

Indian Institute of Technology Kanpur

Masters Thesis

XsWebAll: Accessible Web for All

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*A thesis submitted in fulfillment of the requirements
for the degree of Masters of Technology*

in the

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4th June, 2019

Certificate

It is certified that the work contained in the thesis titled, **XsWebAll: Accessible Web for All** has been carried out under my supervision by **Pawan Kr. Patel** and that this work has not been submitted elsewhere for a degree.

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Statement of Thesis Preparation

I, **Pawan Kr. Patel**, declare that this thesis titled, **XsWebAll: Accessible Web for All** , hereby submitted in partial fulfillment of the requirements for the degree of **Masters of Technology** and the work contained herein are my own. I further confirm that:

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Abstract

Pawan Kr. Patel

XsWebAll: Accessible Web for All

Education is a fundamental right for everyone. In today's world, methods of education are gradually shifting from traditional pen-paper based classrooms to computer-based classrooms. On the one hand, this shift has opened ample opportunities for availing the education at low cost to a large section of the community. On the other hand, there are many students with visual impairment, who are unable to use these digital resources due to their vision limitation. This research is an attempt to understand the challenges faced by visually impaired persons and to suggest remedies to provide better opportunities to visually impaired persons to avail inclusive education using various digital resources.

The entrance examinations are vital to open the world of education in most of the premium institutions across the globe. In India, major entrance examinations (JEE Mains, JEE Advanced, GATE, JAM, etc.) are now computer-based. We conducted a users' study of challenges faced by visually impaired persons during the computer-based tests (CBTs) for these examinations. We further evaluated the effectiveness of multiple accommodations provided in these CBTs. After that, we worked on the more generic problem of accessibility barriers in web applications and challenges faced by web-developers in creating these applications. In order to ease the process of authoring accessible web-pages for web developers, we have created i) An accessible web-development manual, ii) Examples and videos demonstrating accessible vs. inaccessible components of web-applications, and iii) a semi-automated tool to fix accessibility issues in web-applications. We believe that the artifacts developed in this thesis will help sensitize the community towards accessibility issues faced by the visually impaired persons and reduce accessibility issues in web pages and CBTs.

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List of Abbreviations

AT	A ssistive T echnologies
ARIA	A ccessible R ich I nternet A pplications
CBT	C omputer B ased T est
PwD	P ersons w ith D isabilities
VIP	V isually I mpaired P ersons
W3C	W orld W ide W eb C onsortium
WCAG	W eb C ontent A ccessibility G uidelines

Chapter 1

Motivation and Introduction

In today's era of the web, where digital content is the top source of information for everyone, including PwD's. Most of the websites, including educational, financial, and marketing sites, are not accessible at all. As per the census of 2011, In India, the PwD's population is 2.2% (2.68 Cr) of the total. Out of that 78% (2 Cr) of PwDs face difficulties in accessing web content. In India, there are 1.4 Cr literate PwDs out of which only 12.5 Lakhs have completed graduation. This statistics implies that more than 90% of the PwDs have dropped out of education at an early stage, reflects the pathetic situation of PwD's education in India. Nowadays, the internet plays a vital role in imparting knowledge. The inability to access the web is a significant hurdle in pursuing good quality education. Our work is an attempt to enhance the quality of education of visually impaired persons(VIPs) in India by exploring the ways of making useful web applications for all. So that anyone, regardless of vision limitation, will have equal opportunity to access the information on the web.

To understand the challenges and needs of visually impaired persons, one needs to understand their life cycle in the standard Indian education system.

- In today's education system life of visually impaired student starts with filling up an online application form for an entrance examination. As stated earlier in most of the websites visually impaired faces challenges, so they have to depend on others to fill up the application form.
- The next most important step is to pass the computer-based test(CBT), where visually impaired persons have to depend on the scribe for reading and answering the questions, only due to inaccessibility of these computer-based interfaces.

Similarly, visually impaired persons depend on others for daily activities such as shopping, financing. We find out that if all digital information can be made accessible to everyone, then these people will educate themselves and live their own life. The pathetic condition visually impaired persons in motivated us to give an attempt to empower them by:

- understanding their challenges and needs in computer-based tests.
- finding out the root cause for inaccessibility in web applications.

To find out the challenges faced by visually impaired persons (VIPs) in computer-based tests, We used a questionnaire to evaluate the accessibility barriers in the CBTs. 24 participants responded until 15th January, 2019. These were VIPs from IIT Kanpur, IIT Delhi and registered participants at the assistive technologies conference, Empower-2018. We analyzed the accessibility of CBT interfaces, the effectiveness of accommodations provided to VIPs, the comparison between available and expected accommodations, and finally, the preferences of VIPs for various accommodations. Using this data, we have proposed recommendations to adopt more technology-based accommodations in CBTs. See Chapter 3 for more details.

We studied the commonly used practices and best practices for accessible web development and found that most of the web applications are inaccessible due to the following reasons:

- Lack of awareness among developers about challenges faced by visually impaired users.
- Scarcity of training / professional courses of accessible web development.
- Multiple challenges in accessibility testing of the web application.

These challenges faced by developers hinders the accessibility of web application at the root. Hence we first surveyed the common practices and best practices of accessible web development, then created demonstrations of inaccessible and accessible designs of various components of a web application to make aware the web developers about the challenges faced by visually impaired persons in accessing the web content. Finally, we prototyped a manual for accessible web development manual and **XsWebAll** tool to assist the developers in designing accessible web applications. (See chapter 4, 5 for further details)

Chapter 2

Background and Literature Review

This chapter provides an overview of the barriers associated with the issue of web accessibility. Starting with the multiple challenges faced by users and developers with a specific example of education, the role of various assistive technologies, policies in the accessible web-development and finally, evaluation methods for the accessibility testing of a typical web application.

2.1 Web Accessibility Challenges

This section briefly reviews the challenges faced by end users in accessing the web content, developers in creating accessible web content and provide review of case studies of accessible education to find the challenges faced by visually impaired persons in pursuing higher education.

2.1.1 Users' Perspective

Visually impaired users face many challenges in accessing the web-content as described by Carvalho et al., 2018 in their study, "accessibility problems encountered by visually impaired and normal vision users on websites and mobile applications". A total of 514 problems in accessing the web-content have been identified in the study, out of which 409 are faced by visually impaired persons and 105 by normal vision users. This empirical evidence of challenges faced by visually impaired persons in interacting with the websites creates the need for alternative solutions that can be used to resolve the challenges faced by them. One of the major challenges is navigation in complicated websites, as these websites use hierarchical structure to present the related information at a place. Most of the visually impaired persons use assistive technologies (section 2.2) such as screen readers to read the information. Screen readers linearize the hierarchical structure. Hence it becomes difficult for them to understand the semantic structure of typical web page.

A study in accessing the hierarchical structures is conducted by Smith et al., 2003. This study listed out the challenges faced by visually impaired persons in accessing hierarchical structures in IDEs. Authors had pointed out the need for appropriate commands and output to assist the visually impaired persons in navigating the tree (menu) structures efficiently and accurately. A prototype for easy tree navigation was developed and tested on Eclipse IDE for Java. The idea of this study was adapted and applied to make the navigation bar accessible for the visually impaired users.

2.1.2 Developers' Perspective

The inclusiveness of web interface can be described using the four principles of web accessibility defined in WCAG 2.0 guidelines: perceivable, operable, understandable, and robustness of the web application. Abuaddous and Basir, 2016 has presented these principles along with the holistic view of the challenges in creating accessible web content by the developers. The challenges faced by developers are divided into three categories described below

1. **Challenges in Standards and Guidelines:** There are plenty of web accessibility standard and guidelines. This section presents challenges in widely accepted Web Content Accessibility Guidelines 2.0. Although WCAG 2.0 has three different level of conformance testing proposals referred as A (weak), AA (medium) and AAA (strong) but length of documentation is more than 450 pages, with poor navigation features. These guidelines are difficult to interpret for web developers and require some level of expertise in accessibility. These things made it an impossible task to read the WCAG 2.0 during the development phase, which results in ignorance of accessibility of web content.
2. **During web-design and development:** The challenges during the web-development faced by the developers are- lack of motivation, awareness, and training courses on web accessibility. Due to this, most of the time, developers tend to ignore these issues. These factors prevent the effective utilization of web resources by persons with diverse abilities.
3. **During Accessibility Testing of web application:** Accessibility testing is the most critical phase in web-development to ensure the accessibility of a web application. Currently the testing is quite time-consuming as the existing testing tools such as A-Checker 2.4.2, WAVE 2.4.2 are not automated. These tools flag accessibility-related problems but need to fix manually by the developers. Finally, users' testing is done to ensure the accessibility of the design. Conducting the users' study is a big challenge as, users may, have diverse abilities, use different assistive devices to interact with the web-pages, variation in the level of expertise in using the web-technologies. A more detailed review of testing methodologies presented in section 2.4.

2.1.3 Case study: Accessibility in Education

In these days, the use of web-based technologies is heavily increased in the education sector, for example, online entrance and recruitment tests. Hence challenges faced by visually impaired persons in accessing the web content affects their carrier directly. A typical recruitment process involves many steps from the job search to interviewing. A research study by Grussenmeyer et al., [2017](#) presented the accessibility barriers in eleven integral aspects of a classic recruitment process, starting from the job search, application, exams, interview until on-boarding. The accessibility challenges in each step of a job recruitment process were highlighted for eight visually impaired persons from the technological background. The exams are a key component for final recruitment in a typical setting. Hence accommodations in the examinations play a vital role in the success of persons with disabilities. Authors also highlighted the unawareness of examinations authorities about the availability of accommodations for persons with disabilities during the exam. After completing all these steps of recruitment, one has to go to the Institute for his/her study. It turns out that in educational institutions, persons with disabilities have to perform more administrative tasks as compared to persons without disabilities, such as to fill accommodation form, to get accommodation letter, filling extra information every time for a new examination. The accessibility barriers in administrative processes also lead to putting the high effort in performing the task with minimal ways and may have to depend on others. This lead to the unequal outcome and hence, negative emotional responses. Coughlan and Lister, [2018](#) studied the accessibility barriers associated with the various administrative process. They analyzed the level of difficulty of every single administrative process and reported the impacts on the individual. The authors have talked about the barriers in requesting the adjustments / accommodations in studies, examinations, and day-to-day activities such as travel, parking.

2.2 ATs in web and computer-based interfaces

Assistive technology plays a key role in enhancing the accessibility of computer-based tests as presented in a research study by Hakkinen [Assistive Technologies for Computer-Based Assessments](#). Although technology advances have enabled the access of unlimited educational resources to all, including visually impaired persons, there are still many accessibility barriers in CBTs. The author discussed the two main drivers of the development of assistive technology i) innovation in technology ii) trend towards standardization. In order to facilitate the use of assistive technologies across various platforms, the creation of technical accessibility standards of assistive technologies is required.

In particular, to the computer-based assessments, there are various challenges pointed out in this study about the accessible CBT Interface VS the complexity of the platform from the developers' perspective. However, in real life students with disabilities prefers to use their tools rather than inbuilt tools in the platform, so the author suggested the need

for empirical studies about the accessibility of CBTs and Hence to evolve these standards and guidelines related to the accessibility of CBTs.

2.3 Web Accessibility Policies

Web accessibility policies are the primary instrument for implementing accessibility solutions, as presented in a study by Brajnik and Graca, 2018. Authors surveyed the accessibility policies of twenty universities in Europe and highlighted the need for the development of accessibility policies in higher education institutions to cater to the needs (including exam related needs) of persons (students, staffs, and faculties) with disabilities. The basis for measuring the comprehensiveness and concreteness of policy includes three parameters - role, content, and quality of the policy. In the policy-making scenario, authors reported that web-development, and hence web developers to be one of the important components.

2.4 Web Accessibility Evaluation Methods


Accessibility testing of a website is very crucial to ensure the effectiveness and usefulness of the web-design for the persons with a diverse set of abilities. A study by Pandey, 2015 presents the overview of various methods used in the accessibility testing of a web application. There are two modes of accessibility testing, namely: i) Manual testing ii) Automated testing as noted below.

2.4.1 Manual Testing

In this method generally, an accessibility expert, who knows all the rules, regulations, and aware with accessibility conformance tests to achieve the accessibility, tests the website completely. There are multiple methods used by accessibility experts to check the accessibility of a web application. Here are some of the manual testing methods.

HTML Markup Validation

W3C has developed browser-based HTML validator to check the valid markup of the HTML document. It supports the options of URL, validation from an HTML file, and text-input. A screenshot of the same is displayed in figure 2.1. This W3C validator executed on IIT Kanpur website to validate the markup errors. The result showed in the figure 2.2 displays 135 markup errors and 15 warnings. Using this information, it can be concluded that IIT Kanpur website has many accessibility issues to correct.



Markup Validation Service

Check the markup (HTML, XHTML, ...) of Web documents

Validate by URI

Validate by File Upload

Validate by Direct Input

Validate by URI

Validate a document online:

Address:

More Options

Character Encoding

(detect automatically)

Only if missing

Document Type

(detect automatically)

Only if missing

List Messages Sequentially

Group Error Messages by Type

Show Source

Clean up Markup with HTML-Tidy

Show Outline

Validate error pages

Verbose Output

Check

Figure 2.1: W3C html validator


<div><div><div>Markup Validation Service</div><div>Check the markup (HTML, XHTML, ...) of Web documents</div></div></div>		
<div><div>Jump To:</div><div>Validation Output</div></div>		
<div>Errors found while checking this document as XHTML 1.0 Transitional!</div>		
Result:	135 Errors, 15 warning(s)	
Address :	<div>https://iitk.ac.in/</div>	
Encoding :	utf-8	<div>(detect automatically)</div>
Doctype :	XHTML 1.0 Transitional	<div>(detect automatically)</div>
Root Element:	html	
Root Namespace:	http://www.w3.org/1999/xhtml	

Figure 2.2: Validation Results for IIT Kanpur Home Page

Validate font size

In order to validate that, a web application is using the relative font-size or fixed font size, accessibility tester changes the default font-size of the browser and then see whether

font-size of web-page changes or not. If a change happens accordingly, then it means that web application used relative font-size else not. Use of relative font-size give personalization to the end-user to choose the font size of the web-page; this will enhance the user experience across the web-pages without any intervention with font-size for individual websites.

Alternate-text

A screen reader uses alternate text for images to describe the HTML image content to visually impaired users. In this testing, one has to hover the mouse over images in the internet explorer to see the availability of alternate text for the image.

Skip-Navigation

In this testing accessibility tester manually checks the tab-order of various navigation links. This method helps people with mobility impairment to easily navigate the website through various links to jump over the content.

Form labels

In a typical HTML form, every input field is associated with a label to identify the semantics of the input, accessibility expert checks by clicking each label and see the cursor goes to the corresponding input field or not.

The manual testing methods can be used for end to end testing but require much human effort, expertise, and time, so become impractical. Considering the exponential growth in the digital world, one cannot rely on these methods. Hence the need for automated testing arises, and few tools have been developed to achieve the same.

2.4.2 Automated Testing

There are various tools available to automate web accessibility testing. This section reviews some of the popular tools for web accessibility testing.

Accessibility Checker (A-Checker)

AChecker¹ is a browser-based tool to evaluate the basic web-accessibility. It provides the basic accessibility testing with respect to the various WCAG versions and provides the report in two different formats: i) guideline wise ii) line-number wise. The screen-shot of the tool displayed in the figure 2.3.

¹<https://achecker.ca/checker/>

Figure 2.3: A-Checker

Success Criteria 4.1.1 Parsing (A)

Check 185: id attribute is not unique.

Repair: Modify the id attribute value so it is unique.

✖ **Line 1060, Column 3:**

`<body>`

```
<div id="top-menu-container">
<div id="top-shadow"></div>
<div id="top-menu"><ul ...(contentHolder)
```

Figure 2.4: AChecker testing false negative example

This tool does not test for ARIA attributes, which provides the accessibility to screen reader users within the HTML only. A-checker was executed on the IIT Kanpur website and found many accessibility issues to tackle. However, it also displayed some false negatives. A simple example illustrated in figure 2.4, that 'id' attributes are not unique, but they are.

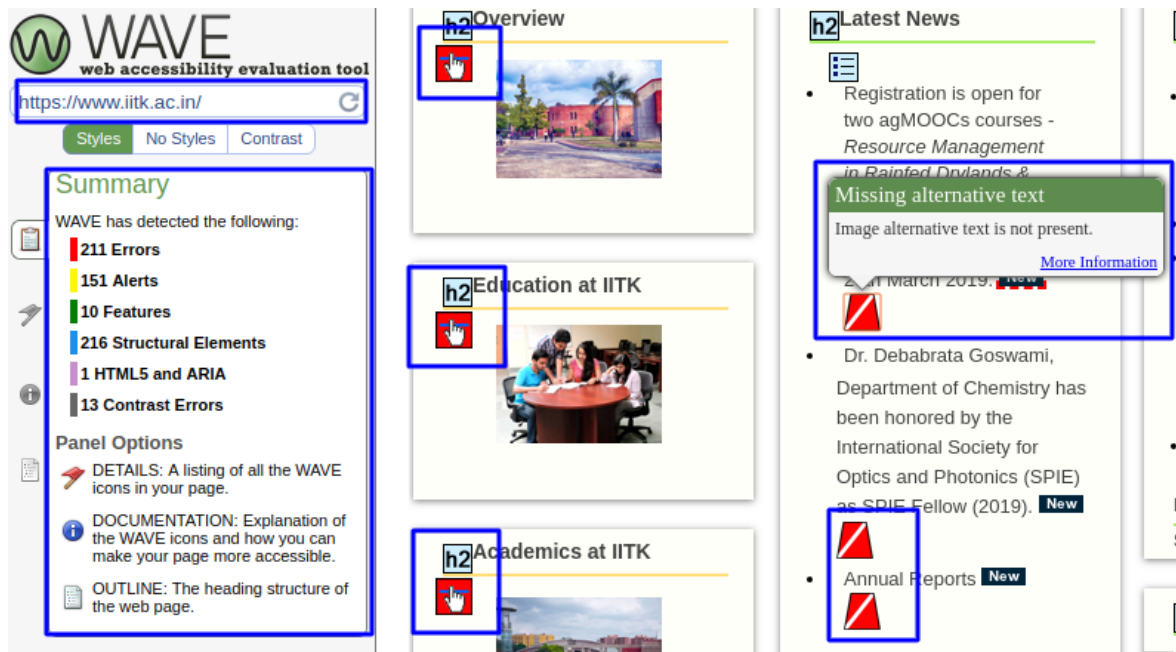


Figure 2.5: WAVE testing results for IIT Kanpur home page

Web Accessibility Evaluation Tool (WAVE)

WAVE² is a freely available accessibility evaluator, it provides the summary of the basic accessibility issues and features implemented in the website. It annotates the web-page highlighting the places, where the accessibility fixes need to be done, as displayed in figure 2.5.

The WAVE tool can identify the simple checks at the user end of a single web-page at a time. In the case of web-developer it is of little use, as s/he has to see the errors manually, then find the line in the code and finally fix it up.

Axe Accessibility Checker

Google Chrome Extension named Accessibility Developer tools³ uses the Axe for accessibility audit of the single web-page. It is a web-based interface to do the automated web accessibility testing along with providing few recommendations for manual testing. The figure 2.6 displays a snapshot of the accessibility audit of IIT Kanpur home. Again this is browser-based checker, which provides the summary of errors.

In the next chapters, an in-depth study of accessibility barriers in accessing the web-content is done. Chapter 3 presents the user study of accessibility challenges in computer-based tests. Chapter 4 focused on the more general problem of accessibility barriers in

²<http://wave.webaim.org/>

³<https://chrome.google.com/webstore/detail/accessibility-developer-t/fpkknkljclfencbdbgkenhalefipecmb?hl=en>

Accessibility

These checks highlight opportunities to [improve the accessibility of your web app](#). Only a subset of accessibility issues can be automatically detected so manual testing is also encouraged.

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Contrast

These are opportunities to improve the legibility of your content.

- 1 Background and foreground colors do not have a sufficient contrast ratio.



Best practices

These items highlight common accessibility best practices.

- 2 [id] attributes on the page are not unique



The value of an id attribute must be unique to prevent other instances from being overlooked by assistive technologies. [Learn more.](#)

Failing Elements

div#contentHolder

Names and labels

These are opportunities to improve the semantics of the controls in your application. This may enhance the experience for users of assistive technology, like a screen reader.

- 3 <frame> or <iframe> elements do not have a title



Figure 2.6: Axe: Accessibility Audit IIT Kanpur Home Page

web applications for visually impaired persons. Finally, the critical challenges in the web-accessibility addressed in the next set of chapters along with the development of a tool called XsWebAll which will automatically detect the accessibility issues at the development stage and allows semi-automated fixation of them.

Chapter 3

Accessibility Evaluation of Computer-Based Tests

In today's world, higher education plays a key role in employment for individuals, including persons with disabilities. To get admission in a prestigious institution and procuring a well-paid job, one has to pass through the phase of highly competitive examinations. Due to the increasing number of applicants, the mode of conducting exams is gradually shifting from traditional pen-paper based tests to online computer-based tests (CBTs). Nowadays, all types of examinations including multiple-choice type, written and programming, are conducted using computers and web-based technologies, referred in this document as CBTs interfaces. Utilization of these technologies is quite confined for visually impaired persons because of barriers to accessing certain components of the interface due to their inability to perform certain physical activities; for instance, visually impaired persons find it difficult to read regular fonts and colored graphs during the examinations. There are plenty of challenges to access the computer-based content, as presented in a study by Abuaddous and Basir, 2016. Hence it is necessary to remove these accessibility barriers in order to provide visually impaired persons with an equal opportunity as that to the persons without any disabilities. Many CBT systems do have provisions for providing accommodations to visually impaired persons to overcome the accessibility barriers during the exams. In India, there are three commonly used accommodations in CBTs:

1. Magnification of the text,
2. Provision of a scribe and
3. Compensatory time to complete the examination.

These methods of accommodations are widely used for many years, and are part of the government of India guidelines for conducting written examination for persons with disabilities¹. However, to the best of our knowledge, systematic study about the effectiveness of these methods has not been conducted yet.

¹<http://www.disabilityaffairs.gov.in/content/page/guidelines.php>

This chapter presents a study evaluating the availability of common types of accommodations in CBTs in India and their positive and negative impacts on the performance of visually impaired persons. A few recommendations proposed for adopting more technology-based accommodations, based on the study of various accommodations and their limitations. These recommendations have arrived from the experiences of visually impaired persons who appeared in various CBTs, standard practices and manuals for example, [The Importance of Information Technology for Visually Impaired Children and Youngsters and the Expectations for Future Development](#); [I for Inclusion by The Xavier's Resource Centre for the Visually Challenged](#). The primary benefits of having technology-based accommodations are availability and consistency (see Section 3.3).

The organization of the chapter as follows: In section 3.1 a detailed description of the methodologies used in the study presented. Section 3.2 list the findings on the challenges faced by visually impaired persons in CBTs. The extended abstract for this work is accepted for oral presentation in the international conference [AAATE 2019](#).

3.1 Methodology

We created a Google form comprising of a single choice, multiple choice, Likert scale type, and short answer type questions. The questions were designed to access the accessibility barriers in the online competitive examinations and entrance tests. Participants were allowed to fill anonymously the past experiences of up to three online examinations in a single form². The complete questionnaire and the raw data collected is available at the project page³.

3.1.1 Survey Design

Questions in the Google form divided into three major sections,

- General information about the participants: Information about the age, disability type, and its extent included in this section along with the objective of the research study and electronic consent for voluntary participation. In order to facilitate complete anonymity of individual participants, no personal information was collected (such as. email, phone number, address, profession) about the candidates, which can be used for their identification. The anonymity is to allow the participants to give honest feedback about the availability and expectations of accommodations in the CBTs. Google form did not have a question about the identification of the gender of the participant since neither the disabilities nor the reasonable accommodations provided in the examinations are affected by the gender of the candidates.

²We allowed data for up to three exams to keep a balance between diversity of exams and candidates. Any participant could have filled multiple forms to give data about more exams, but one can not know about it due to the anonymity of participants.

³<https://www.cse.iitk.ac.in/users/karkare/accSurvey/>

- Examination without any accommodation: In order to discover the accessibility barriers in the CBT interfaces, participants were asked to share their experiences about the accessibility of CBT interfaces without any assistance. The essential questions include the name of examination, the extent of readability of questions, reading upper case words, and sub-scripts / superscripts, typical components which are inaccessible, and reasons behind the inability to the questions. These questions give an idea of what are the common barriers faced by visually impaired persons in a typical CBT.
- Examination with accommodations: This part is designed to analyze the effectiveness of the current practices of providing accommodations to persons with disabilities who have the limitation in reading and writing. Participants were asked about what all accommodations they would like to use and which of them are available during the exam. Apart from that, the participants were asked about the effectiveness of commonly available accommodation such as - scribe, magnification, and compensatory time. Moreover, participants were asked about their preferred way of reading and overall rating of CBT interface on a Likert scale of 0 (Very poor) to 5 (Excellent).

3.1.2 Data Collected

This study is confined to CBTs in India. Although the data about geographical information of participants was not collected, still there is sufficient diversity in the participants due to the fact that we had targeted the participants from national forums that include educational institutes like IIT Kanpur⁴, IIT Delhi⁵, and registered participants at events like Empower 2018⁶ and I-STEM Hackathon 2018⁷. These places/events have the participation of persons with disabilities from all over India. Invitations were sent to registered email ids of persons with disabilities on these forums. We had received responses from 24 participants before Jan 15 2019, out of which one response has been ignored due to no valid entry in the field 'name of examination s/he had appeared in'. In 23 responses, six participants have shared their experiences in two different CBTs; one participant filled the survey for three different CBTs, and the remaining 16 participants had filled the questionnaire for only one CBT.

3.1.3 Data Preprocessing

The very initial step was to clean the data. We followed a semi-automated approach where scripts in Python2.7 along with a little manual intervention was done. Here are

⁴<http://www.iitk.ac.in>

⁵<http://www.iitd.ac.in>

⁶<http://assistech.iitd.ac.in/empower2018/>

⁷<http://inclusivestem.org/hackathon-2018.html>

Table 3.1: Number of participants appeared in various online exams

Name of Exam	# Participants
GATE	7
Bank Exams ⁸	5
JEE-Advanced	3
JAM	3
BITSAT	3
Campus Placement Exams ⁹	3
RRB	1
SAT	1
KVPY	1
ICET	1
Government recruitment exams	1

⁸RRB, SBI PO, IBPS etc.

⁹Participants had reported various interfaces on which they have appeared for campus placement tests which includes Hackerearth, Hackerrank, codecubes, AMCAT and GUVI.

the steps followed for preprocessing:

- Each exam is considered as a separate entry (row) in the analysis. The participants who have shared experiences for more than one CBT, information about such participants was duplicated for each CBT. This approach simplified the analysis of the data while maintaining the completeness and correctness.
- Rows having the invalid response to 'Name of Online Exam you appeared in' were ignored straight away since these rows defeat our core purpose of the study.
- Entries that do not satisfy the conditional dependency of the previously asked question were discarded as it does not make sense to keep them in analysis and to distort the actual result. Here is an example of how invalid entries were discarded. Consider the following questions, where the second question is dependent on the first:

1. Did you get the magnification enabled in the exam?
2. If you have answered "yes" to the previous question. Please let us know to what extent are you able to read the questions/instructions during the exam after enabling the magnification?

For the responses that contain a 'no' or 'not applicable' to the first question, any response in the second question was discarded and considered to be not applicable.

3.1.4 Data Analysis

We made use of Python 2.7 modules, including pandas, numpy, statsmodels, matplotlib, and seaborn, to analyze the preprocessed data. Since the participants who responded were all visually impaired persons except one with cerebral palsy. We analyzed the dimension of the extent of disability (in this case, vision impairment) and made observations of the type of challenges faced by specific ranges of the extent of disability. We compared accommodations available to the visually impaired persons with the expected accommodations they mentioned. This data can be used to find the appropriate modifications in existing practices of accommodating visually impaired persons during CBTs.

3.2 Findings

This section presents the observations and finding of this empirical study based on the responses received until January 15th, 2019. Note that while originally plan is to analyze the extent of disability at five different levels between 0 and 100%, since there was no response in the range of 80% – 90% disability, so this category is omitted in the further discussion.

The age distribution of the participants was as follows: mean age was 23.4 years, the minimum age was 17 years, the maximum age was 35 years, the first quantile was 22 years, the median was 24 years, and the third quartile was 25 years. These observations reflect that participants had much diversity, and they appeared in CBTs either for higher studies or for getting a job. We received data about 11 different exams from different domains, representative of variations in the interfaces of different CBTs as attempted by visually impaired persons in India listed in Table 3.1

We analyzed the general accessibility of CBT interfaces, followed by the effectiveness of various accommodations provided to visually impaired persons in CBTs and the preferences of various accommodations among visually impaired persons.

3.2.1 CBT Interfaces

CBT interface is a combination of many components. The overall accessibility of a CBT interface is determined by the accessibility of individual components. In order to get a brief idea about the accessibility of standard CBT interface, participants were asked to rate the CBT interface available during CBTs on a Likert scale. The responses can be seen in Figure 3.1. A total of 58.6% visually impaired persons rated exam interfaces two or below on a scale of 0 – 5. In particular, 50% of the participants with 90% or more vision impairment gave 0 score to the CBT interface. These responses showed the poor experience of visually impaired persons with the CBT interfaces.

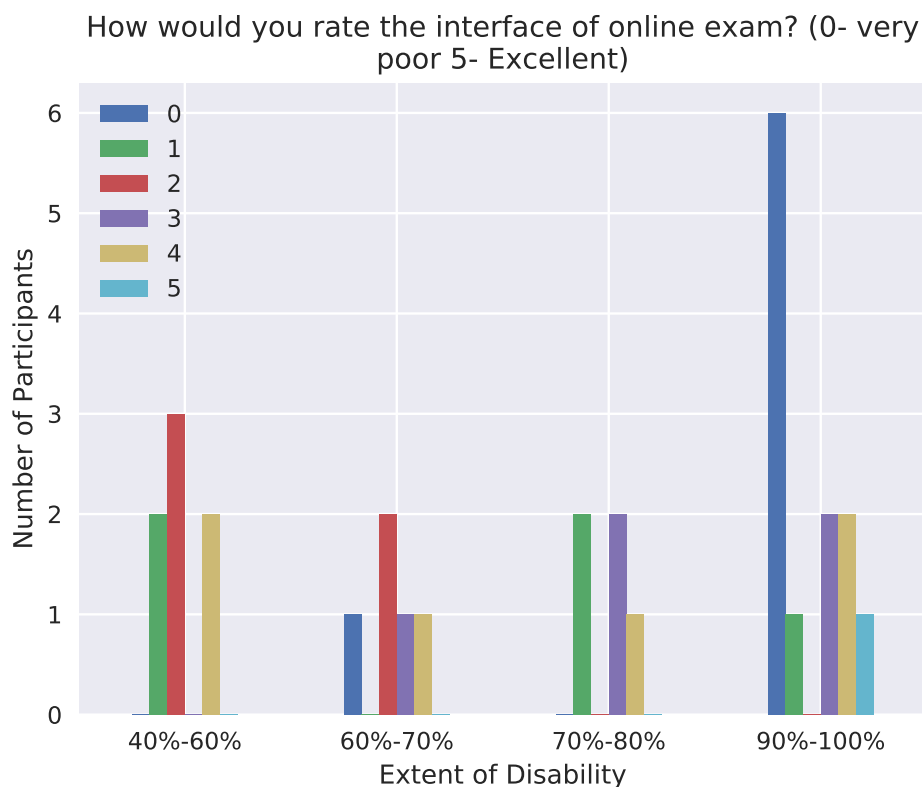


Figure 3.1: Exam interfaces rating

Figure 3.2 shows that more than 60% participants faced significant difficulty (rating 3 or more on scale 1 – 5) in reading the upper case words. This observation was consistent with the results in the research done by the cognitive scientists Arditi and Cho. Arditi and Cho, 2007 on the legibility of letter-case for visually impaired persons and persons without disabilities.

CBTs involving scientific formulae contain subscripts and superscripts. Figure 3.3 described the level of difficulty faced by visually impaired persons in reading the subscripts and superscripts. It can be seen that a vast majority of the participants reported 4 or 5 level of difficulty, irrespective of their extent of disability.

CBT interfaces have other components apart from questions to perform the various operations such as – the selection of the questions, answering the questions, and operating the calculator. We asked the participants to highlight various inaccessible components in a standard CBT interface. Table 3.2 listed their responses. It can be seen that more than one-third of participants had some difficulty in accessing the calculator, images, and icons embedded in the CBT interface. Two participants reported the barriers in accessing anything that requires movement of the mouse.

On digging deeper into the reasons behind the accessibility of questions and other components of CBT interfaces, many participants reported some common reasons for inaccessible platforms. These are shown in Table 3.3. We observed that inappropriate font-size used by the CBTs is the primary cause of inaccessibility for approximately 50%

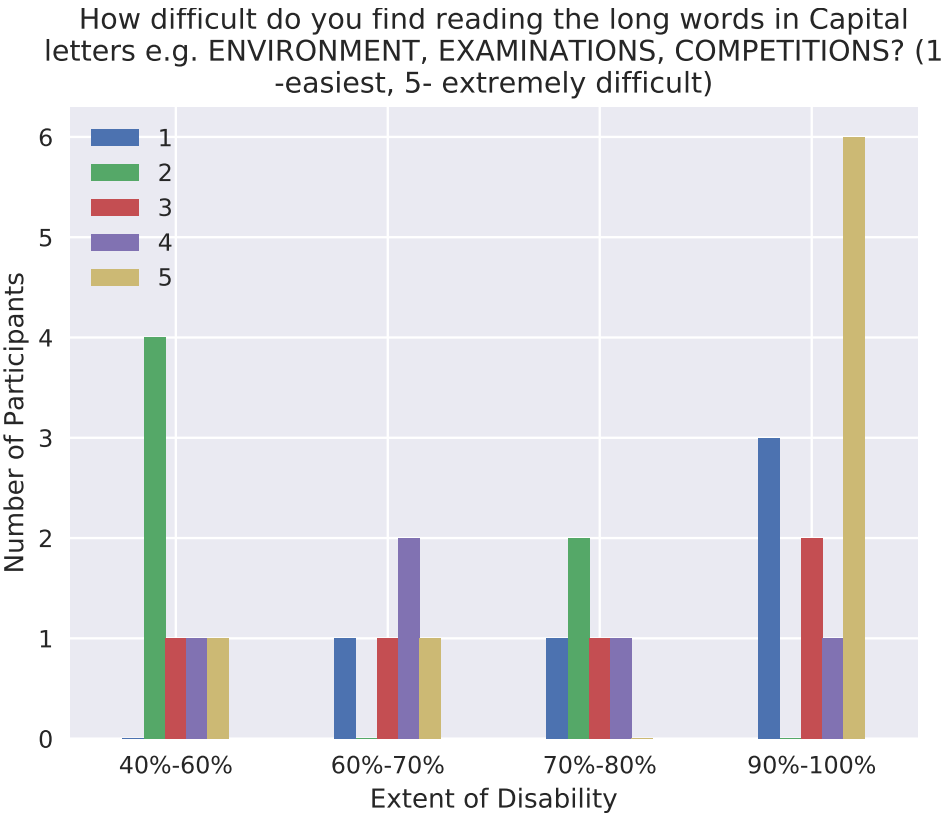


Figure 3.2: Reading the upper-case words

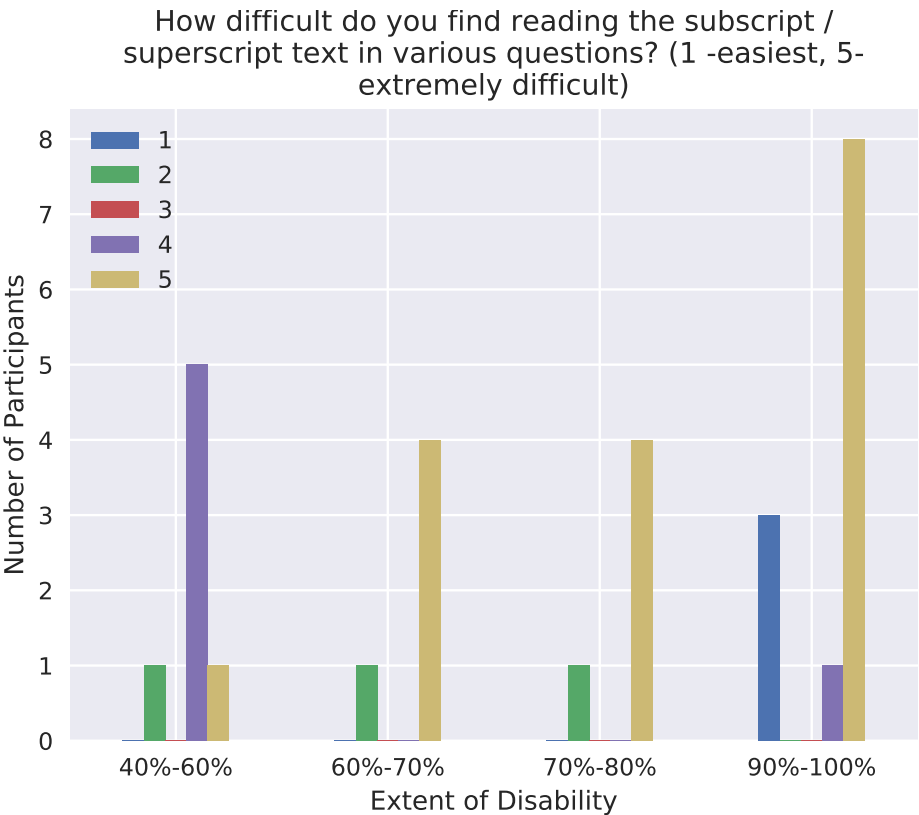


Figure 3.3: Reading the subscripts / superscripts

of the visually impaired participants. Since visually impaired persons have their font-size reading habits, providing options for changing the font-size of specific items will help in

Table 3.2: Inaccessible components of exam interface

Inaccessible Component	# Participants
Calculator	12
Images	12
Icons	10
Interaction with Mouse	2

Table 3.3: Common reasons for inaccessible interfaces

Reasons for inaccessibility	# Participants
Font size was not appropriate	15
Color contrast was poor	9
Lack of screen reader support	5
Poor quality of images	1
Surrounding lighting conditions	1

resolving the primary cause of inaccessibility Arditi and Cho, 2007.

One participant reported a major issue that providing a scribe for a CBT causes him/her to lose any advantage of having a computer-based exam. We quote:

GATE 2018 did not have screen reader installed on their system. And they did not allow it to give it on my laptop. As a result, they provided me scribes. So It apparently makes no difference for me whether it was online or offline. Although the exam was Computer based.

This participant raised an important question about the usability of a scribe in the CBT. Whether the exam is paper-based or computer-based, it does not make a difference to him/her because in either case, the scribe reads the content. This question reflects the kind of accommodations provided for paper-based exams are not sufficient for the CBTs.

In order to discuss the issues with accommodations further, analysis of most common accommodations provided in the CBTs presented below, which includes, magnification, scribe, and compensatory time;

3.2.2 Accommodation: Magnification

To evaluate the effectiveness of magnification, participants were asked to rate the benefit of magnification on Likert scale. The responses are shown in Figure 3.4. The effect of magnification depends on the extent of disability, as can be seen from the bar chart. nine out of 12 people with 90% – 100% visual impairment reported that magnification of

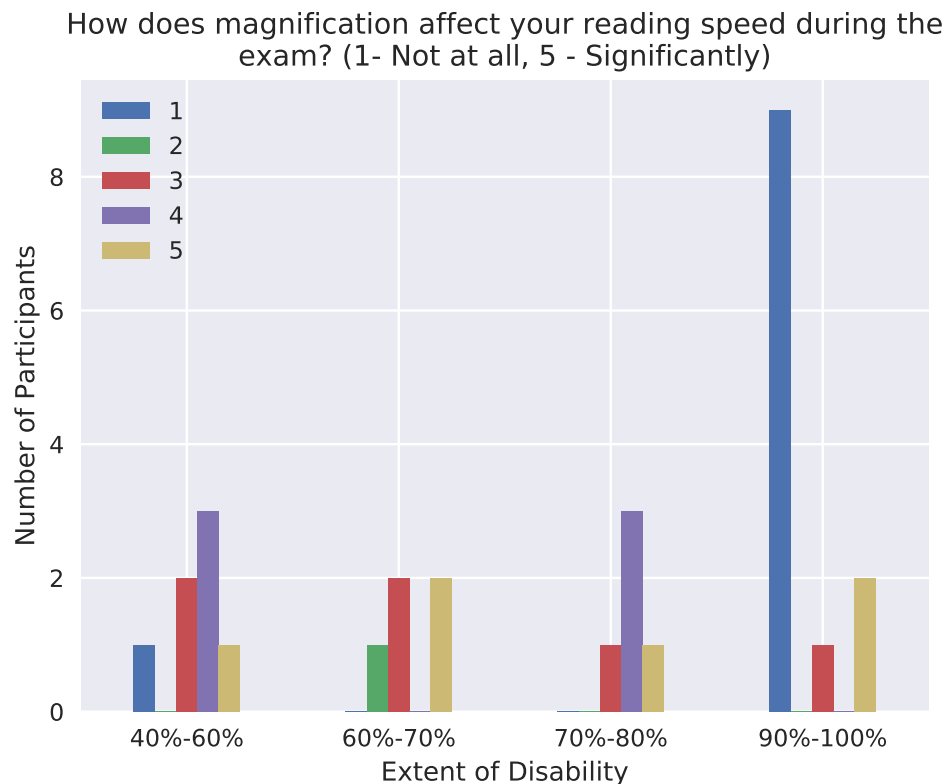


Figure 3.4: Increment in reading speed on magnification

the text was barely useful because of less or no residual vision. On the other hand, 15 out of 17 people with up to 80% disability reported reasonable improvement in reading speed due to magnification.

On querying about a availability of the magnification feature in the examination as showed in Figure 3.5, only 37.9% candidates reported that they got magnification enabled in the exam. 24% candidates did not get this facility during the exam, despite their need. Two primary reasons behind this could be 1) CBT Authorities did not manage to provide the magnification feature. 2) Participants had not asked for the same. It should also be noted that the candidates who did not ask for this accommodation were mostly in the category of 90% – 100% vision impairment, as explained earlier, magnification accommodation is little or no use for them.

In order to evaluate the sufficiency of magnification, participants were asked about the extent of readability of questions after enabling the magnification. Their responses displayed in the Figure 3.6. 81% of the people who got the magnification enabled in the CBT were able to read up to 90% or less. This limited reading access is not sufficient in today's competitive world, where losing a single mark may lead to a lesser grade in a course or disqualification in an entrance. Various reasons due to which participants are unable to read the complete CBT even after enabling the magnification to include insufficiency of the extent of magnification and heavy scrolling of text. The problem of heavy scrolling is identified by 90% of the visually impaired persons, who got magnification enabled in CBT can be seen in Figure 3.7. The effectiveness of magnification for visually impaired

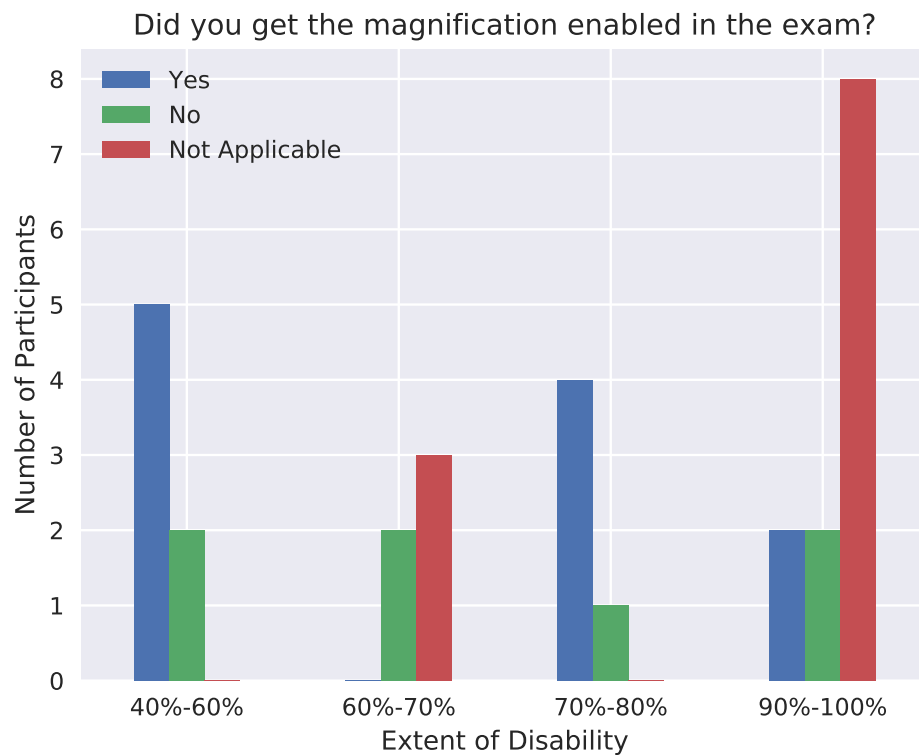


Figure 3.5: Availability of Magnification

let us know to what extent are you able to read the questions/instructions during the exam after enabling the magnification?

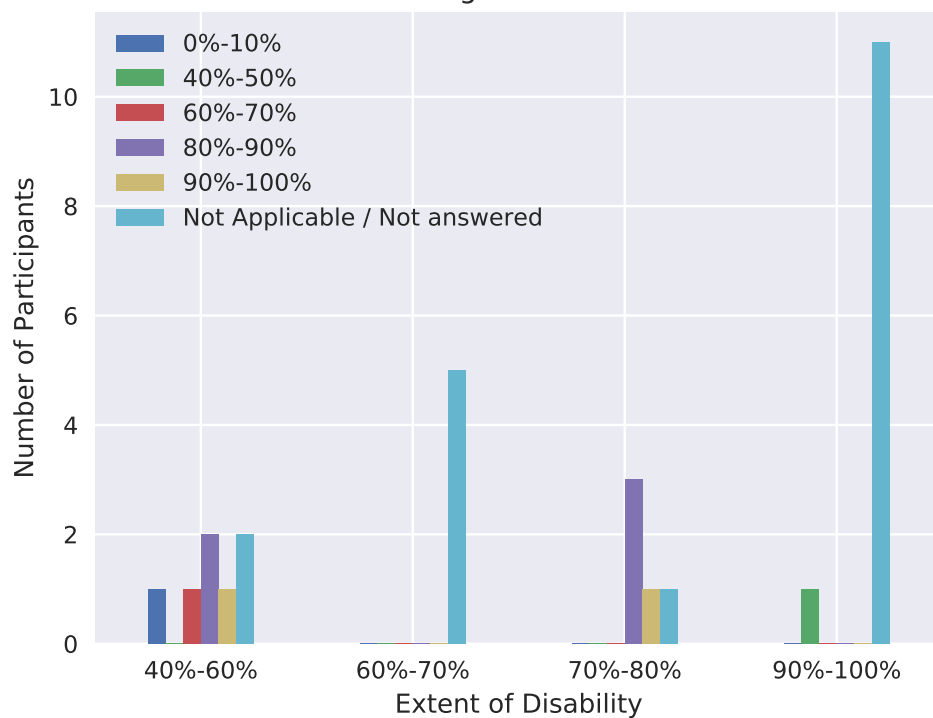


Figure 3.6: Extent of reading after enabling magnification

persons can be enhanced by providing a bigger monitor. This arrangement may reduce the need for the large extent of magnification and hence, the problem of heavy-scrolling.

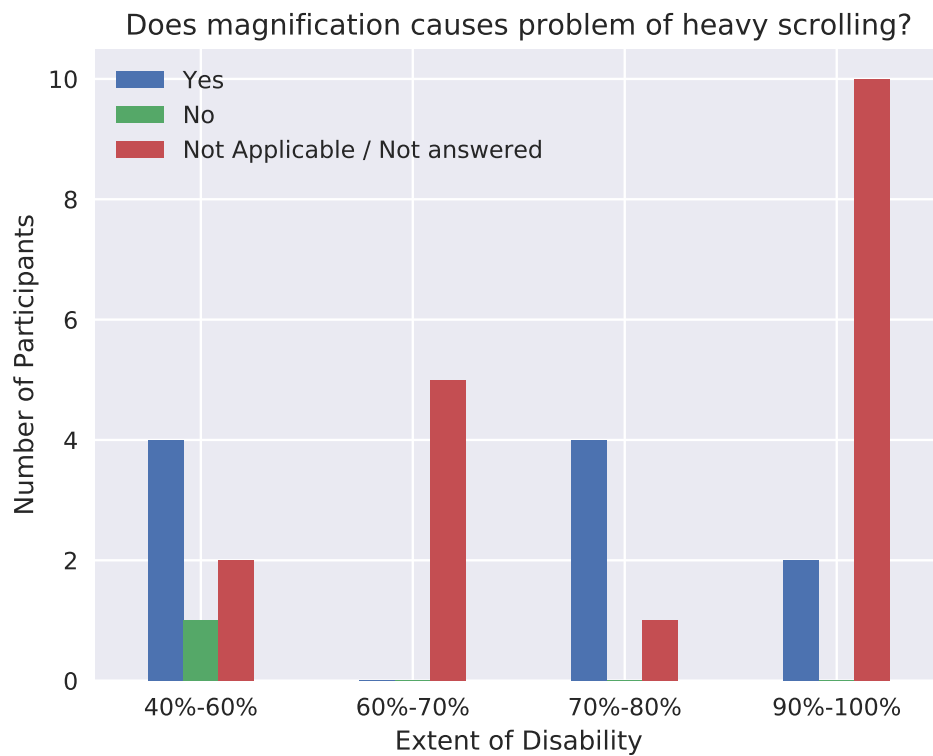


Figure 3.7: Heavy scrolling due to magnification

Responses are given in the Figure 3.8. More than 40% visually impaired persons opined that bigger monitor setup could help them in easy reading of the text. In particular, 75% of visually impaired persons with 90% – 100% impairment reported that bigger monitor setup is no use for them as enabling magnification does not affect their reading performance.

It is observed that the accommodation type 'magnification' was not useful for people with severe vision limitation, i.e., more than 90%. Hence magnification was not a reasonable accommodation for such visually impaired persons. As responses from the visually impaired persons in the figures from 3.4 to 3.8 shows the majority of them opted for no effect or not applicable.

3.2.3 Accommodation: Scribe

A Scribe is another most commonly used accommodation in CBTs to provide equal opportunity to visually impaired persons. Figure 3.9 displays the distribution of scribe accommodation used by visually impaired persons. The participants who have 90% or more disability out of these, 91.6% used a scribe in the CBTs. On the other hand, participants having 80% or less vision impairment, only 35.2% used a scribe in the CBTs. Participants with 90% or more disability preferred to use scribe due to lack of residual vision in their eyes. Hence they require assistance in reading questions/instructions during the CBTs.

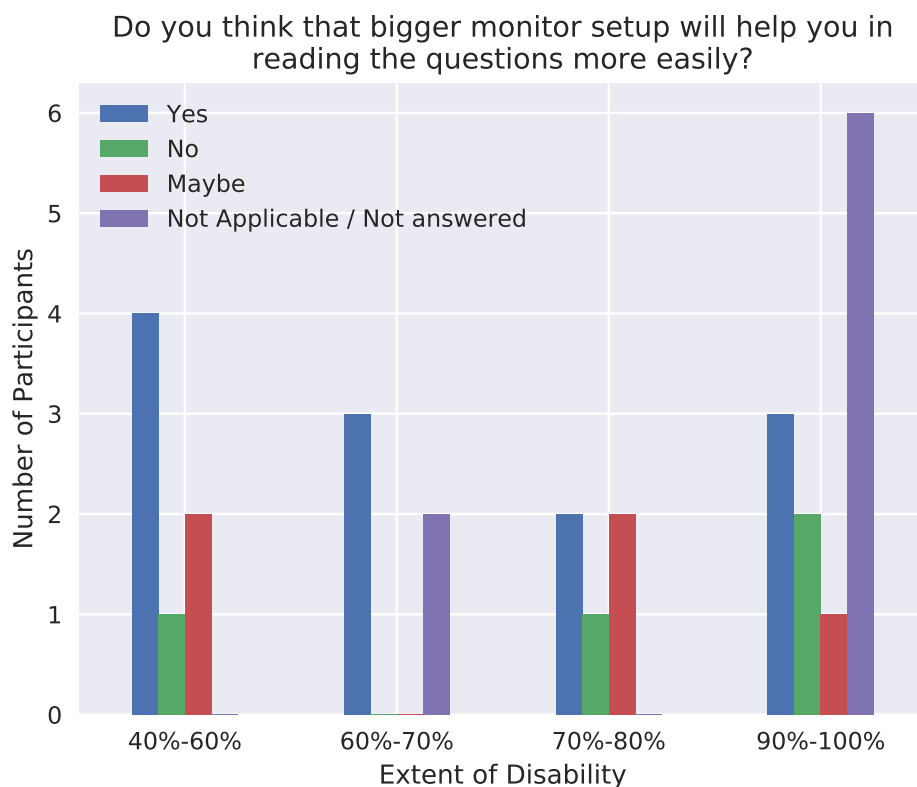


Figure 3.8: Possible effect of bigger monitor setup

While participants with residual sensitivity in their eyes can read the information with sufficient magnification and/or appropriate color contrast.

In order to analyze the effectiveness of the scribe accommodation in CBTs, participants were asked to report the impact of scribe assistance on their performance in the CBT. It can be deduced from the Figure 3.10 that only 27.3% participants out of those who used a scribe during the CBTs reported enhancement in their performance. Rest of the participants reported either drop or no impact in their performance in CBTs due to scribes. Let consider the participants having 90% or more disability, Now from the Figure 3.10 it is easy to see that 41.6% of such participants who used a scribe reported enhancement in their performance, while 50% reported drop or no impact on their performance. The participants having 80% or less disability, 58.8% of them reported drop or no-impact in their performance in CBTs, and only 5.8% reported enhancement in the CBT performance. The above statistics of effectiveness a scribe in CBT showed that accommodation scribe is beneficial for a limited set of visually impaired persons who have very less or no residual sensitivity in their eyes.

The discussion above brought us to a conclusion that visually impaired persons who can read with the magnification do not prefer to use a scribe for assistance in reading. In order to validate the reasoning above, participants were asked to provide feedback about their experiences with the scribe during CBT. The major concerns of the participants were as follows:

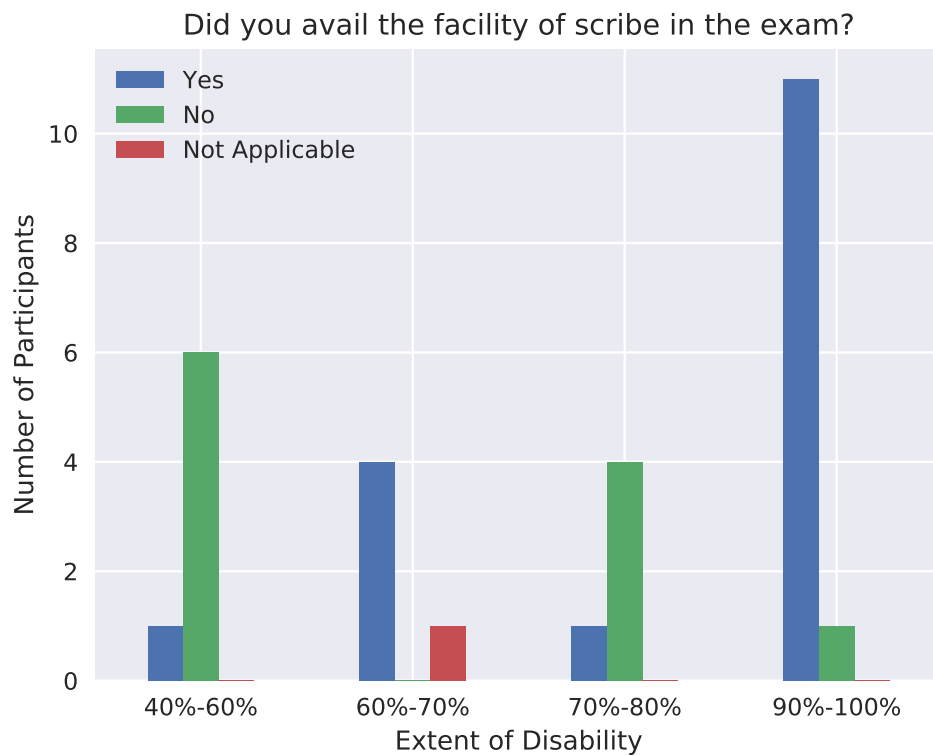


Figure 3.9: Availability of Scribe

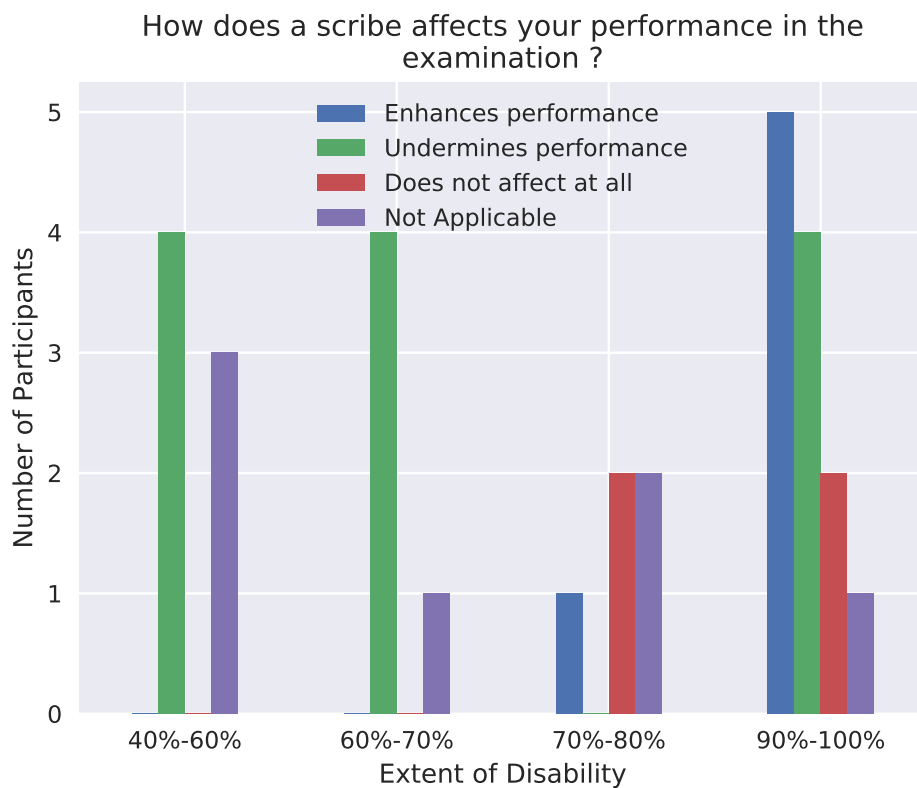


Figure 3.10: Impact on performance by utilizing scribes

- Difference in the reading style of scribe and the participants expect to receive the information.

- Inadequate competence level of the scribe as per the examination requirement, to read the questions and notations with appropriate context.
- Language and accent barriers.
- Lack of practice with a scribe in the day to day life.
- Lack of independence and control over the exam.

We quote some of the comments provided by the participants who used a scribe during CBT:

Screen reader provides independence to re-read and navigate quickly as compare to scribe, especially for the long question, I am habitual of using screen reader as compare to scribe as I rarely get a chance to practice with a scribe.

It's some time feel better to do to the accessibility of equations and other symbols, but assistive technology is better if there is good access.

The scribe was less well versed with English and often did mistakes. He was also unaware of many maths symbols. Also as he was always looking into my paper I was losing confidence in myself.

In normal day to day life, I am habituated to reading by myself rather than by a scribe. Hence it will have a bearing on the swiftness of understanding the question.

Its hard to understand the code being read aloud to me.

3.2.4 Accommodation: Compensatory time

Compensatory time is essential accommodation, which compensates the time consumption in the CBTs due to various accessibility barriers by providing extra time to complete the exam. Intuitively, compensatory time would be a need of every visually impaired person because of some difficulty in reading the question / instructions from the screen. We evaluated the sufficiency of standard time duration in the exam. As it can be seen in Figure 3.11 that 86.2% participants reported standard time duration was not sufficient to complete the exam. This evidence confirmed the intuition about the limitation of the magnification and scribe. In order to get more details, participants were asked if compensatory time was beneficial for them or not. From Figure 3.12 it can be observed that regardless of the extent of visual impairment, participants used the compensatory time. In total, 75.8% participants reported the same.

Figure 3.13 shows that 95.4% of those who had availed the facility of compensatory time reported that it indeed helps in completing the examinations.

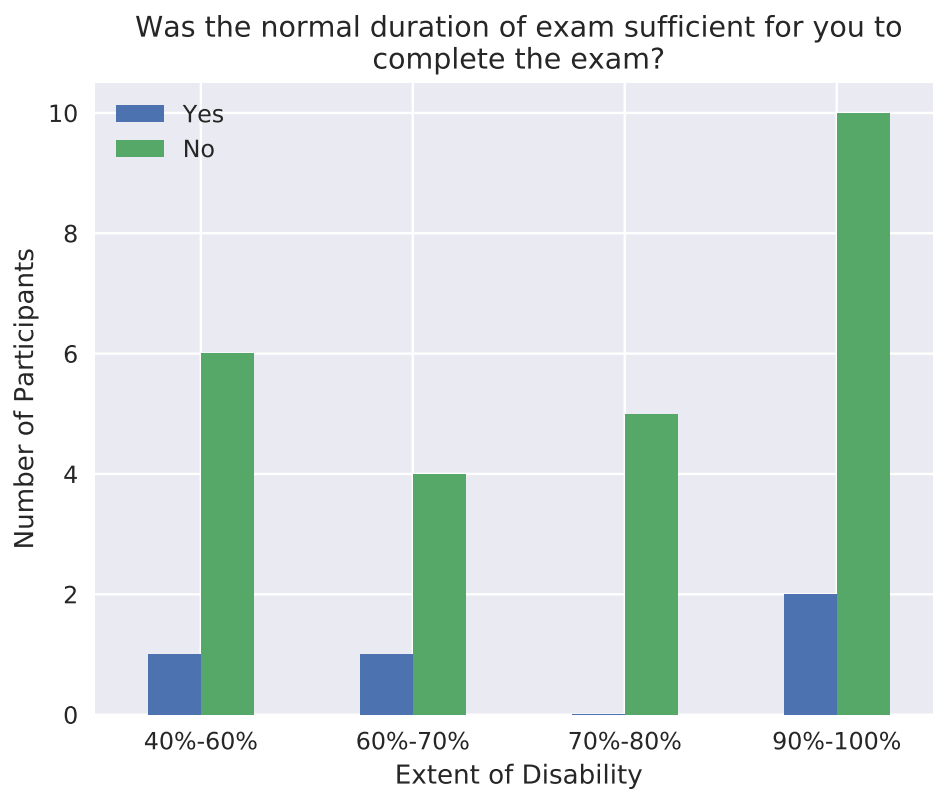


Figure 3.11: Sufficiency of standard time duration

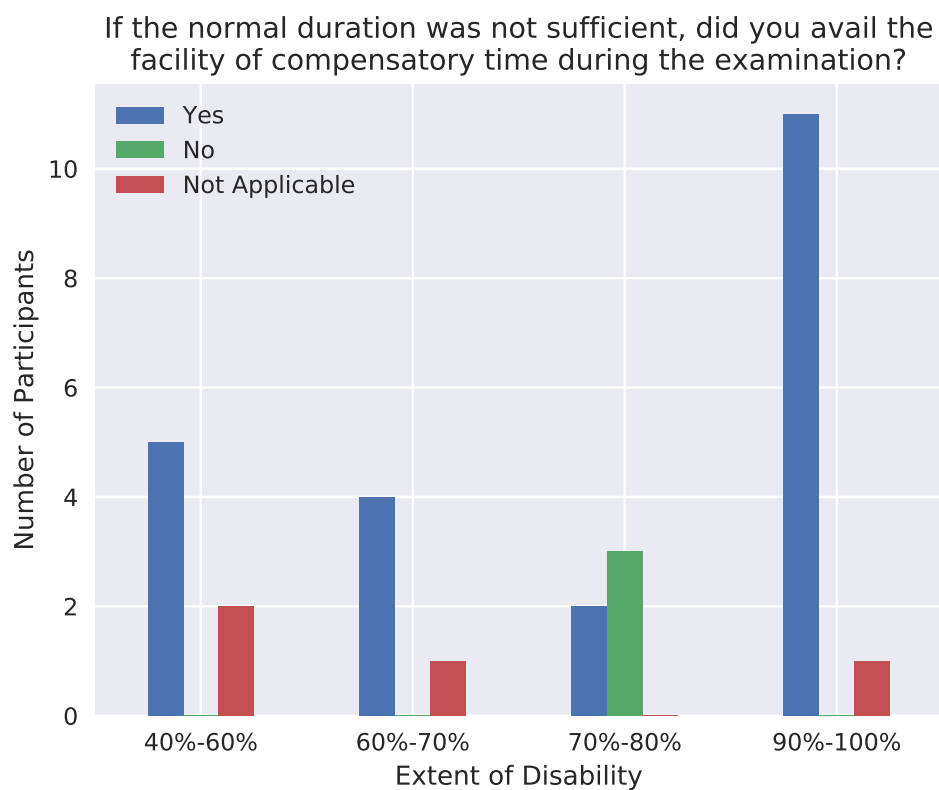


Figure 3.12: Availability of compensatory time

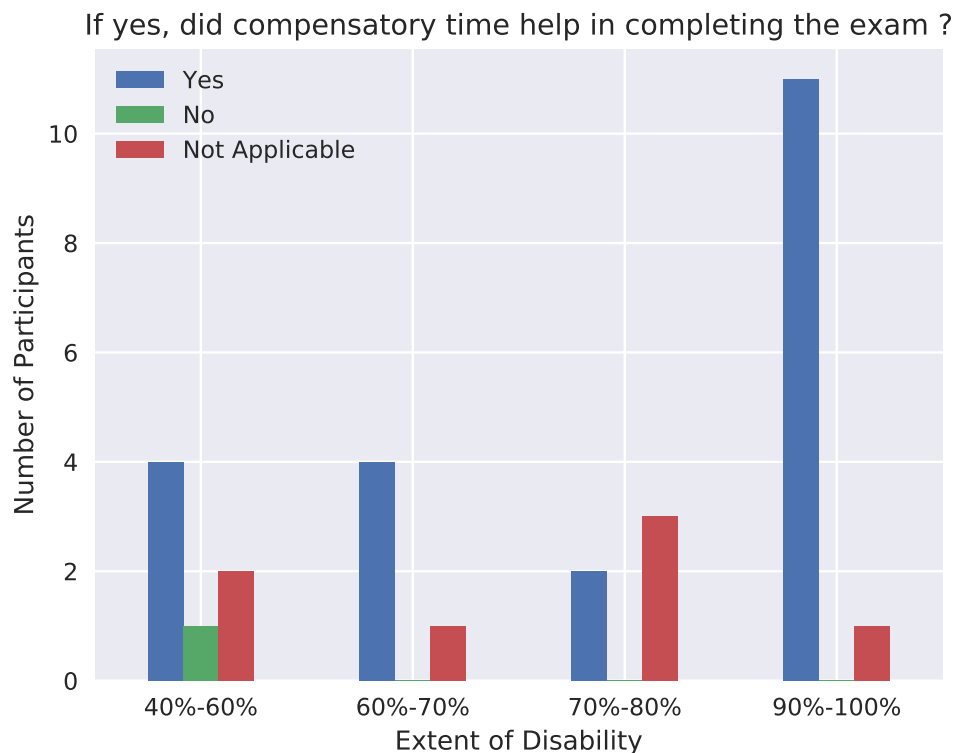


Figure 3.13: Efficiency of compensatory time

3.2.5 Preferences among accommodations

We saw that different type of accommodations were suitable for the different set of individuals depending on the extent of their disability. To further illustrate the fact, we asked participants about their preferred way of reading the questions. As it can be seen from Figure 3.14, 82.3% visually impaired persons having disability 80% or less, prefer to read text with the help of magnification. Very few of them use a screen reader. On the other hand, 58.3% of visually impaired persons having more than 90% vision impairment prefer to read with a screen reader. It is interesting to note that only 6.9% visually impaired persons prefer to use scribe over other types of accommodations.

In reality, a single type of accommodation does not suffice to overcome the accessibility barriers in the CBTs. Hence we made a comparison between the accommodations available and accommodations expected by the participants. The responses were showed in the figure 3.15. Availability and expectation of scribe and compensatory time are very similar and these accommodations used by 50% and 70% of the visually impaired persons. On the other hand, accommodations such as magnification of text, screen reader, option for choosing color contrast and bigger monitor setup were rarely available during CBTs, but 30% – 50% visually impaired persons needed these accommodations.

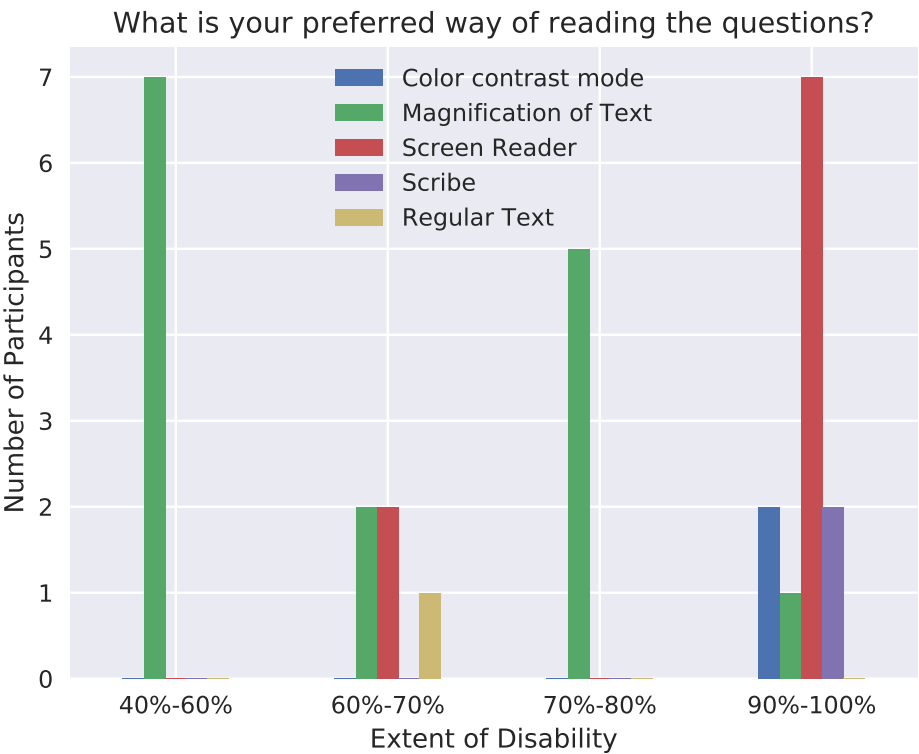


Figure 3.14: Reading preferences

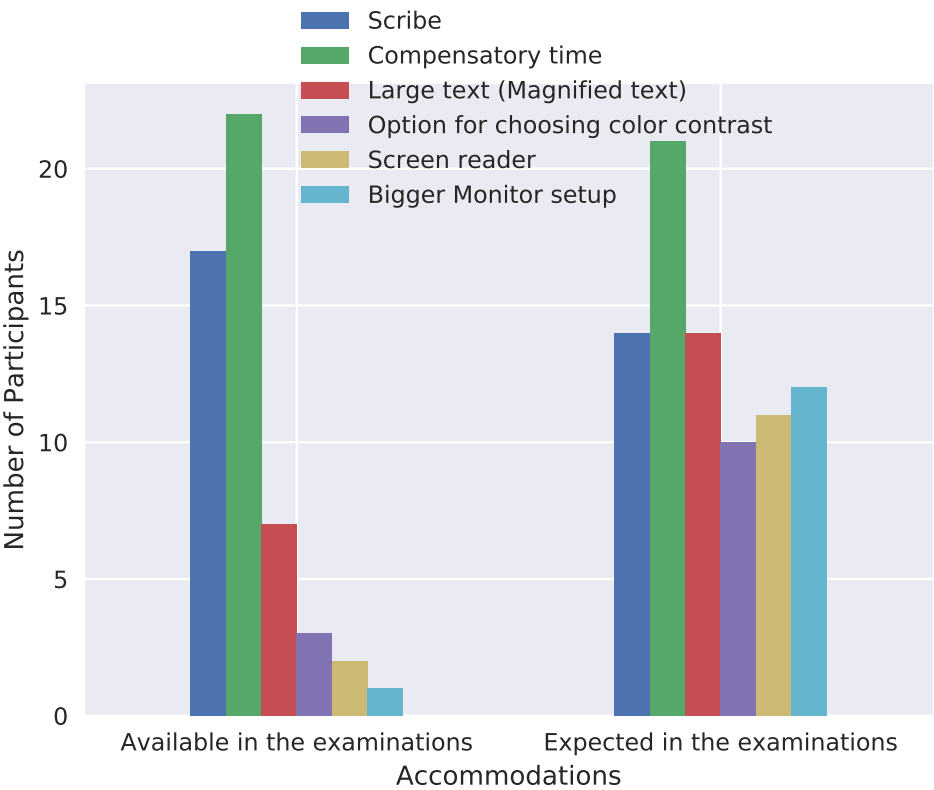


Figure 3.15: Available vs expected accommodations

3.3 Recommendations

Accessibility of CBTs is crucial for the good performance of visually impaired persons. This study shows that there are limitations of commonly used accommodations, such as lack of competence level of the scribe, insufficient magnification, inaccessible mathematical content, and diagrams for screen reader users. In this section, we propose a few recommendations to improve the accessibility of CBTs. These recommendations are based on the feedback provided by the participants of the survey, background work (Sections 2.1.3, 2.2 and 2.3) and other resources [The Importance of Information Technology for Visually Impaired Children and Youngsters and the Expectations for Future Development; I for Inclusion by The Xavier's Resource Centre for the Visually Challenged](#).

In general, technology-based assistance has a significant role in independent living [The Importance of Information Technology for Visually Impaired Children and Youngsters and the Expectations for Future Development](#) of the visually impaired persons. Technology-based assistance is preferred by visually impaired persons because of consistency in support and assurance of availability, as compared to human-based assistance (such as scribe) lacks consistency (for example, having a different scribe for different exams). In recent years, with the advancement in the assistive technology, visually impaired persons can perform reading and writing tasks on their own, subject to the availability of the contents in an accessible format.

As shown in the research study by Web-Aim¹⁰, visually impaired persons can experience different kinds of accessibility barriers due to variations in the causes of visual impairment. Hence there is a need for adaptive accessible CBT interface, which can personalize the CBT as per the requirement of individuals. Since every visually impaired person has a unique set of requirements in terms of accommodations in the CBTs, so CBT conducting authorities should ask the visually impaired persons about their requirement of accommodations at the very beginning of application form filling process. In order to achieve this, there is a need for the formation of accessibility policy for CBTs, which entertains the accessibility and universal design of CBT interface.

To improve the effectiveness of existing accommodations for visually impaired persons, we propose the following accommodation-specific recommendations:

- **Scribe:** To minimize the dependency on a scribe, the following technology-based solutions can be used:
 - Use of screen readers such as JAWS¹¹, NVDA¹².
 - CBT questions in text-based DAISY¹³ format so that screen reader users can access the content.

¹⁰<https://webaim.org/articles/visual/>

¹¹Job Access With Speech: <http://www.karishmaenterprises.com/JAWS.htm>

¹²Non Visual Desktop Access - <https://www.nvaccess.org/>

¹³<https://nfb.org/images/nfb/publications/bm/bm11/bm1102/bm110210.htm>

- Providing CBTs in an alternate format such as computer voiced test similar to the one already available for GRE¹⁴
- **Highlighting:** In our survey, 62% visually impaired persons reported average or more difficulty in reading the upper-case sentences and words. Upper-case words or sentences are used to highlight important things in the text. Here are some alternatives those can be used in the place of upper-case words:
 - Increase the font size of the text
 - Use of bold font-face
 - Use of camel case words
 - Highlighting of text background with different color
 - Create a box around the text
 - Underlining of the text
 - Change of font-family can also be a good option for highlighting.

In order to achieve the objective of highlighting the text and its accessibility, the suitable combination of above can be used. Since the combination of above may vary person to person, hence the system should have the capability to set the appropriate combination before the examination.

- **Magnification:** Accessibility of various icons, subscripts, and superscripts in the text could enhance by providing two kinds of magnification feature in the interface: one which zooms in the whole screen, and the other which zooms only a specific area on the screen to see tiny fonts. Such magnifications are already available on popular operating systems like Microsoft Windows and Apple iOS.
- To avoid heavy scrolling, bigger monitors can be provided to visually impaired persons. This bigger monitor setup will be highly beneficial, as requested by 41.3% participants in the survey.
- Inaccessibility of calculators could be removed by providing talking calculator^l for Inclusion by The Xavier's Resource Centre for the Visually Challenged.

¹⁴https://www.ets.org/research/topics/assessing_people_with_disabilities

Chapter 4

Web Development Practices: A study

A complete web-application made of multiple tiny components such as menu-bar, tables, figures, forms. The actual development is done by building these individual components and putting them together. This chapter presents a comparative study of commonly used web-development practices and the best practices of accessible web-development. The commonly used practices were referred from well known sources w3schools ¹ and tutorials-point ² and best practices for accessible development were referred from WAI-ARIA Authoring Practices 1.1 ³ and accessible web development guidelines of University of Washington ⁴.

4.1 Components of a Web Application

As discussed above, a typical web application consists of many small components. This section describes standard and best practices with code snippets displaying the modifications required to achieve the goal of accessible web design.

In this chapter, code snippets are presented in red and green color background. Red color shows the inaccessible design practices, while Green color shows the corresponding accessible design. In order to illustrate the difference between inaccessible and accessible design, the demonstrations of inaccessible and accessible design of components were created. The source code for these illustrations can be found on bitbucket ⁵.

4.1.1 Simple text

In most of the websites, there are issues related to appropriate font-size as per the user preference. The challenge in font-size is primarily due to the use of fixed font-size, as illustrated in figure 4.1. The easiest solution is to use the relative font-size in em, illustrated

¹<https://www.w3schools.com/html/>

²<https://www.tutorialspoint.com/html/>

³<https://www.w3.org/TR/wai-aria-practices>

⁴<http://www.washington.edu/accessibility/web/>

⁵<https://bitbucket.org/patel456/web-accessibility/>

```
1 <p style="font-size:10px;">This is fixed sized text </p>
```

Figure 4.1: Absolute font-size example

```
1 <p style="font-size:1em;">This is relative sized text </p>
```

Figure 4.2: Relative font-size example

in figure 4.2. Use of relative font-size provides the flexibility to the end user to adjust the font-size through browser settings.

4.1.2 Check-box

Generally, able-bodied users use mouse click to perform operations of selection and de-selection. This method is no use for visually impaired persons as they were unable to figure out where to click. Hence it creates a need for introducing the appropriate keyboard accessibility features, which allows these users to perform the task easily and efficiently. The primary challenges in common practices are the inability to navigate, select check-box, and improper audio feedback about the information associated with a check-box. The following guidelines were suggested for accessible check-boxes.

- use of tab key to navigate between check-boxes.
- use of space/enter key to perform select/deselect operations.
- use of ARIA attributes to provide appropriate role and description of check-boxes to screen reader user.

4.1.3 Drop-down Menu

The primary challenge for visually impaired users in accessing the drop-down menu is to select things quickly. In order to fix this problem, the developer has to create a combo-box, which enables autocompletion with the search option. Using these option visually impaired user can easily perform the required operation using the screen reader easily.

4.1.4 Hyperlink

In order to understand the semantics of a URL link, the presence of meaningful text to hyperlink is important for all users. Figure 4.3 and 4.4 shows the example of inappropriate and meaningful text for a hyperlink.

```
1 <a href="https://goo.gl/forms/">https://goo.gl/forms/</a>
```

Figure 4.3: poor text for hyperlink example

```
1 <a href="https://goo.gl/forms/" role="link">resume submission</a>
```

Figure 4.4: meaningful text for hyperlink example

```
1 
```

Figure 4.5: inaccessible image example

```
1 
```

Figure 4.6: accessible image example

4.1.5 Images

In web, application images can be classified based on the extent of informative content in them, into three categories described below.

1. **Simple informative image:** Images consists of simple information such as a photo of a person, the logo of institution.
2. **Complex informative image:** Images containing the mathematical or scientific information considered as complex informative images.
3. **Decorative image:** Images used to beautify a web application, considered as decorative images.

Screen reader is not able to extract the information from the image. This limitation hinders the access of images to the screen reader users. Hence alternative methods for accessing the image information required. Here are some of the approaches used to describe the images in text format.

Simple informative image

For a simple informative image, alternate text works well to describe the visual information conveyed by the image. The illustrative example for inaccessible and accessible image is shown in figure 4.5 and 4.6 respectively.

Decorative Image

Since decorative images are non-informative so, in order to inform the screen reader about such image `role="presentation"` attribute should be included in the image element.

FIGURE 1. First dose rotavirus vaccination coverage among children aged 3 months,* by quarter — Immunization Information system (IIS) sentinel sites, United States, 2006–2007†

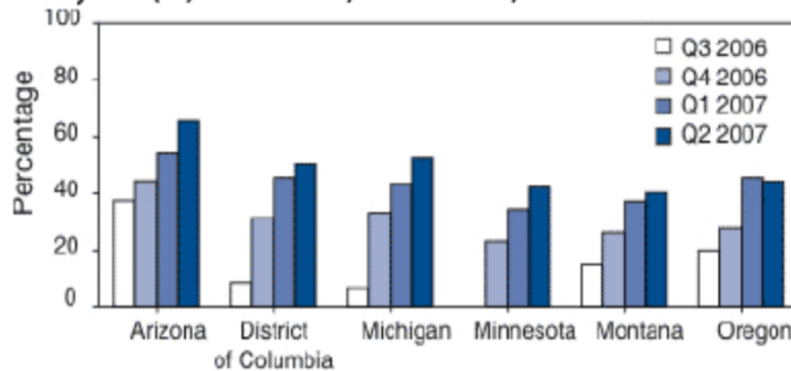


Figure 4.7: Demo Bar-Graph

Table 4.1: First dose rotavirus vaccination coverage among children aged 3 months, by quarter - immunization information system (IIS) sentinel sites, United States, 2006–2007

	Arizona	District of Columbia	Michigan	Minnesota	Montana	Oregon
Q3 2006	35%	10%	5%	0%	15%	0%
Q4 2006	45%	30%	33%	25%	27%	27%
Q1 2007	50%	45%	42%	35%	37%	45%
Q2 2007	65%	48%	50%	41%	40%	44%

Complex informative image

In complex images, the alternate text does not work well as it contains much information. Hence one method is to provide the equivalent text description of the image. Bar graph in figure 4.7 is can be converted to equivalent accessible table (see 4.1.6) displayed in the table 4.1.

4.1.6 Table

Screen reader linearly reads the text as code in the source file. This linear reading makes it difficult to understand the semantics of values associated with columns in case of the table. Hence the semantic structure of the table has to be encoded for the screen reader users. The encoding of association of a cell to the columns is done by markup all column-/row headers using `<th>` attribute and defining the scope as col/row. Here is an illustration of code snippet of inaccessible and accessible design in figure 4.8 and 4.9 respectively.

```

1 <table>
2   <tr>
3     <td> Week </td>
4     <td> Topic </td>
5     <td> Assignment </td>
6   </tr>
7   <tr>
8     <th> 1 </th>
9     <td> Course Introduction </td>
10    <td> Chapter 1 </td>
11  </tr>
12 </table>

```

Figure 4.8: inaccessible table example

```

1 <table role="table">
2 <thead>
3   <tr>
4     <th scope="col">Week</th>
5     <th scope="col">Topic</th>
6     <th scope="col">Assignment</th>
7   </tr>
8 </thead>
9 <tbody>
10  <tr>
11    <th scope="row">1 </th>
12    <td> Course Introduction </td>
13    <td> Chapter 1</td>
14  </tr>
15 </tbody>
16 </table>

```

Figure 4.9: accessible table example

4.1.7 Date-Picker

A date picker is extensively used in online forms where the user has to choose the date for multiple purposes such as date of birth, date of examination, date of journey. The accessibility challenge in date picker for visually impaired persons is to select the date. On the other hand, non-disabled users can easily do the task using mouse clicks. So, there is a need for appropriate key-mappings, which will allow the visually impaired users to navigate and select the date easily and efficiently. The key mappings in current best practices of accessible web development displayed in the table [4.2](#).

4.1.8 Form

In all aspects of education from entrance examination to interview and job search, one has to fill the application form online. Hence the accessibility of form is crucial for the

Table 4.2: Key mappings for date Picker

Key combination	Feature
Right-Arrow(RA)	next date of same year
Left-Arrow(LA)	prev date of same year
Up-Arrow(UA)	prev week of same month
Down-Arrow(DA)	next-week of same month
home	start of current month
end	end date of current month
Shift+LA	same date of prev year
Shift+RA	same date of next year
Enter	select the current date
Esc	move out of date picker

```

1 <div>
2   first name:
3   <input type="text" name="firstname" id="firstname">
4 </div>
5 <div>what is your favorite color </div>
6 <input type="radio" name="color" value="Red" id="color_red"> Red
7 <input type="radio" name="color" value="Green" id="color_green">Green

```

Figure 4.10: inaccessible input field example

carrier of visually impaired persons. Here are some of the common accessibility problems faced by visually impaired students while filling the form.

1. What to fill in which input field, i.e., lack of association of the input field with the corresponding text
2. Form validation and error recovery from filling wrong information in the form.

In order to handle the first challenge above, one has to use `<label>`, `<fieldset>` attribute to associate input field with the corresponding text. The illustration for inaccessible and accessible input field is displayed in figure 4.10 and 4.11.

The challenge of validation and error recovery is quite crucial as sending incorrect / incomplete information may lead to rejection of application form. Here are some guidelines by W3C to provide appropriate feedback to the screen reader user.

- Alert the user to the presence of the error in a clear and accessible manner.
- Allow the user to access the form controls that need to be modified.
- Allow re-submission of the form.
- set the attribute `aria-invalid="True"` so that screen reader can easily identify the error has occurred.

```
1 <div role="application">
2   <label for="firstname">first name:</label>
3   <input type="text" name="firstname" id="firstname" role="textbox">
4 </div>
5 <fieldset>
6   <legend> What is your favorite color? </legend>
7   <div role="group">
8     <input type="radio" name="color" value="Red" id="color_red" >
9     <label for="color_red">Red</label>
10  </div>
11  <div role="group">
12    <input type="radio" name="color" value="Green" id="color_green">
13    <label for="color_green">Green</label>
14  </div>
15 </fieldset>
```

Figure 4.11: accessible input field example

There are multiple ways in which the feedback about the error can be given to visually impaired person

- First, describe the error by prompt, and then focus on a particular field to be modified. It may not be good for banking sites due to security reasons.
- Provide the error message inline with the field where it occurs and set attribute `aria-describedby` so that screen reader can understand the context. The primary disadvantage with the above approach that, a user has to brute force from beginning to end in order to find the errors. This approach may be used in the short length forms such as login.
- Display the errors on top with embedded links for the corresponding field to be modified. When a user submits an invalid form server should regenerate the form with feedback on top so that screen reader user easily accesses the error and can fix it easily by navigating to the field. This approach will not be effective in the case of too many errors. The user may forget which errors have been fixed or not. In order to handle the problem, the developer can provide an additional option for removing the fixed errors, reading the following errors, etc. In this manner, the user will be able to fill the form correctly and efficiently.

4.1.9 Video

The video involves two components listening and seeing. The alternatives for visual and audio has to be provided to make video accessible for persons with disabilities. There are few approaches recommended by webaim given below and illustration is presented in [4.12](#)

- **Captioning the video:** it has multiple advantages in terms of accessibility of content across various dimensions.


```
1 <video controls tabindex="0">
2   <source src="myvideo.mp4" type="video/mp4">
3   <source src="myvideo.ogv" type="video/ogg">
4   <track kind="captions" src="mycaptions.vtt">
5   <track kind="descriptions" src="mydesc.vtt">
6 </video>
```

Figure 4.12: Accessible video example

- Accessible to those who cannot hear.
 - It makes videos full text-searchable.
 - Translation to other languages during playback.
 - can be used to generate an interactive script.
- For visually impaired persons, key for the accessible video is the audio content. Hence scripting is required to create the audio for accessible video.
 - Play video on accessible media player having support for closed captions, descriptions and accessible button control to screen reader users.

It has already been discussed in section 2.1.2 that most of the developers are not aware of the above challenges faced by visually impaired users in accessing the web application. So in the next chapter, we explore the development of a accessible web-development manual and accessibility testing tool. These things assist the naive developer in developing an accessible website from the very beginning.

Chapter 5

Accessible Web Development

This chapter aims to aware, prepare, and assist the web developers about accessible web development. Several demonstrations of inaccessible and accessible designs were presented to make aware web developers about the challenges faced by visually impaired persons in accessing the web applications. We discussed in section 2.1.2 that, there are challenges in interpreting the vast documentation and accessibility testing. So we have attempted to solve these issues by creating a prototype for easily interpretable web manual and XsWebAll accessibility testing tool. In the next sections first, we present a prototype for a web-development manual and then semiautomated tool for accessibility testing.

5.1 Approach

We have fragmented a typical website into individual components and studied various barriers to accessing the individual components and suggested modifications in the design concerning the W3C authoring practices 1.1 for the open web. We next present the typical components of a website, the challenges associated with the individual component, affected audience, and a real-life example of the component of the website.

Table 5.1 presents the sample of challenges associated with the individual components, the audience affected by these challenges and a corresponding real-life example of an inaccessible website. As we can see, there are common challenges in accessing a particular component such as lack of keyboard mapping, navigation problem, and absence of description of graphics content of informative images and many more.

Table 5.2 presents the improvement required in the individual components with a real-life example of the accessible parts. Here are some of the modifications which can be applied on most of the elements such as - enabling ARIA attributes in HTML, use of relative font size rather than absolute (use 1em instead of 10px), mapping keyboard keys to for navigation and alternate text description of the graphical content.

Table 5.1: Individual components of a website, cause of inaccessibility, affected audience and daily life example

Component	Inaccessible Website	Date of Access	Intended Audience		Cause of inaccessibility
Simple text	NPTEL	5/18/2018	Low people, screen reader	Vision no	Use of font size in pixels e.g. font-size: 16px
Check-box	Flipkart	5/23/2018	Screen users	reader	no keyboard mapping
Date-Picker	SBI I-Collect History	5/19/2018	Screen users	reader	no keyboard mapping
Dropdown	Profile Update in NPTEL	5/21/2018	Screen users	reader	Visual selection of item
Form	Profile Update in NPTEL	5/24/2018	Screen users	reader	Lack of feedback of events
Simple Table	NPTEL-phase 4	7/31/2018	Screen users	reader	cell & headers not associated

Table 5.2: Modification suggested for individual components and example of accessible website

Component	Modification Required	Accessible Website	Date of Access
Simple text	Use font size in units of em	I-STEM	5/19/2018
Check-box	Appropriate key mappings	NPTEL	5/19/2018
Date-Picker	Appropriate key mappings	Facebook Registration	5/23/2018
Dropdown	Use of combo-box	SBI-I Collect	5/21/2018
Form	Error on top, Inline errors, Resubmission of form, and keyboard navigation	Facebook Registration	5/23/2018
Simple Table	Include headers, footer with appropriate field name and list the headers corresponding to a cell	NAAI	5/23/2018

5.2 Prototype: Accessible Web Development Manual

An example of a multi-column table is presented below as a sample to be included in the accessibility manual. It illustrates the fact of accessibility issues and methods for fixing. Consider a multi-column / multi-row table; the illustration is divided into two parts: i) inaccessible design and ii) accessible design for the same component.

Students Details		
Engineering Students		
Serial Number	Student Name	Deptartment
1	Ram	CSE
2	Shyam	
3	Mohan	EE

Figure 5.1: displays the table to be designed by a web developer

5.2.1 Example: Table

Suppose a developer has to design the table displayed in figure 5.1. In most of the scenarios developer's goal is to design the table visually, as specified by the client. The client is satisfied to see the expected table as output. Mostly client does not know the tiny details of work accomplished by the developers. At the same time, developers are not aware of the differences between accessible and inaccessible design. Hence to aware the developers, we present the prototype of web manual with the inaccessible design for the figure 5.1, followed by accessible design and compare the screen-reader (NVDA on Chrome) output.

Inaccessible Design

The most commonly used web development practices lead to inaccessible design. The source code for inaccessible sample design used in this example is available [here](#). Suppose a visually impaired person reads this table using a screen reader (we have used NVDA with Google chrome for testing). S/He hears the information about the table as displayed in figure 5.2. The video output of the screen reader for the inaccessible design of the table provided [here](#). There are multiple challenges faced by visually impaired persons in understanding the screen reader output for this design, as noted below.

- In case of complex table, user is unable to remember the correspondence of columns to particular entry. Hence leads to misinterpretation of data.
- In a table of hundreds of columns, where a column value span more than one row. Screen reader speaks row entries only once, in the first encounter. Screen reader skips the remaining column values. Hence there is a challenge in identifying that either column does not contain anything or its value is the same as some previous row's column.

"Student details heading level 3, table with 5 rows and 3 columns,
 Row 1 column 1 to 3 Engineering Students,
 Row 2 column 1 Serial Number column 2 student name 3 department,
 Row 3 column 1 1 column 2 Ram row 3 to 4 column 3 cse,
 Row 4 column 1 2 column 2 Shyam,
 Row 5 column 1 3 column 2 Mohan column 3 EE"

Figure 5.2: Screen reader output of inaccessible design of table in figure 5.1

"Student details heading level 3, table with 5 rows and 3 columns,
 Row 1 column 1 to 3 Engineering Students,
 Row 2 column 1 Serial Number column 2 student name 3 department,
 row 3 Engineering Students Serial Number column 1 1 Engineering Students student name column 2 Ram Engineering Students department row 3 to 4 Engineering Students column 3 cse,
 Row 4 Engineering Students Serial Number column 1 2 Engineering Students student name column 2 Shyam,
 Row 5 Engineering Students Serial Number column 1 3 Engineering Students student name column 2 Mohan Engineering Students department column 3 EE"

Figure 5.3: Screen reader output of accessible design of table in figure 5.1

Accessible Design

A sample of inclusive web design as per the guidelines of "WAI authoring practices 1.1" used to create this example. The source code for the accessible design is available [here](#). In particular one has to provide the sufficient information to the screen reader to understand the structure of the table. Hence visually impaired user can understand the table quickly. The screen reader output for the accessible design of the table is given in figure 5.3 and click [here](#) to listen the same.

With the use of guidelines of W3C, the challenge in accessing the table is fixed up to a certain extent. Now user can work with a table if s/he knows the context. There are still some challenges which can lead visually impaired persons in trouble in new interpreting the information in an unknown context.

- Unable to differentiate between "to", "2" and "two".
- It's hard to distinguish between "EE" and "E".
- Screen reader speaks the multirow entry only once.

The above illustrative example of an inaccessible and accessible design of table along with source code and video output of screen reader will help the developers to understand the problem at the root level and hence fixing the same at the development phase. This example is a sample to be included in the manual we proposed to create.

5.2.2 Example: Menu Bar

An inaccessible design sample of the menu bar is available [here](#). There are multiple challenges can be seen in the above design, which includes, incomplete key-board navigation, no information provided to understand the hierarchical structure of the menu.

The structure of the menu is similar to the tree structure, so we considered it as a graph and assumed the following:

1. An element of menu or sub-menu is a node of the graph
2. If element y is a sub-menu of element x, then x is the parent of y or y is a child of x.
3. Two nodes are a sibling of each other if their parents are the same.
4. An edge is assumed between parent and children to denote relationship.

We used the W3C guidelines to create a demonstration of useable design of menu bar. The video for the demonstration is available [here](#). We identified the following challenges in existing best practices:

- Separate accessible guidelines (key-mappings) for menu and sub-menu. These guidelines confuse visually impaired persons while accessing the unknown menu.
- Abrupt Jumping from child to its ancestors.
- No information related to the node is provided by a screen reader.

Here are the suggested modifications in the existing prototype based on well-known parameters, easy, simple, and quick access to the menu bar. We adapted the concept of accessing hierarchical structures proposed by Smith et al., 2003 and existing W3C guidelines to proposed the key-mappings in table 5.3 associated with a feature to extract information of the menu bar.

5.3 XsWebAll: Accessibility testing tool

We developed A prototype for command line based accessibility testing tool. Currently, our tool supports two ways of detecting accessibility issues in a given HTML file of a web application. Here are the ways:

- It checks for appropriate ARIA role attributes, corresponding to HTML element.

Table 5.3: Sample key mappings and Corresponding operation: Menu Bar

Key	Operation
Arrow Up	Move to previous sibling of current node in cyclic order
Arrow Down	Move to previous sibling of current node in cyclic order
Arrow Left	Move to parent of current node, if no parent then stay at current node
Arrow Right	Move to child of current node, if no child then stay at current node
Space / enter	Activate / follow the current node link
Ctrl + m	Move to first item of menu
Ctrl + I	Audio output of current node information

- It checks for a valid environment of lists, forms, and tables within the HTML document.

We implemented these checks with the use of existing *HTML parser* in python. All the elements specified on W3C *HTML 5.2* is covered in our checks. We further explored the automated fixing of identified accessibility issues and managed to implement a semiautomated way of fixing the accessibility challenges using the stream editor sed.

Chapter 6

Conclusion and Future Work

Education plays a vital role in empowering everyone. Hence providing the equal opportunity to visually impaired persons in every aspect of education is essential. In this work, we have identified the needs for the accommodation of a diverse group of visually impaired persons. The results about the effectiveness and preference of using a scribe in CBTs are contrary to the beliefs. Our observations identified the needs for technology-based accommodations over scribe to a diverse group of VIPs. We showed that the extent of residual vision in VIPs is one of the major factor in determining the type of preferred accommodations. CBT interfaces can be personalized to fulfil the needs of VIPs with the use of assistive technologies. A possible threat to the validity of the study and recommendations (chapter 3) is the small number of participants. To offset this, we have proposed the recommendations based not only on the feedback by the participants but also on the standard practices and manuals [The Importance of Information Technology for Visually Impaired Children and Youngsters and the Expectations for Future Development; I for Inclusion by The Xavier's Resource Centre for the Visually Challenged](#).

In the chapters 4, 5 more general challenge of web-accessibility was addressed, where the comparison between most common and best practices of web development was made, then the challenges for web-developers in creating the accessible web-content were identified. In order to assist the web developers, several illustrative examples of inaccessible and accessible web-designs, a prototype for accessible-web development manual and tool for accessibility testing of the web application was developed.

In the future, the study (chapter 3) can be extended for other disabilities, different types of CBTs, and other geographic locations. Moreover, similar studies can be conducted for the accessibility of online programming competitions. Based on the results of the study, accessible web-development manual for web-developers can be made more robust. Finally, XsWebAll tool needs to make complete for web-accessibility testing, so that developers can utilize the tool for testing.

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