Breaking Barriers: A Novel Framework to Evaluate Usability of Accessibility Applications

M A Hannan Bin Azhar
School of Engineering, Technology and Design
Canterbury Christ Church University, UK
hannan.azhar@canterbury.ac.uk

Tasmina Islam
Department of Informatics
King's College London, UK
tasmina.islam@kcl.ac.uk

Jan Marczak
Department of Informatics
King's College London, UK
jan.marczak@kcl.ac.uk

In today's digital landscape, there is a growing recognition of the significance of accessibility in ensuring that all users can participate fully and enjoy a seamless experience. Numerous external applications, websites, and platforms have emerged to enhance accessibility for individuals with disabilities. However, much of the existing research on accessibility evaluation often employ automated tools that test user interfaces against the well-established W3C Accessibility Guidelines. While such evaluations are valuable in identifying accessibility shortcomings and encouraging adherence to established guidelines, they may not fully capture the diverse and nuanced needs of users with disabilities. This paper introduced a novel framework which takes a comprehensive approach to accessibility evaluation. It considers not only the presence of accessibility features but also their complexity and practical usability. The framework acknowledges that the accessibility of an application goes beyond the presence of isolated features; It also considers the contextual knowledge required for users to fully navigate and utilise these features. This approach enables a more comprehensive evaluation that surpasses technical compliance and explores the practicality and effectiveness of accessibility solutions in real-world situations.

UX (user experience), Usability, Accessibility, Disability, Mobile Apps.

1. INTRODUCTION

The World Health Organisation (WHO) estimates that approximately 16% of the global population lives with some form of disability, and nearly everyone is likely to experience temporary or permanent disability at some point in their lives (WHO, 2023). This percentage is on the rise due to the rapid aging of the population. The elderly, in particular, face a higher risk of disability, with chronic diseases, often potentially disabling, accounting for 66.5% of all years lived with disability in low and middle-income countries in 2011 (Krahn, 2011).

In today's rapidly evolving technological landscape, owning a smartphone, tablet, or laptop is not only considered highly beneficial but increasingly essential for managing daily activities. According to a 2021 survey, 85% of all people in the United States (up from 67% in 2015), 61% of adults aged 65 or older (42% in 2015), and 72% of disabled adults own a smartphone (Faverio, 2022; Perrin et al., 2021). However, the quick emergence and adoption of these technologies have led to their accessibility being overlooked. This lack of accessibility in websites, mobile applications, smartphone features, and artificial intelligence tools can significantly limit individuals in need. Whereas accessibility focuses on discriminatory aspects of user experience,

usability is concerned with effectiveness, efficiency and satisfaction (ISO, 2018). Accessibility features can exist; however, their capabilities can be low due to not accomplishing their ease of use. Statistical research by Thielsch et al. (2018) suggest that there is a strong correlation between the negative user experience of websites and depressive symptoms.

To address these issues, innovative features such as Voice Assistance, Screen Readers, Focus Mode, or Predictive Text aim to facilitate easier navigation through technological challenges. Improved accessibility can benefit not only specific sub-groups but also the general user population. For example, captioned videos designed for people who are hard of hearing can assist everyone in following a movie in a noisy environment or aid in language learning. Research has demonstrated overlapping usability problems encountered by both blind individuals and people without disabilities when studying their behaviour on specific websites (Petrie and Kheir, 2007). However, digital accessibility remains an area that still needs further development and faces various limitations and barriers. For the digital world to be fully accessible, collaboration is required among developers, stakeholders, advertisers, governments, and other parties to build inclusive technologies.

Table 1: *Accessibility features in existing applications*

Accessibility Feature	Description	Target Disability	Operating System	Desktop/Mobile
Screen Reader	*Renders text and image content as speech or braille output*	*Visual*	*Apple, Microsoft, Google*	*Both*
Screen Magnifier	*Enlarges part of the screen*	*Visual*	*Apple, Microsoft, Google*	*Both*
Voice Assistant	*allows hands-free operation of a digital device*	*Visual, Motor*	*Apple, Microsoft, Google*	*Both*
Display Settings	*Various display customisation*	*Visual*	*Apple, Microsoft, Google*	*Both*
Live Listen & Sound Recognition	*Continuously listen for certain sounds (e.g., doorbell, crying baby) and notify when it recognises them*	*Auditory*	*Apple*	*Mobile*
Customised Notifications	*Custom interface for notifications and ability to turn on specialised notifications like a flashlight blink*	*Auditory*	*Apple, Microsoft, Google*	*Both*
Calming Sounds	*Calming background sounds*	*Cognitive*	*Apple*	*Mobile*
Spoken Content	*Speak selected text or entire screen*	*Cognitive*	*Apple, Google*	*Mobile*
Reader Mode	*View articles without ads and other distracting items. Adjust settings like font colours or background*	*Visual, Cognitive*	*Apple, Microsoft, Google*	*Both*
Focus Mode	*Minimise distractions by silencing notifications*	*Cognitive*	*Apple, Microsoft, Google*	*Both*
Dictation	*Dictate text anywhere you can type it*	*Visual, Cognitive*	*Apple, Microsoft, Google*	*Both*
Predictive Text & Auto-Correction	*See recommended word choices and do automatic spellcheck while typing*	*Cognitive*	*Apple, Microsoft, Google*	*Mobile*
Switch Control	*Control your device using a switch that lets you control device freehand*	*Visual, Motor*	*Apple, Microsoft, Google*	*Both*
Head/Eye Control	*Move the pointer on the screen using the movement of your face and head*	*Motor*	*Apple, Microsoft, Google*	*Both*
Sticky Keys	*Press a set of modifier keys one at a time in instead of all at once*	*Motor*	*Apple, Microsoft, Google*	*Desktop*

2. ACCESSIBILITY NEEDS AND GUIDELINES

The International Classification of Functioning, Disability, and Health (ICF), established by the WHO, serves as the prevailing international standard for classifying disabilities. This classification system plays a pivotal role in the disability field, as it guides innovations, policies, and accessibility features tailored to specific sub-groups. However, it is essential to recognise that disability types are not rigidly confined; they can overlap, exist on a spectrum, and necessitate a more contextual assessment (Krahn, 2011). The World Wide Web Consortium (W3C) has formulated the Web Content Accessibility Guidelines (WCAG) which presently serve as the recommended standard for enhancing website accessibility (Caldwell et al., 2008). Within this research domain, WCAG also provides a classification of disabilities. WCAG 2.0 focuses on several key principles to guide developers in creating accessible websites. These principles include making information perceivable, designing an operable and understandable user interface, facilitating easy navigation, and providing robust and reliable content (W3C, 2023). By adhering to these principles, developers can enhance the accessibility of their websites and accommodate the specific needs of users with disabilities. While WCAG primarily addresses web content, W3C also offers supplementary guidance on applying WCAG 2.0 principles to mobile applications. Previous research suggests that complying with accessibility standards does not always guarantee a flawless user experience (Aizpurua et al. 2015) and that even if a website follows the WCAG, users' satisfaction is not 100% (Karreman et al., 2007).

Accessibility features can be categorised on multiple levels, distinguishing between internal operating system (OS) features and external applications. In Table 1, a comprehensive list of features present in various operating systems is provided, along with a brief description of each feature and the disabilities they target.
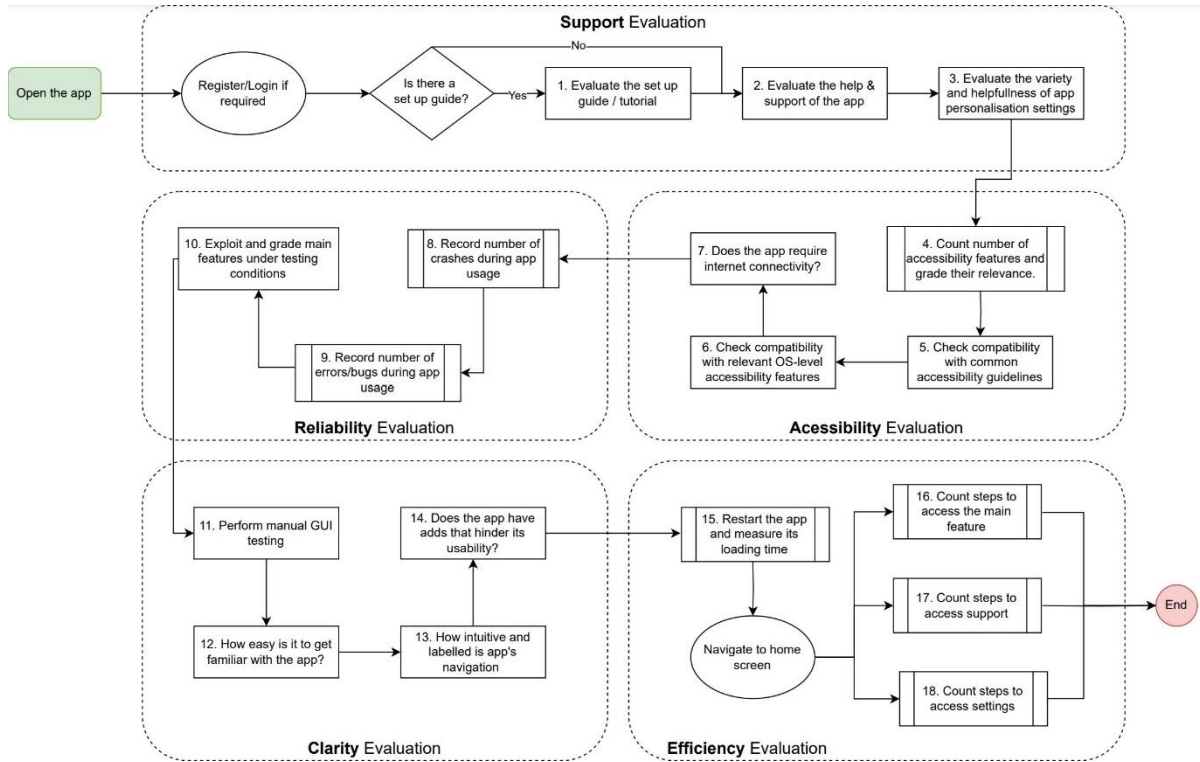
Figure 1: Framework to evaluate accessibility applications.

Accessibility features can be further categorised based on whether they are computer features, mobile features, or features found on external websites. Additionally, these features can be associated with specific disability sub-groups that they aim to assist. In Table 1, the naming convention used by Apple, which offers a wide range of accessibility features, was adopted. It is worth noting that Apple's software is considered to have the most extensive accessibility features among desktop and mobile devices, as highlighted in an interview with a blind technology expert (Gaggi et al., 2019). However, it should be acknowledged that Apple's devices tend to be relatively expensive, limiting their accessibility to certain user populations. The focus of the table is on accessibility features that do not require specialized hardware. However, it is evident from the table that there is a clear lack of accessibility features specifically targeted at individuals with speech disabilities. Conversely, sensory disabilities, such as visual and auditory impairments, are more prominently addressed.

3. PROPOSED ACCESSIBILITY FRAMEWORK

This section details a framework (Fig. 1) for evaluating accessibility applications in terms of their overall usability. Previous research around accessibility evaluation has been mainly focused on manual or automated assessment of accessibility in mainstream applications that do not necessarily provide any accessibility features (Yan et al., 2019; Frazão et al., 2020).

Unlike automated tools primarily examining user interface and W3C Accessibility Guidelines compatibility, the proposed framework integrates user experience as the fundamental aspect in evaluating accessibility applications.

3.1. Usability Metrics

To assess the usability and overall user experience of accessibility applications, a comprehensive framework was developed. This framework comprises five distinct categories, each aimed at quantifying different aspects of usability:

(i) SUPPORT: This category evaluates the user's subjective impression of the level of support provided by the application. Franz et al. (2019) found that older adults experience challenges remembering how to access and configure accessibility features. This motivated us to include metrics concerned with easy access to support, such as chat support, feedback forms, FAQs, etc.

(ii) ACCESSIBILITY: The accessibility scale focuses on the overall accessibility of the platform. It considers factors such as adherence to W3C accessibility principles and compatibility with assistive technologies like screen readers.

(iii) RELIABILITY: The reliability scale assesses the extent to which the application can be trusted to consistently perform well without encountering any significant problems or glitches.

Table 2: *Usability evaluation metrics*

Id	Name	Description	Category	Type
1	Tutorial	Quality of instructions on how to use the application provided to the user at the start	Support	Subjective
2	Help & Support	Level of help and support access	Support	Subjective
3	Personalisation	To what degree can you personalise user experience	Support	Subjective
4	Accessibility Features	How many accessibility features does the application offers and are they all relevant	Accessibility	Quantitative
5	Accessibility Guidelines	Compatibility with common accessibility guidelines	Accessibility	Subjective
6	Compatibility with OS accessibility	Level of compatibility with relevant OS accessibility features	Accessibility	Subjective
7	Internet connection	Does it need internet connection and is offline version implemented well	Accessibility	Yes or No
8	Crashes	Number of times application crashes	Reliability	Quantitative
9	Errors	Number of encountered errors/bugs	Reliability	Quantitative
10	Exploitation	How does the app perform under relevant but hard conditions (e.g., for camera-based apps how well it does its job in low light)	Reliability	Subjective
11	GUI	Visual pleasance of the graphical user interface	Clarity	Subjective
12	User-Friendliness	How easily does the user get familiar with the application	Clarity	Subjective
13	Navigation	How intuitive and labelled is the navigation in the application	Clarity	Subjective
14	Advertisements	Does the app have adverts that hinder the clarity of the content presented	Clarity	Subjective
15	Loading time	Loading time of the application	Efficiency	Quantitative
16	Steps to main functionality	Number of steps to access the main functionality from the home screen	Efficiency	Quantitative
17	Steps to support	Number of steps to access support from the home screen	Efficiency	Quantitative
18	Steps to settings	Number of steps to access settings from the home screen	Efficiency	Quantitative

(iv) CLARITY: Billah et al. (2017) emphasise the need for consistent user experience, including uniform navigation and shortcuts across applications. This aligns with the clarity evaluation assessing user familiarity, GUI coherence, and navigation consistency.

(v) EFFICIENCY: The efficiency scale provides some standard measures of quantitative analysis. We argue that loading time, and quick reachability of core functionality as well as support are necessary for a good usability.

Each category encompasses individual metrics that can be evaluated subjectively by testers or quantitatively measured to support the grading process. The metrics were chosen by considering both accessibility requirements and heuristic evaluations reported in the literature (Quiñones and Rusu, 2017). Table 2 provides detailed information on the metric names, descriptions, categories and measurement types. The grading system for each usability category and its associated subjective metrics follows a scale from 1 (worst) to 5 (best) to assess the performance. While quantitative metrics provide strong justifications for subjective scores, the grading often involves comparing applications, particularly those with similar purposes.

3.2. Evaluation Framework

The framework depicted in Figure 1 consolidates the usability metrics and offers a methodical assessment process for testers to adhere to. The flow of the framework is organised based on the five usability categories, ensuring that each metric is evaluated individually. The development of this framework stems from rigorous experimentation and testing of accessibility apps, thorough analysis of app limitations and accessibility requirements, and heuristic evaluations reported in the literature. Each rectangular step within the framework corresponds to the usability metrics outlined in Table 2 and is assigned a corresponding numerical label. Rectangular steps with a border on the side indicate quantitative metrics that involve the measurement of time, feature counting, and similar factors. On the other hand, circular steps represent intermediary instructions intended to assist the evaluator with navigation and do not influence the scoring process.

4. EVALUATION OF ACCESSIBILITY APPLICATIONS

A thorough evaluation of ten external accessibility applications was conducted (listed in Table 3), encompassing both visual and hearing impairments.

Table 3: *Accessibility software chosen for evaluation*

Tool Name	Description	Category	Type	Operating System	Price
ReaderMode	*Distraction free online web reader for news articles. Provides additional features for dyslexia*	*Reader Mode*	*Desktop*	*Google Chrome Extension*	*Free or Paid (premium)*
Reader View	*Distraction free online web reader for news articles*	*Reader Mode*	*Desktop*	*Google Chrome Extension*	*Free*
Sullivan+	*Visual-aid app to enhance accessibility of the visually impaired.*	*Vision Aid*	*Mobile*	*iOS, Android,*	*Free*
Envision-AI	*Versatile app that speaks out the world using camera and AI.*	*Vision Aid*	*Mobile*	*iOS, Android*	*Free*
Night Eye	*Custom web browsing themes and UI*	*Browser Customisation*	*Mobile & Desktop*	*iOS, Android & Browser Extensions*	*Free Trial + Premium*
Dark Reader	*Custom web browsing themes and UI*	*Browser Customisation*	*Mobile & Desktop*	*iOS & Browser Extensions*	*Free> Desktop Paid>Mobile*
Magnifying Glass	*Camera-based screen magnifier*	*Magnifier*	*Mobile*	*iOS, Android*	*Free*
Magnifier Plus	*Camera-based screen magnifier*	*Magnifier*	*Mobile*	*iOS, Android*	*Free*
Roger Voice	*Captions phone calls in real time*	*Transcription*	*Mobile*	*iOS, Android*	*Free Trial + Premium*
Ava	*Transcribes and captions any audio*	*Transcription*	*Mobile*	*iOS, Android*	*Free Trial + Premium*

Out of the ten applications, eight were for visual disabilities, while two were for hearing impairments. The selection of applications targeting visually impaired individuals was motivated by the recognition that visual disability is a widely prevalent condition and can be effectively assessed by regular users without specialised expertise. All of these apps were categorised and grouped into pairs based on their primary features, which include:

- READER MODE: These applications typically function as web-extension tools that enable users to read online articles in a distraction-free manner. They often enhance the readability of lengthy articles by removing unwanted elements, offering settings tailored to accommodate dyslexic and visually impaired users.
- VISION AID: These apps typically utilise camera-based identification and reading functionalities to provide environment descriptions for individuals who are blind. They assist users by describing their surroundings.
- BROWSER CUSTOMISATION: Usually taking the form of web-extension tools, these applications allow users to customise the CSS and themes of various websites according to their preferences.
- SCREEN MAGNIFIER: These apps function as digital loupes by offering magnification capabilities. They zoom in on difficult-to-read texts and objects, providing enhanced visibility and autofocus functionality, while also offering features such as applying colour filters, and adjusting brightness or contrast.

- TRANSCRIPTION: These tools involve speech-to-text conversion and aid individuals with auditory impairments by transcribing conversations, videos, phone calls, and other auditory content.

The selected tools comprise mobile applications, some with desktop versions, and mobile-compatible web extensions. These cross-platform applications, widely used and regularly updated, were evaluated on iOS (iPhone 12) and macOS (MacBook Pro 2021), with some assessments on Android devices. The evaluation outcomes, overall scores by usability category, and detailed metrics can be found in Tables 4 to 8.

4.1. Evaluation of Guides and Support

Simplicity of use and comprehensive assistance are crucial for effective accessibility software, encompassing FAQs, chat support, feedback forms, tutorials, and more. A setup guide or introductory tutorial is particularly important to alleviate user apprehension. Unfortunately, as shown in Table 4 and 6, the evaluated platforms performed poorly in the support category, with an average score of only 2.8 out of 5. Many platforms lacked essential setup guides or tutorials, limiting users' understanding of the application. While Night Eye and Magnifying Glass offered informative tutorials, they lacked additional support options. In-app help and support sections were often absent, deficient in critical information, or difficult to access. Browser extensions frequently directed users to official websites for assistance, without facilitating access within the extension software itself.

Table 4: *Overall scores for each Usability category*

App Name	Usability					
	Support	**Accessibility**	**Reliability**	**Clarity**	**Efficiency**	**Final Grade**
ReaderMode	*2*	*5*	*5*	*5*	*3*	*4.0*
Reader View	*2*	*3*	*4*	*3*	*4*	*3.2*
Sulivan+	*4*	*4*	*2*	*4*	*3.5*	*3.5*
Envision-AI	*3*	*5*	*5*	*5*	*3.5*	*4.3*
Night Eye	*2*	*3*	*3*	*3*	*4*	*3.0*
Dark Reader	*3*	*3.5*	*4*	*4*	*3*	*3.5*
Magnifying Glass	*2*	*3*	*4.5*	*4*	*4*	*3.5*
Magnifier Plus	*2*	*3.5*	*4*	*4*	*3*	*3.3*
Roger Voice	*4*	*4*	*3.5*	*5*	*3*	*3.9*
Ava	*4*	*4*	*4.5*	*4.5*	*2*	*3.8*
Average Grade	*2.8*	*3.8*	*4.0*	*4.2*	*3.3*	*3.6*

Table 5: *Evaluation of usability metrics id 15 to 18 (Efficiency)*

App Name	Loading Time	Steps to the Main Functionality	Steps to Support	Steps to Settings	Grade
ReaderMode	*2 seconds*	*1 click*	*2 clicks (from the app). The access to support from the extension is very hard.*	*1 click*	*3/5*
Reader View	*Instant loading time*	*1 click*	*Technically 1 click but the support does not really work.*	*1 click*	*4/5*
Sulivan+	*2 seconds*	*0 clicks (the app opens on the main feature)*	*2 clicks*	*2 clicks*	*3.5/5*
Envision-AI	*3 seconds*	*0 clicks (the app opens on the main feature)*	*2 clicks*	*1 click*	*3.5/5*
Night Eye	*1 second*	*0 clicks (the app opens on the main feature)*	*2 clicks*	*1 click*	*4/5*
Dark Reader	*Instant loading time*	*1 click*	*3 clicks*	*1 click*	*3/5*
Magnifying Glass	*1 second*	*0 clicks (the app opens on the main feature)*	*No support*	*1 click*	*4/5*
Magnifier Plus	*1 second*	*0 clicks (the app opens on the main feature)*	*No support*	*2 clicks*	*3/5*
Roger Voice	*1.5 seconds*	*0 clicks (the app opens on the main feature)*	*2 clicks*	*1 click*	*3/5*
Ava	*2.5 seconds*	*1 click*	*2 clicks*	*2 clicks*	*2/5*

Table 6: *Evaluation of usability metrics id 1 to 3 (Support)*

App Name	Tutorial	Help & Support	Personalisation	Grade
ReaderMode	*Lack of the set-up guide in the extension. However, if the user navigates to their website, it does provide helpful guides and videos This should be more easily accessible. 2.5/5*	*Chat support is provided; however, at the time of testing, the chat member was last active 15 days ago. There is a lack of support access from the extension itself instead of their website 2.5/5*	*The extension and their website are not really customisable. 1/5*	*2/5*
Reader View	*Lack of the set-up guide in the extension. Inexperienced users may have some troubles with using this extension. 1/5*	*The app's website has a FAQs label, which is poorly organised and unreadable. User can contact the company by email;2/5*	*The extension is not really customisable. You can change the language on the website and use the extension itself to change its appearance. 2/5*	*2/5*
Sulivan+	*Very good set up guide, when opening the application for the first time. Clearly explained, structured with pictures, text and helpful tips. 5/5*	*Vert good help and support section with a lot of tutorials, videos, features guidance and licensing. However, the text presented in some of guidance is cut and there is no way to fully see*	*Good number of settings like voice, sound effects, modes. Not much can be done with the appearance of the app. 3/5*	*4/5*
Envision-AI	*Lack of the set-up guide shown at the beginning. There are tutorials accessible later, but user should be taught how to use the app 2/5*	*Support in the form of tutorials is accessible from the settings, user can give feedback but there is no way to contact support. 2.5/5*	*Good number of settings, both for UI personalisation and app's features customisation. Example includes dark mode, different detections, speech settings etc.4.5/5*	*3/5*
Night Eye	*Good set up guide shown at the beginning. However, there is no way to access it again and recall all the gestures and information to use the app. Extension settings lack explanation. 2.5/5*	*Support not accessible from the app but only from the extension. The website with help is however hard to reach and is unreadable (long text chunks, bad spacing, no breaks etc.) .2/5*	*Weak on the app side (only language). The extension side has good number of features, which are however not explained. 2/5*	*2/5*
Dark Reader	*Lack of the tutorial on how to turn on the extension, however the app provides tutorial on how to use it. Good explanation of settings 3.5/5*	*Easily accessible e-mail address for queries and they have a FAQs section. 4/5*	*Extension can be used to personalise the official website. There is however lack of extension customisation. 2/5*	*3/5*
Magnifying Glass	*Good tutorial that disappears and is not accessible after you close it. The user needs to memorise the gestures and options. 3/5*	*No support section and no way to contact the app developers. There is also lack of explanation on gestures. 1/5*	*App provides options that can be turned on like flashlight, stabiliser or different modes. There is nothing to personalise in terms of accessibility. 2.5/5*	*2/5*
Magnifier Plus	*Lack of the set-up guide.1/5*	*There is an explanation of gestures, but they are incorrectly placed in 'About' section. There is also 'share feedback' option but no real contact. 2.5/5*	*User can turn on options such as vibrations, sound and larger font. More should be possible in terms of accessibility 2.5/5*	*2/5*
Roger Voice	*Simple and nice set up guide that explains the main features. Could show a bit more but is enough to understand the app 3.5/5*	*Good FAQ section and easily accessible custom service. These options are also very easy to find. 4.5/5*	*User can personalise the theme in the app with options for contrast, and different modes. Language and text size can also be modified 4/5*	*4/5*
Ava	*Lack of the set-up guide. Instead, there is a 'discover' option with tutorials and explanations 3/5*	*There are good tutorials and support 5/5*	*There is a lot of useful settings with big variety. 4.5/5*	*4/5*

Table 7: *Evaluation of Usability metrics id 8 to 10 (Reliability)*

App Name	Crashes	Errors	Exploitation	Grade
ReaderMode	*0 crashes encountered throughout the usage of the app.*	*0 errors encountered throughout the usage of the app.*	*No problems encountered when trying to exploit this app.*	*5/5*
Reader View	*0 crashes encountered throughout the usage of the app*	*0 errors encountered throughout the usage of the app.*	*The extension does not work well on websites that do not show articles.*	*4/5*
Sulivan+	*2 crashes encountered throughout the usage of the app. The app first froze and then turned itself off when using some of its features.*	*3 errors encountered throughout the usage of the app. The app froze 2 times when accessing some sections and one time the model was not working due to 'no connection' although the internet was good.*	*This app struggles identifying objects in low-light conditions. For some reason a lot of 'scene description' included cats in there. It seems like their model is not that complex.*	*2/5*
Envision-AI	*0 crashes encountered throughout the usage of the app.*	*0 errors encountered throughout the usage of the app.*	*The app does well in low-light condition. It identifies it and turns on the flashlight for a split second. Their model is also more precise and identifies the user if it's not sure.*	*5/5*
Night Eye	*0 crashes encountered throughout the usage of the app.*	*4 errors encountered throughout the usage of the app. User can't slide the brightness slider, instead only tapping is allowed. The slides also do not go all the way. Next even when the settings were reset for a website, some content like adds still had their appearance changed.*	*Hard to exploit such feature of this type of application. The app does not work well on some websites that have a complicated colour scheme.*	*3/5*
Dark Reader	*0 crashes encountered throughout the usage of the app.*	*1 error encountered throughout the usage of the app. The 'filter + theme' option is buggy, as it changes itself and can't be customised.*	*Hard to exploit such feature of this type of application. The app does not work well on some websites that have a complicated colour scheme.*	*4/5*
Magnifying Glass	*0 crashes encountered throughout the usage of the app.*	*0 errors encountered throughout the usage of the app.*	*The app copes well in testing conditions, as it allows to turn on the flashlight and control the brightness (it does not do it automatically).*	*4.5/5*
Magnifier Plus	*0 crashes encountered throughout the usage of the app.*	*1 error encountered throughout the usage of the app. The app froze and had to be restarted.*	*The app copes well in testing conditions, as it allows to turn on the flashlight and control the brightness (it does not do it automatically).*	*4/5*
Roger Voice	*0 crashes encountered throughout the usage of the app.*	*0 errors encountered throughout the usage of the app.*	*The app misses some words during a call in a normal, quiet environment. It misses many words in a noisy room.*	*3.5/5*
Ava	*0 crashes encountered throughout the usage of the app.*	*0 errors encountered throughout the usage of the app.*	*The captions work relatively well in a noisy environment. Not many words were missed during testing.*	*4.5/5*

Table 8: *Evaluation of usability metrics id 11 to 14 (Clarity)*

App Name	GUI	User-Friendliness	Navigation	Adds	Grade
ReaderMode	Very good GUI for both the website and the extension. Icons are labelled with hover-on text. The contrast is good, and the colours are pleasant. The UI is minimal, clean and the spacing of information is clear. 5/5	The app is very easy to get familiar with. Everything is easily accessible, intuitive and explained properly. The settings change the website's appearance in real time. 5/5	The navigation is very intuitive, and the user should not have any issues exploring the app. 5/5	The only adds that the app shows are for their premium services. 4/5	5/5
Reader View	GUI of the website could be better, provide easier navigation, headings font sizes etc. There are only 2 colours used on the website. The extension is well made; however, the buttons don't have text indicators. 2.5/5	User needs some time to get familiar with the app. The introductory website is poorly made, however once you get used to the app its usable. 3/5	App navigation is straightforward and simple. But the pages on the website are very long and lack links to subsections. The search bar does not work. 3/5	No adds on the extension part of the app. 5/5	3/5
Sulivan+	GUI is kept simple and minimal. Left and right-side menus could be presented in a nicer way and the app could use some colours. 3.5/5	User should not have issues getting familiar with the app. A lot of it is explained or self-explanatory. 4.5/5	The navigation could be improved and labelled in a better way. The user can encounter problems discovering side panels. 4/5	The app does not show any adds 5/5	4/5
Envision-AI	Very good GUI. Kept simple but aesthetic and clean. The colours, buttons and layout are pleasant. 5/5	The app is easy to get used to and self-explanatory. Regardless a guide would be nice 4/5	The navigation is flawless. Everything is clear and labelled. 5/5	The app does not show any adds 5/5	5/5
Night Eye	The GUI of the app is average. The extension UI is very nice. The only problem is small clickable buttons that do not indicate if they are active or not. 3/5	The user can have problems when knowing the app. There are lots of poorly explained features, bad navigation, no tutorials etc. 2.5/5	The navigation is simple and straightforward however tiny buttons can make it very frustrating experience. 3.5/5	The app does not show any adds 5/5	3/5
Dark Reader	The GUI is satisfactory and simple. It can feel a bit too clamped together, as the spacing could be a lot better. 3.5/5	The app is easy to get familiar with. The extension if easy to use but some of the features (e.g., site list) could be explained better. 4/5	App has a lot of navigation links which is helpful. Once the user accesses help area he can't go back to the home page which is tricky. 4/5	The extension does not have any adds. 5/5	4/5
Magnifying Glass	Easy and clean GUI. It's satisfactory for such a simple app but some nicer touch would be appreciated. 4/5	The app is very easy to understand, however gestures can be hard to memorise. 4/5	The navigation is very straightforward. It could be improved with labels 4/5	There are some adds that can frustrate 3/5	4/5
Magnifier Plus	The UI is very nice and clean. The theme of the app is also pleasant 4.5/5	The app is very simple, hence easy to get familiar with. The settings could have more explanation. 4/5	The navigation is pretty simple; however, exiting the side menu can only be done with gestures. 3.5/5	The app does not show any adds 5/5	4/5
Roger Voice	Very pretty, clean, pleasant and simple GUI. Using the app is overall a pleasure. 5/5	Getting used to the app is very quick and simple, especially after a good start tutorial. 5/5	The navigation in the app is very easy and intuitive. Everything is labelled. 5/5	The app does not show any adds 5/5	5/5
Ava	GUI of the app does not have any fallbacks. Everything is clean and pretty. 5/5	User needs some time to understand the app as it has a lot of options and menus. The app tutorial would be very useful here. 3.5/5	The app has nicely labelled menus, which make the navigation very easy. 5/5	The app does not show any adds 5/5	4.5/5

Similarly, the personalisation aspect exhibited considerable inconsistency, with insufficient options for modifying colour themes, font sizes, languages, and other customisation features. Undoubtedly, there is a pressing need to prioritise support within accessibility applications, ensuring that users are adequately assisted throughout their usage journey.

4.2. Performance of the Accessibility Apps

The evaluation results revealed that the Vision Aid and Transcription application categories achieved higher average overall scores of 3.9 and 3.85, respectively, compared to the remaining applications, which scored an average of 3.4. The difference arises from the targeted design approach of Vision Aid and Transcription apps, which cater to individuals with distinct disabilities like visual or hearing impairments, whereas other apps like magnifiers or browser customisation tools are created to meet general accessibility needs. Notably, Envision-AI, Roger Voice, and Ava, belonging to the Vision Aid and Transcription categories, demonstrated exceptional performance across multiple metrics. These apps showcased professional designs, intuitive user interfaces, compatibility with accessibility standards, and thoughtful implementations. Roger Voice and Ava utilised similar speech-to-text technology for call and audio transcription, respectively, raising the possibility of combining these services into a single application to streamline user experiences.

Conversely, Dark Reader and Night Eye, as browser extensions for webpage customisation, performed poorly within their category. Night Eye received the lowest overall usability score of 3.0. It consistently lacked support, adherence to accessibility guidelines, compatibility with operating system accessibility features, suffered from subpar design, and experienced reliability issues. The use of grey text on a dark background further compromised information clarity. In contrast, Dark Reader offered a simple yet clean interface with appropriately labelled options, improving user experiences.

4.3. Compatibility with OS-level Accessibility

With the increasing integration of accessibility settings in mobile devices, standalone accessibility applications should ensure compatibility with OS-level features such as screen magnifiers and screen readers. During the evaluation, the applications for reader mode, vision aid, browser customisation, and screen magnification were tested. However, assessing OS-level auditory accessibility features was out of the scope for testing transcription apps. The evaluation was conducted utilising iOS's screen reader, VoiceOver, and magnification software, While iOS's magnification software generally performed well in all apps, VoiceOver encountered issues in 5 out of 8 applications. Many of these apps

demonstrated inadequate development, resulting in the screen reader's inability to recognise components on the main screen.

4.4. Evaluation of Accessibility Features

One of the categories within the framework's usability metrics focuses on the number of features offered by an application. It is not simply about having the highest quantity of accessibility features, but rather how effectively these features are integrated within the application. Sulivan+ and Envision-AI stand out by incorporating diverse object detection features into their vision-aid applications, leveraging camera technology for scene, face, colour, and object recognition. Consequently, both apps attained high scores in the 'Accessibility' category in Table 4.

It is crucial to note that while adding more features, especially for different disabilities, may appear advantageous, it also carries the risk of creating an incoherent application. In contrast, merging the features of transcription apps like Roger Voice and Ava has the potential to yield a more versatile and valuable application. Combining audio and call transcription, which employ similar technologies, would reduce the need for multiple separate apps. Similarly, Reader Mode and Browser Customisation applications share the common goal of enhancing the internet browsing experience. Integrating features from both categories into a single platform could unlock greater usability potential. Achieving an optimal balance between the number of accessibility features and application complexity should be carefully considered during the development process. Ribeiro et al. (2018) highlight the current challenges in the mobile accessibility space, particularly the limited availability of applications catering to diverse disabilities. They advocate for greater versatility, a mindful understanding of user needs, and the creation of applications that effectively address those needs.

5. CONCLUSIONS

This paper presents a comprehensive framework for evaluating accessibility apps that considers not only the presence of features but also their complexity and practical usability. It recognises that accessibility encompasses more than isolated features and emphasises the importance of contextual knowledge for users to effectively navigate and utilise these features. The evaluation conducted in this paper has highlighted recurring limitations in popular accessibility applications, necessitating attention and improvement. Inadequate support within the apps emerged as a major issue, impeding users' accessibility experience. Ensuring seamless integration and synchronisation with the accessibility features

inherent to the operating system should be prioritised to provide a consistent and smooth user experience. Another notable finding was the discrepancy between the iOS and Android versions of these applications. Differences in functionality, design, and usability between platforms can frustrate users who switch devices or operating systems. For instance, the user interface of Sulivan+ on Android presented more issues and was less visually pleasing compared to its iOS counterpart. The Android version of the Magnifying Glass application also differed from its iOS version. Despite the diverse accessibility settings available on Android and iOS devices, navigating the multitude of options remains challenging.

The evaluation of the accessibility apps detailed in this paper highlighted the significance of a uniform, enjoyable user interface, efficient navigation, and the application's potential to enhance disability-inclusive user experiences. The proposed framework enables a thorough assessment beyond technical compliance, focusing on the practicality and effectiveness of accessibility solutions in real-world scenarios.

6. REFERENCES

Aizpurua, A., Arrue, M. and Vigo, M. (2015) Prejudices, memories, expectations and confidence influence experienced accessibility on the web, Computers in Human Behavior, vol. 51, pp. 152–160.

Billah, S. M., Ashok, V., Porter D. E., Ramakrishnan I.V. (2017) Ubiquitous Accessibility for People with Visual Impairments: Are We There Yet? Proc SIGCHI Conf Hum Factor Comput Syst.

Caldwell, B., Cooper, M., Reid, L.G., Vanderheiden, G., Chisholm, W., Slatin, J. and White, J. (2008) Web content accessibility guidelines (wcag) 2.0, WWW Consortium (W3C), vol. 290, pp. 1–34.

Faverio, M. (2022) Share of those 65 and older who are tech users has grown in the past decade, https://www.pewresearch.org/short-reads/2022/01/13/share-of-those-65-and-older-who-are-tech-users-has-grown-in-the-past-decade/ Last accessed: 8/07/2023.

Franz, R. L., Wobbrock, J. O., Cheng, Y. and Findlater, L. (2019) Perception and Adoption of Mobile Accessibility Features by Older Adults Experiencing Ability Changes. In Proceedings of the 21st International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '19). NY, USA, 267–278. https://doi.org/10.1145/3308561.3353780.

Frazão, T. and Duarte, C. (2020) Comparing accessibility evaluation plug-ins, in Proceedings of the 17th International Web for All Conference, pp. 1–11.

Gaggi, O., Quadrio, G. and Bujari, A. (2019) Accessibility for the visually impaired: State of the art and open issues, in 16th IEEE Annual Consumer Communications & Networking Conference (CCNC), pp. 1–6.

ISO (2018) Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts.https://www.iso.org/standard/63500.html, Last accessed: 8/07/2023.

Karreman, J., Van der Geest, T. and Buursink, E. (2007) Accessible website content guidelines for users with intellectual disabilities," Journal of applied research in intellectual disabilities, vol. 20, no. 6, pp. 510–518.

Krahn, G. L. (2011) Who world report on disability: a review, Disability and health journal, vol. 4, no. 3, pp. 141–142.

Perrin, A. and Atske, S. (2021) Americans with disabilities less likely than those without to own some digital devices. https://www.pewresearch.org/short-reads/2021/09/10/americans-with-disabilities-less-likely-than-those-without-to-own-some-digital-devices/ Last accessed: 8/07/2023.

Petrie, H. and Kheir, O. (2007) The relationship between accessibility and usability of websites, in Proceedings of the SIGCHI conference on Human factors in computing systems, pp.397–406.

Quiñones, D. and Rusu, C. (2017) How to develop usability heuristics: A systematic literature review, Computer standards & interfaces, vol. 53, pp. 89–122.

Ribeiro, F. R., Silva, A., Barbosa, F., Silva, A. P. and Metrôlho, J. C. (2018) Mobile applications for accessible tourism: overview, challenges and a proposed platform, Information Technology & Tourism, vol. 19, no. 1, pp. 29–59.

Thielsch, M.T. and Thielsch, C. (2018) Depressive symptoms and web user experience, PeerJ, vol. 6, p. e4439.

WHO (2023) Disability and Health. Retrieved from https://www.who.int/news-room/fact-sheets/detail/disability-and-health,Last accessed: 8/07/2023.

W3C (2023) Accessibility principles. https://www.w3.org/WAI/fundamentals/accessibility-principles/, Last accessed: 8/07/2023.

Yan, S. and Ramachandran, P. (2019) The current status of accessibility in mobile apps, ACM Transactions on Accessible Computing (TACCESS), vol. 12, no. 1, pp. 1–31.