	3	4	0	0	1	0
L	4	4	0	0	0	0
M	2	4	2	0	0	0
N	3	3	1	1	0	1
O	3	4	1	0	0	0
P	2	3	2	1	0	0
Q	3	3	1	0	0	1
R	3	4	1	0	0	0
S	2	4	0	0	0	0
T	3	4	0	0	1	0

Figure 4.2: Observation sheet of participants based upon task accomplishment

While conducting user testing, the investigator has recorded about the user experience and behavior about the experiment based on task accomplishment. The task accomplishment procedure was organized into three parts: task accomplished, task unaccomplished, and task misunderstood.

- Accomplished: The user completed the given task without any error.
- Unaccomplished: The user did not complete the task with accuracy or make some error.
- Misunderstood: User was entirely out of the track of the task assignment and misunderstood about the task.

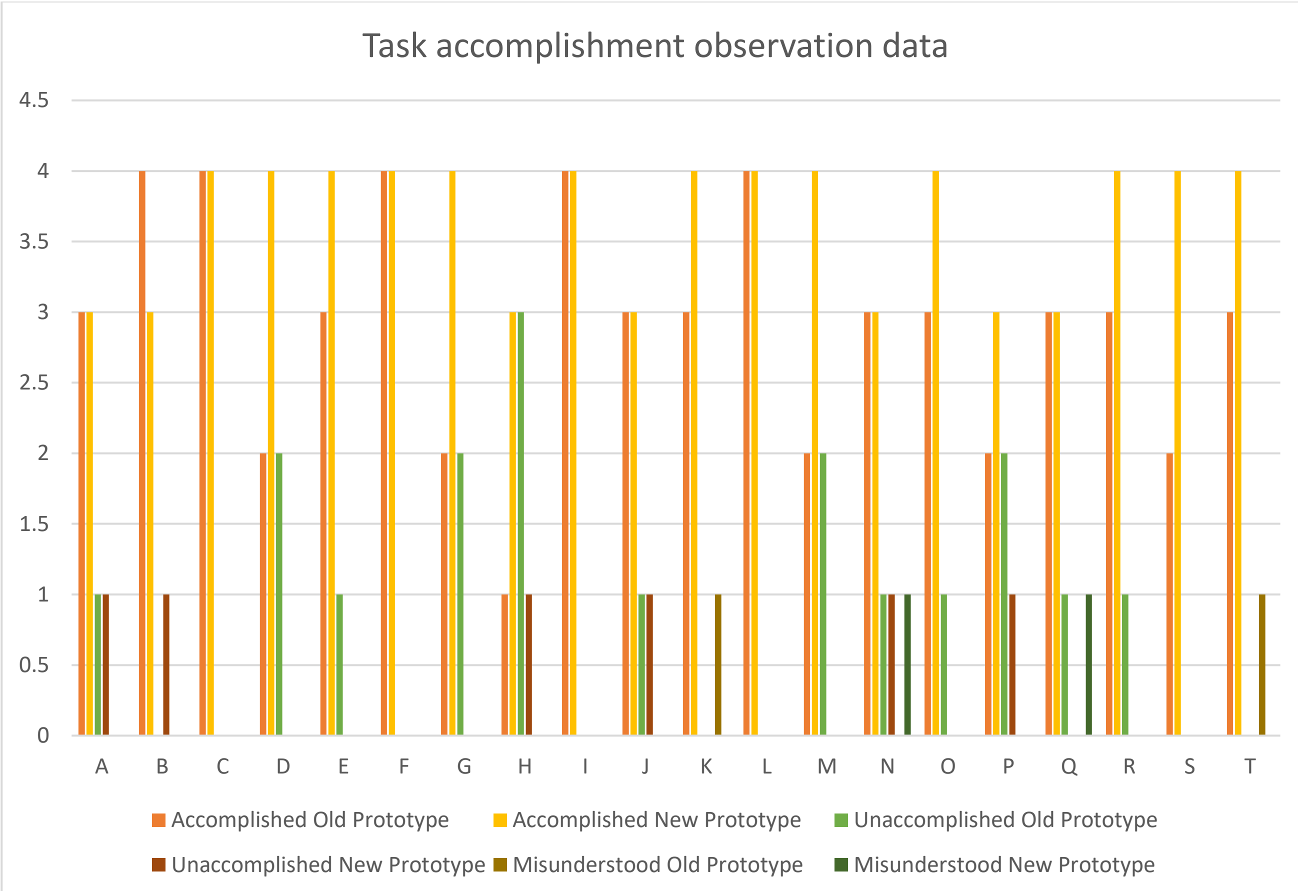


Figure 4.3: Observation data in bar diagram

4.3 Time spent on the prototype

During the user testing, the author has also recorded the total time duration spent by participants on each prototype. The table below shows the time spent by each participant on each prototype.

Participants	Time spent on prototypes	
	Old Prototype	New Prototype
A	20	19
B	18	16
C	17	18
D	21	19
E	22	20
F	16	15
G	15	14
H	15	14
I	20	18
J	20	18
K	22	20
L	19	17
M	17	15
N	18	16
O	17	17
P	16	18
Q	18	17
R	21	18
S	22	19
T	19	20

Figure 4.4: Time spent on by participants on each prototype

4.4 Interview with participants

After the completion of user testing and NASA-TLX workload experiment, participants were asked several questions related to the overall procedure. The interview was concerned with the exploration of facts about their experience and knowledge. It helps us for the assumption of measurable and fixes reality about the research process. A discussion was also needed to find out how the participants feel and think about research and what was their opinions, which helps us to investigate the usefulness and effectiveness of experimental procedure and services. Human dimension was required to add to the above obtain statistical data, which allows us describing and understanding these data in more deepen ways. The sets of a question that were asked to the participants are as listed in the appendix below (See Appendix C).

The response of every participant was recorded in a sheet. Similarly, the main points describe by them were also noted. All these data were analyzed during the data analysis phase.

5 Data Analysis and Results

This chapter provides the result of the experiment conducted and its data analysis. The main objective of this experiment was to determine whether the functional changes in the e-commerce web prototype could bring positive influence in terms of efficiency and work-load or not.

The total number of 20 participants took part in the experiment. The complete information about the participants was collected, i.e., age, sex, education, English proficiency, profession, qualification, background information, internet use per day, experience on online shopping, experience shopping with text to speech converter. Since, there were two types of experimental methods, interview and NASA-TLX experiment, separate tools of data analysis were used. The interview-based data were analyzed in a detailed analytical methodology. Similarly, the data collected deploying NASA-TLX methodology was analyzed with one-tailed paired t-test hypothesis testing tool. The data obtained from NASA-TLX was introduced in SPSS tool, in which the variance of the mean from both samples was calculated. Both results were contextually related to the acceptance or rejection of the hypothesis.

The valuable result was derived from the report of the data analysis procedure. These results were the critical findings of our research process. Similarly, other relevant findings were also explored simultaneously along the process.

5.1 Hypothesis Testing (One-tailed Paired T-Test)

Statistical data derived from experimental investigations are computed, analyzed, and reported via a test of significance (Lazar, Feng, & Hochheiser, 2017). The significance test is the process used by the researcher to find out whether the null hypothesis is accepted or rejected, in favor of the alternative hypothesis that was generated as the base of research (DeGroot & Schervish, 2012). These tests provide the evidence for acceptance or rejection of the hypothesis according to the research scenario. The significance test is the scientific approach of breaking down the numerical data into comparable related variables, and that comparison provides a significant result (Creswell, 2002).

In this research, all the required statistical data were gathered from the user testing process under a controlled experimental environment. These data were collected after the participants were asked to go through procedure NASA-TLX. For statistical analysis, one-tailed paired t-test hypothesis testing methodology was used. SPSS from IBM was used as a tool for these data, to run the test.

The above-collected data were deployed into the SPSS tool, and following tabular data and graphs were derived :

Table 5.1: Mean and median of the respective workload of prototype

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Workload on old prototype	43.0500	20	16.35293	3.65663
	Workload on proposed prototype	36.4500	20	17.73630	3.96596

Table 5.2: Correlation value of old and new prototype workload score

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Workload on old prototype & Workload on proposed prototype	20	.594	.006

Table 5.3: Final statistical value of t at the level of significant 0.05 and degree of freedom 19

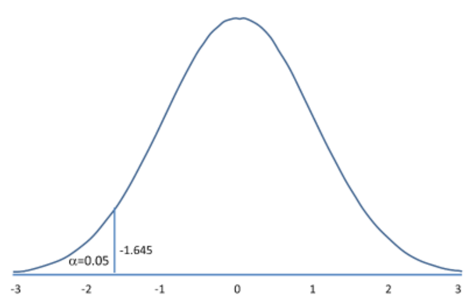
Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Workload on old prototype - Workload on proposed prototype	6.60000	15.41496	3.44689	-.61442	13.81442	1.915	19	.071

In the above table, the mean value of the old prototype is 43.05, and the new prototype is 36.45. Similarly, the standard deviation of the early prototype is 3.66, and the new prototype is 3.97. These values were crucial for the analysis of significance between the mean of two different population.

The correlation score of 0.60 tells that the rating of the old prototype tends to be similar in terms of ranking with the new prototype. There is a positive difference between the two means of each prototype. The positive correlation shows that the ranking from one to twenty tends to be the same, which indicates a higher score at X is associated with higher scores at Y also. A positive correlation is essential for the paired sample t-test because it signifies more significant the association among two variables. The standard error will be less in testing the hypothesis, that means will be different when there is a positive correlation between two variables.

The final table is the actual statistical test tabular values. SPSS provides the mean difference, which is 6.6 along with the difference in standard deviation value and error value difference as well. At the right-hand side, we can see the value to t = -1.915, as the lower confidence interval value is negative, at the degree of freedom 19 significance level is 0.05, and the value of p is 0.33.



Rejection Region for Lower-Tailed Z Test (H_1: $\mu < \mu_0$) with α =0.05

The decision rule is: Reject H_0 if $Z \leq 1.645$.

Lower-Tailed Test	
a	Z
0.10	-1.282
0.05	-1.645
0.025	-1.960
0.010	-2.326
0.005	-2.576
0.001	-3.090
0.0001	-3.719

Figure 5.1: Normality Distribution Table and Figure for the one-tailed test (Wayne W. LaMorte, 2017)

The above table demonstrates that, at 0.05 level of confidence, the calculated value $t_{(-1.915)} < t_{(-1.645)}$ the tabular value. Hence, the researcher concluded that there is a significant difference between two prototypes statistically, which implies that use of a shortcut key and reducing design content has an impact in terms of frustration and the mental workload for the users who use a screen reader to interact with webpages.

5.2 Significance test of each workload factor

Table 5.4: Mean and Standard deviation of all TLX workload factors

Workload Factors in NASA-TLX	**Old Prototype**		**New Prototype**	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Mental Demand	55.5	11.11	35	11.48
Physical Demand	29.5	14.51	29	11.49
Temporal Demand	57	9.79	33.25	7.66
Performance	48.5	17.10	31.25	11.69
Efficiency	54.25	13.31	31.25	9.01
Frustration	61	17.45	24.5	6.05

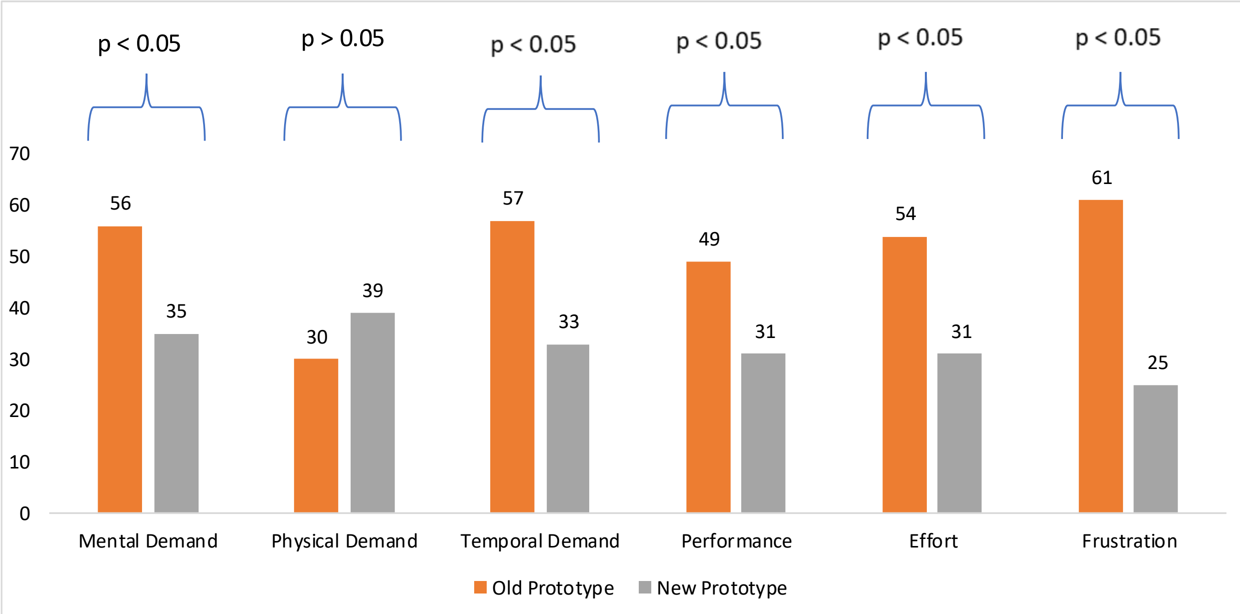


Figure 5.2: Significance test of individual workload factors of NASA-TLX

In the above diagram, there is a significant difference between mental demand, temporal demand, performance, effort, and frustration as the value of p is less than 0.05 ($p<0.05$). It implies that the use of shortcut key and reduced design content has a significant impact in terms of mental workload, temporal demand, performance, effort, and frustration. However, the value of $p>0.05$ in physical demand implies that there is no significant difference in terms of physical demand on both prototypes. The users face an equal amount of physical demand on both prototypes hence use of shortcut key, and reduced design content does not have any impact in terms of physical demand in e-commerce webpages.

5.3 Analysis of the observation sheet's data

In the observation sheet, we have recorded the task accomplishment data of participants as well as the time spent on each task by the participants. Below is the mean and standard deviation of both data:

Table 5.5: Mean and Standard Deviation of Observation Sheet Domains

Observation Sheet domains	**Old Prototype**		**New Prototype**	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Task Accomplished	2.9	0.86	3.65	0.49
Task Unaccomplished	0.9	0.92	0.3	0.48
Misunderstood	0.1	0.3	0.1	0.3
Time spent	18.67	2.38	17.27	1.97

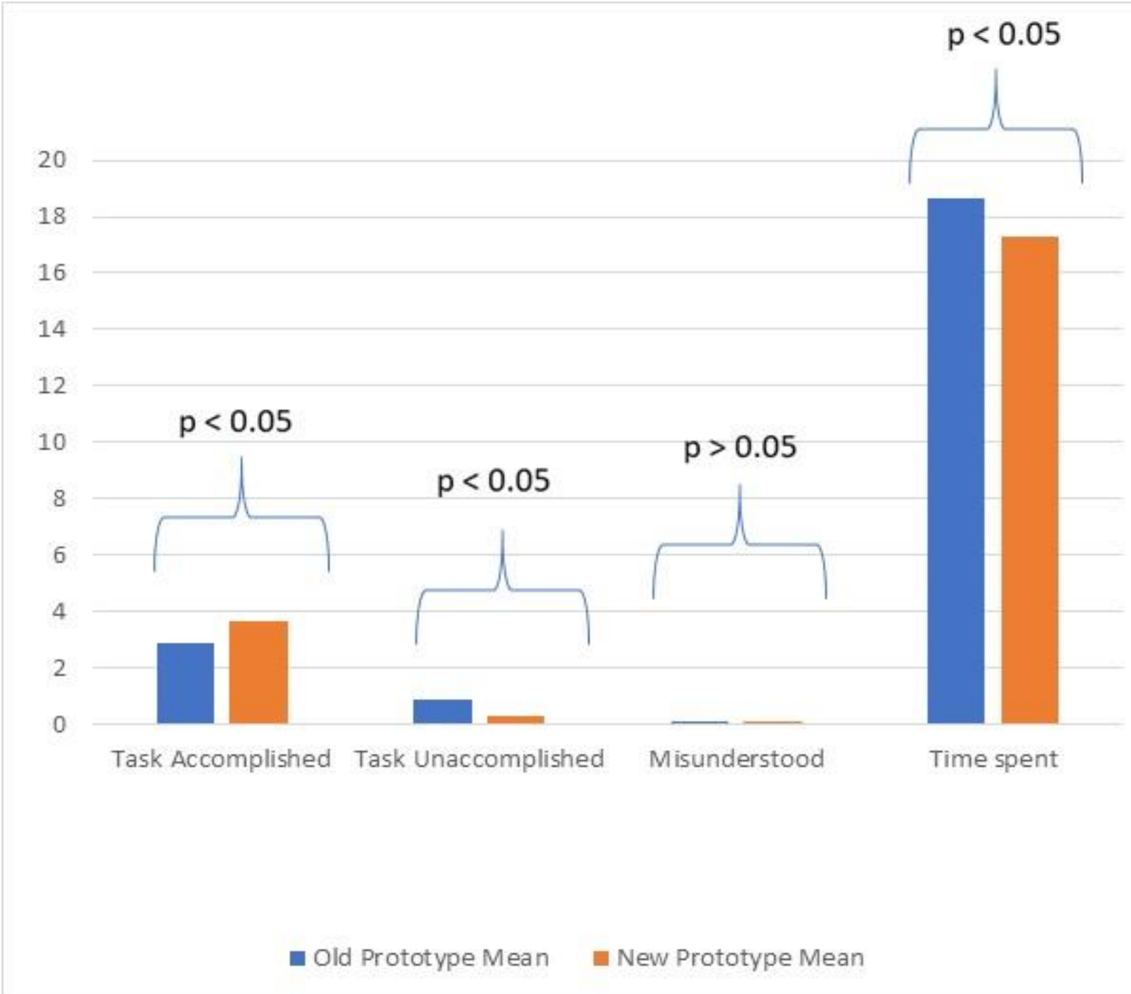


Figure 5.3: Significance test of observation sheet domains

With the value of $t_{(3.67)}$ and $p < 0.05$, the author concluded that the task of a new prototype was accomplished with a lower workload. Similarly, the task that was not completed was also less in the new prototype rather than the old prototype as the test result $p<0.05$ is significant in this case as well. However, the overall confusion among the participants regards the task accomplishment seems to be equal. The value of misunderstood is comparably low with compare to other domains in the observation sheet so this value could be compromised in terms of error during the experiment. Similarly, the value of $p<0.05$ in case of time spent and the test was significant, which implies the time taken to complete the task in the new prototype was lower than of old prototype. This important test of observation sheet also supports the morality of our alternative hypothesis at a glance.

5.4 Analysis of interview data

The findings of the one-tailed paired t test could address only the impact of using the shortcut key in the proposed prototype. To support the acceptance of the alternative hypothesis, the investigator has also interviewed participants after the experiment to find out the users' behavior from the interview's perspective and validation of hypothesis acceptance. This interview was useful to assume the negotiated and dynamic reality. With the help of discussion, data were derived and recorded in the survey sheet. Data collected from this interview were analyzed by refrains from the description of informants and were reported in the described form of language of informants.

The data collected and analyzed from NASA-TLX produce a statistical analysis of whether there is an impact or not. Similarly, one-tailed paired t-test, the hypothesis testing procedure also shows the direction of the effects or impact of the changes. In support of these quantitative data, the interview was crucial in this research process from where we could find out the subjective impact of the changes and helps to acceptance of an alternative hypothesis. Twenty participants were asked to carry out a specific task on both prototypes at first. Then after, a series of questions which enlist the findings of the experiments were summoned to the participants. The questions were all related to the problems and experience while experimenting. All those replies were written in a paper during the interview and later used for descriptive analysis.

The participants found a different experience when they were blindfolded. Some of them even express sympathy for the difficulties from which visually impaired people must go through in their daily life. They explained that it was far more difficult for them to be blindfolded and perform the task. None of them have before experienced being blindfolded and use the computer. Nearly, 90% of the tasks were accomplished by all the participants, 9% of tasks were partially completed, and only 1% of the task was misunderstood by them in both prototypes. The difficulties faced by the participants were almost common in the old prototype. The accomplishment of the task for them was challenging using the screen reader. Pressing the tab key to traverse every element was frustrating for most of the participants.

On the other hand, while using the shortcut key in a new prototype, they feel some easiness to traverse to the web elements quickly, which increases their efficiency and reduces their time to complete the task. Distinguishing the proper shortcut key was a little problematic for all the users. However, the initial training worked for most of the participants correctly as well. Their experience with the standard keyboard also helps them to locate the key, and use of braille keyboard sticker assist them in finding it as well. However, most of the participants express the problem of ambiguity with a shortcut key. Nearly all of them were confused while they must traverse to the contact and the cart. Though the uncertainty was trying to resolve using the different hotkeys, CTRL+ALT+C for contacts, and ALT+C for carts, the participants seems to be confused which one to use in which condition, which was listed as one of the limitations of using the shortcut key in the webpage for navigation and need some more proper logical solution in near future work. The participant's response toward the design content seems to be the same. During the test, when participants must traverse the web using screen reader, they found lots of content unnecessary and increase the time for navigation in the old prototype. As the screen reader traverses to each element in the web, they have no other option rather than pressing the tab and reach to the desired section. Participants feel little easy to navigate in a new prototype using the screen reader as there were only the essential contents added in the prototype.

The overall response of the participant regarding the test was typical in both prototype as they were almost the same in both prototypes. However, from the view of navigation using screen reader participants find some easiness in a new prototype rather than an old prototype.

6 Discussion

This chapter includes the debate on the summary of findings, analysis of a report related to subjective preferences and performances, comparative and relative review, approaches, limitations, and recommendation of prototype design.

6.1 Summary of findings

The researcher has discussed a lot of previous researches that have been carried out in the field of web designing, considering the aspects of accessibility, usability, universal design, and inclusion. From the use of WCAG guidelines to the use of artificial intelligence, researchers have bounced a high level of findings in this field. Hence, it was challenging to find out the issue to initiate the research process. Leporini and Paternò (2004) have explained the use of shortcut keys in their set of standards to increase the usability of websites. Buzzi et al. (2009) discloses the complex design content in e-commerce web applications and their impact on blind users. Takagi et al. (2007) proposed a solution to the logical division of web content to increase the usability of the web, including an e-commerce web application. Similarly, Lazar et al. (2007) enlisted factors that could frustrate the screen reader users, in their previous research. The difficulties and complex issue of navigation and interaction with the web were formerly discussed by several researchers (Buzzi et al., 2009; Lai, 2011).

This research work was a further exploration of previous findings and assumptions and filling the gap of the previous conclusions. This research further discovers the impact of using shortcut key and reducing the complex design content into simpler form. Sighted users can traverse to any of the aspects of the network along with the one clicks of the mouse; however, until this date, it is one of the significant barriers for visually impaired people. The screen reader still works in the forward direction whenever pressed the tab key, which could result in the frustration of web users. The research hypothesis was based upon an assumption that the use of shortcut key and reducing the unnecessary content from the web could be helpful for the visually impaired people in terms of reducing workload and frustration.

For the generalization of the research process, the e-commerce website was taken into concern by the author for research. E-commerce website moreover has common design elements like home, contacts, carts, products, search button and consists of a complex structure which was discussed previously in literature reviews. Nevertheless, it necessarily does not mean that the findings of this research process will apply to e-commerce websites only. The findings of this research would open many other possible research doors which could bring the more effective result in the factor of navigation in sites for screen reader users.

The only way for the acceptance of the alternative hypothesis was the corrective analysis of the data that were gathered from the experimental methods. Since two prototypes from the same population were being measured along with the significant changes in the web prototypes; only the one paired t-test was a valid hypothesis testing procedure in this research work. The t-test was commonly used to test whether there was a significant difference between the mean of two different population or the same population as well. The direction of the t-test was important in this research process because the investigator has generated the hypothesis that the use of shortcut key and reducing the design content in the e-commerce web design prototypes will have its significant effect to improve the navigation and interaction experience for screen reader users. Hence, one-tailed t-test was used. Similarly, as the investigator has already explained, along with these quantified data, the descriptive analysis of user experience and behavior was also crucial in this research process.

The acceptance of the alternative hypothesis clearly shows that using the shortcut key and reducing the design content could bring a significant impact in terms of workload and frustration. On the other hand, from interview data, the investigator analyzed that the participants feel little easy to traverse in the proposed prototype with the help of shortcut keys rather than in old prototype using traditional navigational approach. The descriptive analysis of the result also shows that participants experience was almost common in terms of the blindfolded experiment. Along with these data, the data from the observation sheets were also analyzed, which supports that the task accomplishment was comparatively successful in proposed prototypes rather than the old prototypes. The highest difference between workload perception among the old and new prototype falls in frustration factors. Most of the participants score navigation in the new prototype by half scores of NASA-TLX with compared to the early prototype, which manifests participants have a difficult time for navigation in the old prototype and accomplish the given task, which renders the results for the usability of prototypes in terms of perception. The participants rated proper and appropriate for the new prototype over the old prototype where the users must rely only on the tab button for the navigation to the web elements. These claims were made based upon the results gained from the initial investigation, however, could be further investigated in near future works.

6.2 Experimental scenarios

E- commerce website was used for the experiment as the content in these websites are most common in all front-end design. Similarly, from previous research, the researcher has addressed that the content of the e-commerce application is complex and challenging for visually impaired users to interact. Hence, for smooth validation of experimental result e-commerce website were chosen in this research process. All the standard accessibility and usability guidelines were followed, which results in the integrated web interface output. The designed prototype was simple, consistent, and only the vital elements were used. Similarly, it was a user and a keyboard friendly, ease for screen readers, consists the descriptive alt text for images and links, device and browser compatible, corrective contrast and simple background, readable text, and standard HTML codes.

Most of the issues and problems were presumed before the initialization of experiments. Problems like participants could get exhausted when gone through such an experiment following all the experimental conditions were addressed formerly. Similarly, they could feel some pressure during the experimental procedure. Participants were asked to take a break along with standard break time during the whole experiment to address all these issues and problems. Similarly, they were also guided to leave the experiment any time if they feel discomfort during the process. They were also allowed to leave any questions if they don't want to answer. Moreover, they could ask any questions or queries anytime if they have any during the probationary period.

The research was primarily concerned with the people who need aids for visual interaction with web projects. However, due to limited resources and availability of real blind users, the research was forcefully bound with sighted users and made them as blindfolded users, which could have had its adverse effect in terms of experimental design, data collected and gathered the result. More accurate and consistency could have been gained if these barriers of the experiment were appropriately addressed. Hence, this becomes of the limitation of this research work and open the road for further future work in the same topic and idea.

Lots of experiments applied to the research process; however, choosing the correct one was the great dilemma. The primary aim of the researcher was to gather the user experience and behavior in terms of pressure or frustration of users who use a screen reader to interact with websites. The author could also use a questionnaire with Likert scale where it relates to the activity of the users go through during the experiment and later analyses those data. But possibly, the author perceives that this kind of experimental methodology could address the physical behavior of users, rather than mental and psychological experiences. Hence, NASA-TLX workload, the experimental methodology was chosen, as it is one of the tested methodologies in terms of workload related to human psychology along with other physical preferences. NASA-TLX pursues enhancing the performance and safety of the task. The tool of subjective workload is applicable in the vast range of fields with various languages.

Similarly, it is one of the credential references for the researchers who are interested in a mental workload task. The necessary information was provided to the participants about the NASA-TLX experiment. The result could have been altered if the users were not offered all this required information about the experimental methods and what kind of data it will extract.

Along with the NASA-TLX experiment, an interview was also essential to find out the social behavior of participants. It was crucial for the validation of the hypothesis testing procedure. The data provided by the participants, along with the investigation, was not fully viable to stand with th hypothesis that the researcher has generated. The interview questions were more related to the degree of influence, issues, problems, experience, and views of the participants whose outcomes were analyzed in the descriptive form and compared whether these results support our generated hypothesis or not.

6.3 Limitations

Due to different circumstances, several limitations occurred while conducting the research process. These limitations are briefly explained below, along with the reason for their occurrence.

6.3.1 Participants

One of the most absorbed limitations of this research procedure was the use of the correct participants. The whole research process was concerned with the blind people, their problems while using the screen readers and interacting with the web. However, the researcher could not use the real blind people as the participants for the experiment. Well, there were several reasons for this limitation. Availability of real blind users was difficult and time-consuming.

Moreover, the investigator needed such blind users who have practical experience of using computers along with the help of screen readers and technical knowledge and expertise. Though it was not so difficult to find out these actual participants; the time factor was another constraint for the research process. The research process was supposed to be carried out with more participants as far as possible. Hence, it was a great challenge to find out the real participants in a given time constraint.

Similarly, another potential problem that could occur for the actual participants was ethical considerations. It could be hard to convince every real participant about the research process, why it is being carried out, and what kind of possible data will be considered. Hence, these barriers lead the researcher for the use of sighted users as their participants in blindfolded manners. The accuracy of the outcomes or errors could be varying moreover if the researcher could use the real participants instead of these sighted users in blindfolded ways.

Though, sighted users were chosen in such a way that all of them have computer and web experience. A lot of extra effort was required to address them the research process methodology. None of them have ever used a screen reader in their daily life purpose while interacting with web pages. Hence, it was a little challenging to convince them, why they were chosen instead of real participants. Similarly, initial training for using a screen reader and braille stickered keyboard was time-consuming. Perhaps, if the actual participants were has been used, then the researcher could save this time and experiment more fluently.

6.3.2 Braille Keyboard

The motive of the research process was to create a shortcut way for navigation for screen reader users, which could save their time and decrease their frustration level while interacting through webpages. Hence, the role of the keyboard was vital in this experiment. It would have been better if the investigator could use the real braille keyboard instead of using the braille sticker in the actual keyboard. Due to the limited resources, the real braille keyboard was not used in the experimental procedure. Instead, braille stickers were used for those keys which were being used in the actual experiment. Users were needed some initial training to remember the braille representation of the letters that were going to be used, which was also time-consuming. However, the real braille keyboard would have been needed more if the researcher has used the actual blind participants in our experiment. For these blindfolded participants, the use of a braille keyboard could create more confusion because they would need to go for knowing every key and its braille representation. Hence, on the one hand, this was a limitation of this research process, but on the other hand, this could create some problem as well.

6.3.3 Content of Prototype

The prototype in this experiment was chosen in the favored environment. There were millions of e-commerce webpage along with their design content. Since there are no standard guidelines to follow for these design contents, it would inevitably vary for each web content. The e-commerce content was chosen in a controlled and favored environment so that we could conduct our experiment efficiently.

Similarly, the proposed prototype was also developed obligingly. The web elements where users could traverse were created and designed initially. There is no such standard gateway for designers to include the same content as proposed in this research process. However, it was necessary to cover these contents in a coercing manner. The motive of the experiment was to find out the effect of using shortcut keys in the navigation procedure rather than the web contents. Similarly, the proposed e-commerce outlay was just a prototype rather than a complete e-commerce package. The result could be influenced if the proposed prototype was a full e-commerce package, as it will insist including more design contents and elements.

6.3.4 Learning effects

The participants were not blind participants. Sighted users were blindfolded, and the experiment was conducted, which would convey the inferiority in their expertise and experience to interact with the webpage by using a screen reader than being sighted users. Moreover, initial training for participants with the experimental environment was necessary to experiment smoothly. Since the task given almost had a typical structural arrangement where the process was organized identically, users may have gone through learning effect. They may have learned about the process and the task from initial prototypes, which further makes them easier to explore another task quickly than before. Probably, this learning effect could have fabricated a vital role in discovering the proposed prototype more feasible and usable.

6.3.5 Intuitive Impact

Scales of measurement were subjective scales in this experiment. The scale which was used to measure the workload while navigating through the screen reader and perform a task might lead the collected data intuitively influence. Even though subjective scrutiny of these data shows the less intuitive impact on the result, there could be a colossal perspective and the inherent difference between real blind users and sighted users. Furthermore, the use of shortcut key in proposed prototypes was designed and used in bodily consideration for an easy navigation process, which was not endorsed by a user test. Hence, the use of shortcut key for easy navigation could have the intuitive impact of user consideration.

6.3.6 Convolution of measurement scales

Convolution of measurement scales in another limitation of this research process. The scales of measurements of NASA-TLX are often contemplated as one of the convoluted scales to use and administrate. There could be a vast difference in measurement scales, as the study depends on intuitive perceptions of users. An experienced or skilled user might realize the task easy to accomplish while users with less skill and experience might perceive difficult and tedious under the same condition, which might have been affected by the result of the study.

7 Conclusion and Future Works

The overall structure of research was based upon the hypothesis generated by the author during the inititation of study. The generated hypothesis by the author was :

H_0: The screen users do not feel any frustration while navigating through complex webcontent and its structure using the traditional approach. The use of shortcut key in webpages and reducing the complicated structure into the simpler form will not make any impact in navigational behavior of screen reader users.

$H_{1:}$ The screen reader users feel frustration while navigating through complex webcontent and its content using the traditional approach. The use of shortcut key and eliminating these complex structure into the simpler one could address these problems.

Based on the above hypothesis, the author investigated the effect of using hotkeys/shortcut keys in webpages, during navigation for screen reader users. The investigator tries to figure out whether the users feel less frustrating to use these keys rather than rely on traditional navigation approach or not. The author conducts user testing, where tasks were assigned to blindfolded users. The participants were asked to answer the questionnaire of NASA TLX based upon their user testing experience. Similarly, the users were also interviewed to find out the degree of impact of using navigational shortcut keys and reducing the sophisticated design into a simpler form.

The overall findings of the study show that the use of a navigation key in webpages is an effective way for the users to interact and navigate using the screen reader. The workload was measured in six different factors among which only the physical workload seems to be little more in case of using these shortcut keys while all other five elements of workload, mental, effort, performance, temporal and frustration were found less while using these shortcut keys.

Moreover, the researcher also finds out that the users feel relaxed and comfortable to use webpages when the webpages are well structured, and only essential components were used. The study was made with the reference of e-commerce websites. Similarly, from the analytical survey, the researcher also figured out that well description of the product, using alt-text for selected product image, in e-commerce webpages help the screen reader users to approximate the product reality. From these results, the author concludes that the use of shortcut keys during keyboard navigation for screen reader users helps to make the webpages for usable.

This research opens the pathway for much future research work. There are lots of limitations that were addressed in this research process. By addressing all these limitations, other researchers could conduct a more effective research study shortly and investigate the more pathway for the usability of webpages. During the research process, the author found out that the need for physical demand increases while using keyboard navigation. The alternative of keyboard navigation such as voice recognition and control could be used in near future research work, which could be more effective and efficient than keyboard navigation procedure.

Similarly, this research study was compact for e-commerce webpage with familiar content. There are billions of webpages which are entirely different from each other in content basis. Hence, there is a need for a proper research study for standard gateway/guidelines of using keys for navigation which could be applied to all types of webpages.

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9 Appendices

9.1 Appendix A

OSLO METROPOLITIAN UNIVERSITY

Department of Computer Science

Faculty of Technology, Art and Design

Participation Information Sheet

Research Title : Impact of shortcut key and design content for navigation in the context of an e-commerce website for visually impaired people

Researcher : Bijaya Khatiwada

Please Tick!

☐I confirm that I have read and understood the information sheet for the above study and have had the opportunity to ask questions.

☐I know that my participant is voluntary, and I am free to withdraw at any time, without giving any reason.

☐I agree that data because of my participations may be stored anonymously and used for research purposes. Upon my withdrawal data collected because of my participation will be destroyed.

☐I agree not to reveal the details of this study to anyone as this research is still ongoing.

Name of Participant	Name of Investigator	Date

9.2 Appendix B

Paticipant ID _____ Date _____________

Demographic Survey

Instructions: Please do not write any kind of personal information that could disclose your identity. This information sheet contains holds the participants basic data including their knowledge of computer, internet and web experience. These data will be kept confidential and solely used for research process only.

<u>Please check the box which best describe you</u>

1 . Gender

☐ Male ☐ Female

2 . Age

☐ Less than 20 years ☐ 21-24 years ☐ 25-29 years

☐ 30-34 years ☐ 35-39 years ☐ Less than 20 years

3. Education Level Completed

☐ Primary School ☐ Secondary School ☐ High School

☐ Bachelors ☐ Masters ☐ PhD

4 . Experience with computer

☐ Less 1 year ☐ 2-3 years ☐ 3-5 years

☐ 6-7 years ☐ More than 8 years

5 . Experience with World Wide Web

☐ Less 1 year ☐ 2-3 years ☐ 3-5 years

☐ 6-7 years ☐ More than 8 years

6 . Internet access per day

☐ Less 1 hours ☐ 2-3 hours ☐ 3-5 hours

☐ 6-7 hours ☐ More than 8 hours

7 . Purpose of using Internet

☐ Entertainment ☐ Communication ☐ Academic

☐ Professional ☐ Commercial ☐ Others ………………

☐ More than single purpose

8. Experience with online shopping

☐ Yes ☐ No

9. How frequently you used online purchasing ?

☐ Every Month ☐ 2-3 Month ☐ 4- 5 Month

☐ More than 6 Month

10 . Experience with Screen Readers

☐ Yes ☐ No

9.3 Appendix C

9.3.1 List of Task Assigned

Prototype A (Old Prototype)

Task 1:

Step 1: Please select white new balance shoe and add them to cart.

Step 2: Please go to cart .

Step 3: Please press the order button.

Step 4: Please go to the homepage.

Task 2:

Step 1: Please select any brown color leather shoe and add to cart.

Step 2: Please go to cart page.

Step 3: Please press the order button.

Step 4: Please go to the homepage.

Task 3:

Step 1: Please find the product named Nokia 7 in black and add to cart.

Step 2: Please go to cart page.

Step 3: Please press the order button.

Step 4: Please go to the homepage.

Task 4:

Step 1: Please select black jacket and add to cart.

Step 2: Please go to cart page.

Step 3: Please press the order button and go to payment page.

Step 4: Please go to the homepage.

Task 5:

Step 1: Please select blue jeans and add to cart.

Step 2: Please go to cart page.

Step 3: Please press remove item button.

Step 4: Please go to the homepage.

Task 6:

Step 1: Please select the brown trouser.

Step 2: Please go back to the home page.

Task 7:

Step 1: Please add any product of your choice to the cart.

Step 2: Please go to cart.

Step 3: Please press the order button.

Step 4: Please go to the homepage.

Task 8:

Step 1: Please choose a product that costs 10$.

Step 2: Please go to cart.

Step 3: Please press the order button.

Step 4: Please go to the homepage.

Task 9:

Step 1: Please choose a product that costs more than 50$.

Step 2: Please go to cart.

Step 3: Please press the order button.

Step 4: Please go to the homepage.

Task 10:

Step 1: Please choose a white t-shirt.

Step 2 : Please put it into the cart.

Step 3: Please go to the homepage.

Prototype B (New Prototype)

Task 1:

Step 1: Please add a white shoe to the cart.

Step 2: Please go to cart.

Step 3: Please press the order button.

Step 4: Please go to the homepage.

Task 2:

Step 1: Please add football -t-shirt to the cart.

Step 2: Please go to cart.

Step 3: Please press the order button.

Step 4: Please go to the homepage.

Task 3:

Step 1: Please select the brown trouser.

Step 2: Please go back to the home page.

Task 4:

Step 1: Please add brown trouser to the cart.

Step 2: Please go to cart.

Step 3: Please press the order button.

Step 4: Please go to the homepage.

Task 5:

Step 1: Please add any product of your choice to the cart.

Step 2: Please go to cart.

Step 3: Please press the order button.

Step 4: Please go to the homepage.

Task 6:

Step 1: Please go to contact us page and ask for any query.

Task 7:

Step 1: Please add a t-shirt of your choice.

Step 2: Please go to cart.

Step 3: Please press the order button.

Step 4: Please go to the homepage.

Task 8:

Step 1: Please choose a product that costs 10$.

Step 2: Please go to cart.

Step 3: Please press the order button.

Step 4: Please go to the homepage.

Task 9:

Step 1: Please choose a product that costs more than 50$.

Step 2: Please go to cart.

Step 3: Please press the order button.

Step 4: Please go to the homepage.

Task 10:

Step 1: Please choose a product of any of your choice.

Step 2: Please put it into cart.

Step 3: Please delete it from the cart.

9.3.2 Interview Questionnaire

- How did you feel shopping online while blindfolded ?

  ……………………………………………………………………………………………

- Were you able to complete the task given ?

  ……………………………………………………………………………………………

- What were the difficulties you face while ordering online ?

  ……………………………………………………………………………………………

- Did you feel frustration while using the screen reader ?

  ……………………………………………………………………………………………

- What is your opinion towards the use of shortcut keys in the webpage for navigation ? Were they use while you were using them ?

  ……………………………………………………………………………………………

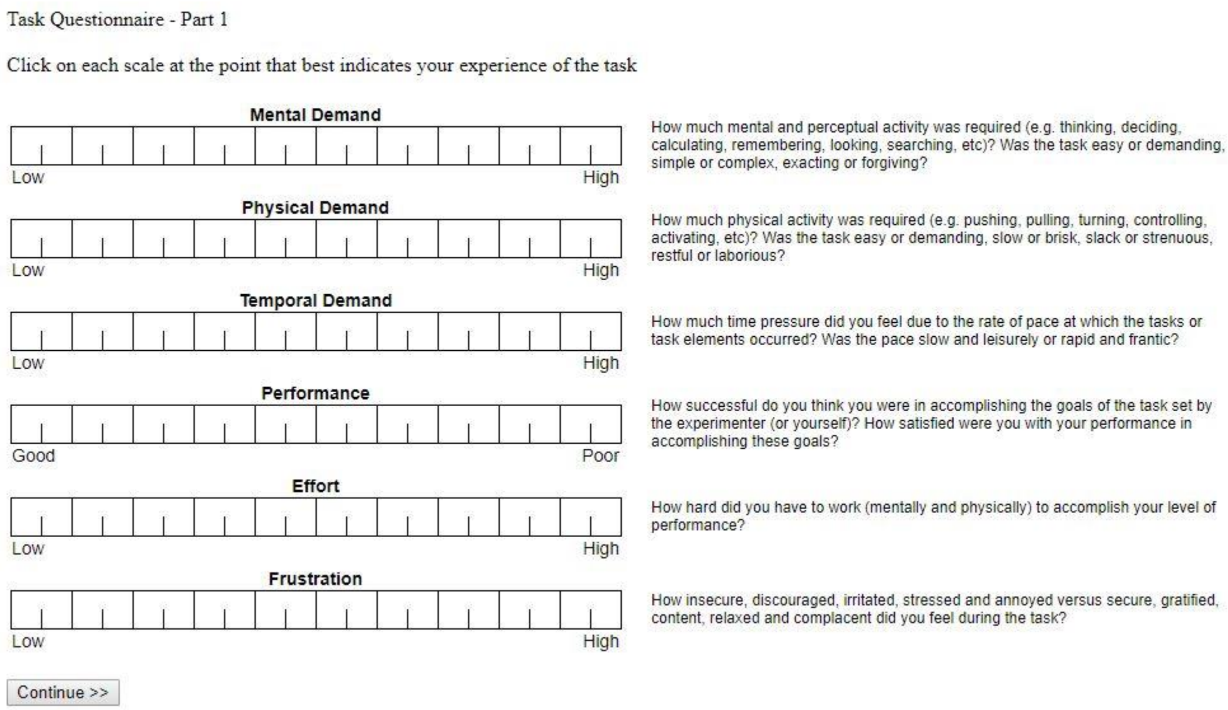
  ……………………………………………………………………………………………

- Did the design content obstacle you while you were using the screen reader to accomplish a task?

  ……………………………………………………………………………………………

9.4 NASA-TLX Questionnaire

9.4.1 Part 1



Task Questionnaire - Part 1

Click on each scale at the point that best indicates your experience of the task

Mental Demand

Low — High

How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?

Physical Demand

Low — High

How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Temporal Demand

Low — High

How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?

Performance

Good — Poor

How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?

Effort

Low — High

How hard did you have to work (mentally and physically) to accomplish your level of performance?

Frustration

Low — High

How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Continue >>

9.4.2 Part 2

Task Questionnaire - Part 2

One each of the following 15 screens, click on the scale title that represents the more important contributor to workload for the task

Continue >>

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Mental Demand

How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?

or

Effort

How hard did you have to work (mentally and physically) to accomplish your level of performance?

Task Questionnaire - Part 2

One each of the following 15 screens, click on the scale title that represents the more important contributor to workload for the task

Continue >>

Click on the factor that represents the more important contributor to workload for the task

Mental Demand

How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?

or

Effort

How hard did you have to work (mentally and physically) to accomplish your level of performance?

Click on the factor that represents the more important contributor to workload for the task

Mental Demand

How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?

or

Physical Demand

How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Click on the factor that represents the more important contributor to workload for the task

Performance

How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?

or

Frustration

How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Click on the factor that represents the more important contributor to workload for the task

Effort	How hard did you have to work (mentally and physically) to accomplish your level of performance?
or	
Performance	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?

Click on the factor that represents the more important contributor to workload for the task

Physical Demand	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
or	
Temporal Demand	How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?

Click on the factor that represents the more important contributor to workload for the task

Physical Demand	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
or	
Performance	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?

Click on the factor that represents the more important contributor to workload for the task

Performance	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
or	
Mental Demand	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?

Click on the factor that represents the more important contributor to workload for the task

Frustration	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?
or	
Effort	How hard did you have to work (mentally and physically) to accomplish your level of performance?

Click on the factor that represents the more important contributor to workload for the task

Physical Demand	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
or	
Frustration	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Click on the factor that represents the more important contributor to workload for the task

Effort	How hard did you have to work (mentally and physically) to accomplish your level of performance?
or	
Physical Demand	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Click on the factor that represents the more important contributor to workload for the task

Physical Demand	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
or	
Temporal Demand	How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?

Click on the factor that represents the more important contributor to workload for the task

Frustration	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?
or	
Mental Demand	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?

Click on the factor that represents the more important contributor to workload for the task

Temporal Demand	How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
or	
Frustration	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Click on the factor that represents the more important contributor to workload for the task

Performance	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
or	
Temporal Demand	How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?