

Some Studies on Accessible Mobile Interfaces for Visually Challenged

SACHIN TANWAR



DEPARTMENT OF DESIGN

INDIAN INSTITUTE OF TECHNOLOGY DELHI

JULY 2025

Some Studies on Accessible Mobile Interfaces for Visually Challenged

by

SACHIN TANWAR

DEPARTMENT OF DESIGN

Submitted

In fulfilment of the requirement for the degree of Doctor of Philosophy

To the



INDIAN INSTITUTE OF TECHNOLOGY DELHI

HAUZ KHAS, NEW DELHI - 110016

JULY 2025

Dedicated to

My Family

CERTIFICATE

This is to certify that the thesis entitled - Some Studies on Accessible Mobile Interfaces for Visually Challenged, being submitted by Mr. Sachin Tanwar for the award of the Degree of Doctor of Philosophy to the Department of Design, Indian Institute of Technology Delhi, is a record of bonafide work by him under my supervision and guidance. The matter embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

P.V. Madhusudan Rao

Professor,

Department of Design,

Indian institute of Technology Delhi,

Hauz Khas, New Delhi - 110016,

INDIA.

ACKNOWLEDGMENT

I would like to express my great appreciation to my supervisor, **Prof. PVM Rao** who guided me with patience and inspired me all this time. With his excellent knowledge and passion for the design of accessible products, he closely verified and reviewed my work giving the important directions and insightful ideas in the research period and writing this thesis. Beyond the professional collaboration, I would like to thank him for the moral support and the encouragement he gave me to complete my doctoral research.

I would like to thank my student research committee members - *Prof. Deepti Gupta* (Chairperson), *Prof. Tapan Gandhi* (External expert), and *Prof. Jyoti Kumar* (Internal expert), and other faculty members from Department of Design who have provided their valuable inputs and feedback throughout my research journey. I am thankful to the Indian Institute of Technology Delhi for providing me with a scholarship to pursue doctoral research and the necessary funding for this research work. I want to express my gratitude to the Assistech Lab, & Department of Design, IIT Delhi, for all the help they provided with the infrastructure, exposure to assistive technology products, users, and knowledgeable experts, for helping and supporting me through my research studies.

Finally, I would like to express my deep sense of gratitude to my father, Mr. Brahm Prakash, my mother, Mrs. Brijesh, and my brother, Lalit Tanwar, for the immense support and motivation and making me what I am today. My wife, Dr. Kanika Jolly & daughter Teshika Tanwar, have been at my side during this incredible and arduous journey. I would like to thank them and express my sincere gratitude for inspiring and supporting me to navigate this research work towards completion.

Also, I would like to thank my colleagues from IIT Delhi, Ganesh S, Anchal Sharma, Swagatam, Gulshan Kumar, Gauri, Dr. Piyush Chanana and all my other friends from the Department of Design for their moral support and companionship during my PhD journey.

Sachin Tanwar
2016 DDZ 8478

ABSTRACT

Globally, over 43 million people are visually challenged (VC), and an estimated 295 million live with moderate to severe visual impairment, according to the World Health Organization. In India alone, there are more than 9 million VC individuals—the highest for any country. Despite growing smartphone penetration and advancements in assistive technologies like screen readers, visually challenged users continue to face significant usability challenges. Mobile apps are still largely designed for sighted users, often overlooking non-visual interaction needs. This research addresses that critical gap, aiming to promote digital equity through more inclusive, experience-driven design.

Despite advancements in digital accessibility standards, many mobile applications still struggle to provide equitable user experiences for visually challenged (VC) individuals. While compliance with accessibility guidelines such as WCAG 2.1 has improved, these standards often overlook the deeper usability challenges faced by non-visual users who rely on screen readers. This thesis addresses these gaps through a comprehensive series of studies involving over 100 participants. The research highlights significant disparities in usability between VC and sighted users, revealing that while apps may meet basic accessibility criteria, their interaction models often prioritize visual aesthetics and efficiency over accessibility for VC users. Ethnographic research and NASA TLX assessments provide deeper insights into the cognitive demands and usability challenges experienced by VC users, particularly in tasks like form filling and error management.

Based on these findings, the SEE (Sensory-Equitable Experience) Framework is developed—a co-design approach aimed at improving VC user comfort, confidence, and usability perception. Prototype testing validates the framework's effectiveness in enhancing the overall user experience for VC individuals. This thesis proposes a shift in perspective from mere technical compliance to a more inclusive and user-centred design approach. It advocates for mobile UX practices that consider diverse user needs and experiences, aiming to set new standards in digital accessibility and usability.

सारांश

विश्व स्वास्थ्य संगठन के अनुसार, दुनियाभर में 4.3 करोड़ लोग पूरी तरह नेत्रहीन हैं, और लगभग 29.5 करोड़ लोग मध्यम से गंभीर दृष्टिबाधा से ग्रस्त हैं। अकेले भारत में, 90 लाख से अधिक लोग नेत्रहीन हैं – जो किसी भी देश में सबसे अधिक है। हालांकि स्मार्टफोन की पहुंच और स्क्रीन रीडर जैसी सहायक तकनीकों में काफी प्रगति हुई है, फिर भी दृष्टिबाधित उपयोगकर्ताओं को उपयोगिता से जुड़ी गंभीर चुनौतियों का सामना करना पड़ता है। अधिकांश मोबाइल ऐप अब भी दृष्टिशाली उपयोगकर्ताओं को ध्यान में रखकर बनाए जाते हैं, जिससे नॉन-विजुअल इंटरफेस की ज़रूरतें अक्सर नज़रअंदाज़ हो जाती हैं। यह शोध इसी महत्वपूर्ण अंतर को संबोधित करता है, ताकि अधिक समावेशी और अनुभव-केंद्रित डिज़ाइन के ज़रिए डिजिटल समानता को बढ़ावा दिया जा सके।

हालांकि डिजिटल एक्सेसिबिलिटी के मानकों में काफी प्रगति हुई है, फिर भी कई मोबाइल एप्लिकेशन दृष्टिबाधित (VC) उपयोगकर्ताओं को समान अनुभव प्रदान करने में विफल रहते हैं। WCAG 2.1 जैसे एक्सेसिबिलिटी दिशानिर्देशों का पालन बढ़ा है, लेकिन ये मानक अक्सर उन गहरी उपयोगिता समस्याओं को नज़रअंदाज़ कर देते हैं जिनका सामना नॉन-विजुअल यूज़र्स—जो स्क्रीन रीडर पर निर्भर करते हैं—करते हैं। यह शोध श्रृंखलाबद्ध अध्ययनों के माध्यम से इन समस्याओं को उजागर करता है, जिसमें 100 से अधिक प्रतिभागियों को शामिल किया गया। अध्ययन से यह स्पष्ट हुआ कि जबकि कई ऐप्स तकनीकी रूप से एक्सेसिबल माने जा सकते हैं, उनकी डिज़ाइन प्राथमिकताएँ अक्सर विजुअल उपयोगकर्ताओं की कुशलता को केंद्र में रखती हैं और दृष्टिबाधित उपयोगकर्ताओं की ज़रूरतों की उपेक्षा करती हैं। एथ्नोग्राफिक अनुसंधान और NASA TLX मूल्यांकन के माध्यम से यह शोध उन कार्यों की पहचान करता है जिनमें VC उपयोगकर्ताओं को अत्यधिक मानसिक प्रयास, भ्रम और असुविधा होती है—जैसे कि फॉर्म भरना या त्रुटियों को पहचानना और उन्हें सुधारना।

इन निष्कर्षों के आधार पर SEE (Sensory-Equitable Experience) फ्रेमवर्क विकसित किया गया है, जो एक सह-डिज़ाइन दृष्टिकोण है जिसका उद्देश्य VC उपयोगकर्ताओं के अनुभव को बेहतर बनाना है। इस फ्रेमवर्क को प्रोटोटाइप परीक्षण के माध्यम से मान्य किया गया, जिसने इसके प्रभावी होने को साबित किया। यह शोध तकनीकी अनुपालन से आगे बढ़कर एक समावेशी और उपयोगकर्ता-केंद्रित डिज़ाइन पद्धति की ओर बदलाव का प्रस्ताव करता है। यह मोबाइल UX डिज़ाइन में विविध उपयोगकर्ताओं की ज़रूरतों को ध्यान में रखने की वकालत करता है और डिजिटल एक्सेसिबिलिटी और यूज़ेबिलिटी के क्षेत्र में नए मानक स्थापित करने का लक्ष्य रखता है।

Table of Contents

Page No.

Certificate.....	i
Acknowledgments	ii
Abstract.....	iii
Table of Contents.....	v
List of Figures.....	xi
List of Tables.....	xiii
Keywords.....	xv

Chapter 1

Introduction and Research Context.....	1
1.1 Background and Motivation.....	1
1.2 Problem Statement.....	2
1.3 Research Objectives & Questions.....	4
1.4 Significance of this Research.....	6
1.5 Overview of Research Methodology.....	7
1.6 Ethical Considerations	10

Chapter 2

Foundations of Accessibility and Screen Reader UX based on literature.....	12
2.1 History and Importance of Accessibility in Digital Interfaces.....	12
2.2 Key Concepts & Definitions.....	13
2.2.1 Accessibility.....	13
2.2.2 Digital Accessibility.....	13
2.2.3 Universal Design.....	13
2.2.4 Accessible Design.....	14
2.2.5 Inclusive Design.....	14
2.2.6 Assistive Technologies.....	15
2.2.7 Sensory-Equitable Experience (SEE).....	15
2.3 Accessibility Standards and Legal Frameworks.....	15

2.3.1 Web Content Accessibility Guidelines (WCAG).....	16
2.3.2 Section 508 of the Rehabilitation Act (USA).....	16
2.3.3 Americans with Disabilities Act (ADA).....	17
2.3.4 EN 301 549 (European Standard).....	17
2.3.5 Rights of Persons with Disabilities (RPWD) Act, 2016 (India).....	17
2.3.6 Summary of Standards Across Jurisdictions.....	17
2.4 Limitations of Current Guidelines and Compliance Models.....	18
2.5. Assistive Technologies and Mobile Accessibility.....	19
2.6 Usability and User Experience Issues.....	25
2.6.1 Steep Learning Curve and Cognitive Load.....	25
2.6.2 Error-Proneness and Gestural Interaction Issues.....	26
2.6.3 Interface Compatibility and Accessibility Gaps.....	26
2.6.4 Cross-App and Cross-Platform Inconsistency.....	27
2.6.5 User Frustration and Workarounds.....	27
2.7 Review of Prior Work on Non-Visual UX using Assistive Technologies.....	29
2.7.1 Screen Readers and the Loss of Designers' Intent.....	32
2.7.2 Lack of Comparative Studies with Sighted Users.....	32
2.7.3 Gaps in Understanding Mobile User Experience for VC Users.....	32
2.7.4 Overlooking User Diversity (Age, Roles, Contexts).....	34
2.7.5 Need for Experience-Centred, Multi-Method Research Approaches.....	36
2.7.6 Summary of research gaps.....	37
2.7.7 Justification for the Current Study.....	40

Chapter 3

Initial Studies – WCAG Audits and Pilot Studies.....	42
3.1 Introduction.....	42
3.2 Study Design and Methodology.....	43
3.2.1 Objectives of the Study.....	43
3.2.2 Selection of Applications and Websites.....	43
3.2.3 Participant Selection and Demographics.....	44
3.2.4 Testing Procedure and Task Scenarios.....	44
3.2.5 Methodology and procedures.....	45
3.2.6 Ethical Considerations.....	45

3.3 WCAG Audit Findings.....	45
3.4 Pilot User Testing with Visually Challenged Participants.....	49
3.5 Summary and implications.....	54

Chapter 4

Evaluating the Effectiveness of Visual-First Design Patterns in

Non-Visual Contexts.....	55
4.1 Introduction.....	55
4.2 Research Methodology.....	57
4.2.1 Study Objective and Research Design.....	57
4.2.2 Participant Recruitment and Profiles.....	58
4.2.3 Mobile Application Selection Criteria.....	59
4.2.4 Task Scenarios.....	60
4.2.5 Methodology and procedures.....	65
4.2.6 Data Analysis Approach.....	66
4.2.7 Task Execution with Think-Aloud.....	66
4.2.8 Environment and Equipment.....	67
4.2.9 Analysis.....	67
4.2.10 NASA TLX method : Weighting Criteria and Implementation	68
4.3 Findings.....	69
4.3.1 Quantitative Task Outcomes.....	69
4.3.2 Thematic Insights.....	76
4.3.3 Summary of Key Findings.....	80
4.4 Synthesis of Findings.....	80
4.4.1 Design Success for Sighted Users vs. Breakdown for VC Users.....	81
4.4.2 How other successful Sighted Patterns Create Barriers for VC Users.....	81
4.4.3 User Strategies as Coping Mechanisms.....	82
4.4.4 Emotional and Cognitive Implications.....	83
4.5 Implications for Inclusive Design.....	83
4.5.1 Moving Beyond Compliance-Driven Accessibility.....	83
4.5.2 Rethinking Interaction Design Principles.....	84
4.5.3 Prioritizing Error Recovery and User Confidence.....	84
4.6 Summary of the Study.....	85

Chapter 5

Technology Choices and Cross-Platform Behaviour.....	87
5.1 Background and overview.....	88
5.2 Research Methodology.....	90
5.2.1 Participants Details.....	90
5.2.2 Task scenarios and categories.....	91
5.2.3 Methodology and procedures.....	92
5.2.4 Data Analysis.....	92
5.3 Findings and Results.....	93
5.3.1 Platform Usage Patterns: Students vs. Professionals.....	93
5.3.2 Technology choices.....	94
5.3.3 Rationale Behind Device Preferences.....	100
5.4 Summary and Implications for Inclusive Design.....	105

Chapter 6

Deep Dive — Design Elements, Screen Readers, and Cognitive Load.....	108
6.1 Study Overview and Objectives.....	109
6.2 Research Methodology.....	110
6.3 Key Findings and Analysis.....	113
6.3.1 Addressing Screen Reader Interaction Mismatches.....	121
6.3.2 Focus on Emotional and Cognitive Outcomes.....	122
6.4 Cognitive Load and NASA TLX Analysis.....	122
6.5 Synthesis of UX Gaps and Design Implications.....	129
6.5.1 High Cognitive Load as an Indicator of UX Breakdown.....	129
6.5.2 Key UX Breakdowns Identified.....	130
6.5.3 User Strategies and Workarounds.....	130
6.5.4 Implications for Design and Development.....	130
6.6 Thematic Insights from User Experiences.....	131
6.7 Design Learnings and Implications.....	134

Chapter 7

The SEE Framework — A Sensory-Equitable Design Model for

Accessible Mobile UX.....	137
7.1 SEE Principles.....	137
7.1.1 Principle 1: Dynamic Content Updates and State Awareness.....	138
7.1.2 Principle 2: Contextual Clarity and Information Structure	139
7.1.3 Principle 3: Meaningful and Consistent Focus Management.....	140
7.1.4 Principle 4: Clear and Context-Aware Error Feedback.....	142
7.1.5 Principle 5: Reducing Cognitive Overload Through Section-Skipping Mechanisms...	144
7.1.6 Principle 6: Intelligent Recovery from User Disorientation.....	147
7.1.7 Principle 7: Rewind and Replay: Enhancing Text Navigation within Paragraphs.....	149
7.1.8 Principle 8: Detecting Cognitive Stalls: Providing Guidance When Users Seem Stuck.....	149
7.1.9 Principle 9: Contextual Responsiveness: Adapting Screen Reader Behaviour to Environment and Content Sensitivity.....	150
7.1.10 Principle 10: Smart Structuring and Task Preparation in Complex Multi-Field Interfaces.....	151
7.1.11 Principle 11: Managing Complex Data Sets and Enhancing Task Awareness.....	152
7.2 Prototype Design and Validation Study.....	155
7.3 Synthesis and Future Directions.....	158

Chapter 8

Conclusion and Recommendations.....	162
8.1 Summary of Key Findings.....	162
8.2 Research Questions.....	164
8.3 Theoretical Contributions.....	165
8.4 Practical Implications.....	167
8.5 Limitations of the Research.....	169
8.6 Future Directions.....	171
8.7 Concluding Summary.....	174
References.....	176

Appendix I: User recruitment & onboarding.....	190
Appendix II - APPENDIX 2: Questionnaires.....	196
Research publications.....	202
Biodata.....	203

List of Figures

Figure Number	Figure Description	Page Number
Figure 4.1	Workflow for shortlisting and evaluating mobile applications based on UI components, screen reader compatibility, preliminary sighted user testing and further testing those with VC users	60
Figure 4.2	Indicative screenshot of an app that allows in-line reply for individual chats.	70
Figure 4.3	Indicative screenshot of an app that displays all the taxi's standing nearby current location.	71
Figure 4.4	Indicative screenshot of an e-commerce or social media app that provides trending search suggestions and history as the user starts to type in the search field.	72
Figure 4.5	Indicative screenshot of an app that has a player window minimized to allow users to multi-task.	73
Figure 4.6	Indicative screenshot of an app that allows users to undo action that was recently taken.	75
Figure 4.7	Comparison of frustration of VC and sighted users using NASA TLX.	78
Figure 4.8	Comparison of efforts of VC and sighted users using NASA TLX.	79
Figure 5.1	Four photos of participants using their PC and mobile for questions and tasks based on this study.	90
Figure 6.1	Mock-up of designs from 2 screens that include some form fields but poorly located action buttons which make it difficult for VC users who rely on screen readers (that are sequential in nature). Observe the location of primary action buttons which do not appear in the sequence of information.	113
Figure 6.2	Mock-ups from two apps that display various categories of travellers on a hotel booking app for hotel reservation and the other one allows users to choose topics of interest for article recommendations in a reading app. Confirmation has to be done manually instead of glancing at the fields that were inputted or selected for VC users.	115
Figure 6.3	A mock-up of screen that displays an error field when user tries to submit a form.	116

Figure 6.4	Mock-up of two app screens that displays dynamic information in form of visual indicator such as strength of password or character length in a form field as user types.	117
Figure 6.5	Mock-up of two app screens that allows users to input Email ID manually first before the available shortcuts of signing up using social accounts. Since the screen reader reads sequentially, users will not know available options beforehand.	118
Figure 6.6	Mock-up of three apps having different types of FTUs (first one is paginated, second is based on 3 mini pages controlled by 'next' button and third one is using highlight to highlight the feature on the screen - one feature at a time.	119
Figure 7.1	NASA TLX score comparison of experiences of users (lower the better).	158

B. List of Tables

Table Number	Table Description	Page Number
Table 1.1	Summary of Research Methods and Representative References Used in This Study.	8
Table 2.1	Key features and interactions based comparison of major screen readers is presented below that covers mobile and PC based screen readers.	21
Table 2.2	Summary for identified research gaps.	38
Table 3.1	Identified Accessibility and Usability issues (on a PC).	48
Table 3.2	Identified Accessibility and Usability issues (on Mobile devices).	48
Table 4.1	Participant Demographics.	59
Table 4.2	Task scenarios and associated design patterns reflecting modern mobile app interfaces, as applied in comparative testing with sighted and visually challenged users.	61
Table 4.3	Overview of qualitative testing methods and their respective objectives in capturing accessibility-related user experiences.	65
Table 4.4	Comparative analysis of user responses across interaction categories for sighted and visually challenged participants.	80
Table 4.5	Comparative impact of commonly adopted sighted-user interface enhancements on the usability experience of visually challenged users.	82
Table 5.1	Differentiation of cognitive and emotional user experience responses among visually challenged users.	89
Table 5.2	Task- and context-driven platform preferences (PC vs. mobile) among student and professional visually challenged users.	98
Table 6.1	Screen reader challenges and their impact on VC users' interaction with the content on mobile.	121
Table 6.2	Scores and weighted average of response of 25 users after performing task 1.	123
Table 6.3	Scores and weighted average of response of remaining 25 users after performing task 2.	124
Table 6.4	Scores and weighted average of response of 15 users after performing Task 3.	125

Table 6.5	Scores and weighted average of response of 15 users after performing Task 4.	125
Table 6.6	Scores and weighted average of response of first 25 users after performing Task 5.	126
Table 6.7	Scores and weighted average of response of remaining 25 users after performing Task 6.	126
Table 6.8	Total scores (average scores were multiplied by respective weightage and finally divided by the total number of weights given).	127
Table 6.9	Summary of emerging themes, user concerns, and corresponding design implications for visually challenged users.	134
Table 7.1	Proposed accessibility guidelines for UX designers and screen reader developers based on study findings.	153
Table 7.2	Improvements achieved through SEE-supported prototypes in response to legacy screen reader and UX design challenges.	156

C. Key Words

To support non-specialist readers and ensure clarity, the following terms are defined:

- **ARIA** (Accessible Rich Internet Applications): A WAI specification that enhances accessibility of dynamic content by adding semantic information to HTML elements.
- **OCR** (Optical Character Recognition): Technology used to convert printed or handwritten text into machine-readable text. Useful in reading physical documents via screen readers.
- **NVDA** (NonVisual Desktop Access): A popular free screen reader for Windows (PC).
- **JAWS** (Job Access With Speech): A widely used commercial screen reader for Windows (PC).
- **TalkBack**: Android's built-in screen reader.
- **VoiceOver**: iOS screen reader for Apple devices.
- **Touch Target Size**: Minimum tappable area (typically 48dp by 48dp) ensuring accessibility for all users, including those with motor or vision impairments.
- **CSS pixel**: A relative unit of screen measurement in web design used to define dimensions and layouts.