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Visually Impaired Usability Requirements for Accessible Mobile Applications: A Checklist for Mobile E-book Applications

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ABSTRACT

The definition of an e-book is a book in an electronic format, which can be beneficial to all readers, mainly those struggling with print books because of their vision impairments. Nevertheless, the visually impaired cannot access regular e-books because they do not meet their unique needs, and they require a more accessible e-book to reach the same expected advantages as those typically seen. Due to the lack of a clear list of these needs, developers are not aware of the specific requirements of the visually impaired for e-book applications. This paper aimed to analyse the visually impaired usability requirements for usable and accessible e-book applications. Three main activities

were conducted: reviewing the literature, conducting an online survey of the visually impaired, and comparing the two results obtained earlier to acquire verified usability requirements. This study reviewed current works on the usability and accessibility of e-books from 2010 to 2022. Besides, this study also conducted reviews on common accessibility needs and standards for mobile applications. A total of 24 usability requirements were identified from the literature and compared with ten results from seven visually impaired respondents using an online survey. With these verified usability requirements, designers and practitioners can use them as a checklist to ensure all needs are considered when designing mobile e-books for the visually impaired.

Keywords: Accessibility, checklist, mobile e-book applications, usability requirements.

INTRODUCTION

With the increased demand for digital information, e-books, and e-readers, the importance of designing usable and accessible application interfaces for users with different abilities intensifies (Ballantyne et al., 2018). Mobile devices are increasingly used to read e-books (Mei Kodama et al., 2021), and the primary beneficiaries are readers with disabilities, such as the visually impaired (Patel & Morreale, 2014). Designers and evaluators must acknowledge concerns about the visually impaired's easy access to electronic resources (Hassouna et al., 2017; Khan & Khusro, 2020). Nonetheless, countless users with vision disabilities found mobile applications inaccessible (Alajarmeh, 2021; Khan & Khusro, 2020). The National Federation of the Blind (NFB) has also stated that many e-books fail to meet the needs of visually impaired readers. Therefore, people with visual impairments remain disadvantaged when it comes to accessing digital resources (Bartalesi & Leporini, 2015; Khowaja & Fatima, 2019).

The lack of accessibility or the provision of only partial accessibility in applications is a barrier for both individuals and businesses (Yan & Ramachandran, 2019). Difficult-to-use applications will either stress and frustrate users or cause them to abandon them in favour of a more convenient and accessible alternative (Di Gregorio, 2021). Researchers are increasingly concerned about accessibility because

of the increased use of mobile applications. As a result of this trend, a research field has emerged devoted to developing mobile applications suitable for people with disabilities, such as the visually impaired, who represent around 15 percent of the planet's population (WHO, 2021). It has become increasingly critical to provide accessible application functionality as people with disabilities become more dependent on handheld devices (Yan & Ramachandran, 2019). In the past, most accessibility research has concentrated on the web, providing developers with guidelines and tools to implement accessible websites (Abuaddous et al., 2017; Power et al., 2012; Vigo & Brajnik, 2011). This is also true for web-based e-books, which typically emphasise e-book content (format) accessibility (Baker-Eveleth & Stone, 2015; Fahmy et al., 2012; Khowaja & Fatima, 2019). Indeed, mobile applications have not been thoroughly examined and remain an open research challenge (Alajarmeh, 2021; Di Gregorio et al., 2022; Siebra et al., 2018; Yan & Ramachandran, 2019). The lack of accessibility research on mobile e-book applications also exists, as only a few usability evaluation models of e-book applications consider application accessibility an essential factor to be evaluated (Sulaiman & Mustafa, 2019). Additionally, evaluation studies in this domain provide a few accessibility metrics, such as screen readers, zoom, alternative text, and changing text configuration (Al-Qatawneh et al., 2019; Senjam et al., 2021). Nevertheless, these metrics are insufficient to offer a usable e-book application for visually impaired users of mobile e-book applications (Siebra et al., 2018). Meanwhile, few studies have considered and identified the usability requirements of e-book applications for the visually impaired (Shin et al., 2017). Therefore, this study will address the gap in the usability requirements of accessible e-book applications for the visually impaired.

The requirements of a system are the features or behaviours it should exhibit according to the stakeholders (Zachariah & Nonyelum, 2020). Designing with user needs and limitations in mind is critical to develop a clear understanding of their requirements for tasks (Al-Megren & Almutairi, 2019). Identifying the visually impaired's user requirements for the application at an early stage of development is vital to ensuring that the developed application is used and benefitted by them (Nathan et al., 2016). However, there is no concrete and clear list of these requirements. Therefore, through a literature review and survey, this paper aims to analyse usability requirements for usable and accessible e-book applications for the visually impaired. Literature

that focuses on examining and developing e-books that reflect the perspective of visually disabled people is carefully reviewed to define the requirements. Besides, the study reviewed the current guidelines and requirements for general mobile applications to address the requirements more deeply. Moreover, the study surveyed visually impaired students at one local Malaysian university.

There are several sections in this paper, beginning with a brief introduction. Following that is a review of previous works and the methodology section. The final part outlines the results and conclusions.

LITERATURE REVIEW

Several research communities are increasingly interested in the topic of accessibility, including software engineering and human-computer interaction. Different perspectives on the problem can be explored through these multidisciplinary research opportunities. This section presents the state of the art of mobile application accessibility and accessible e-book application usability for the visually impaired. Even though accessibility principles and guidelines have been explored in the context of web applications for a long time, they are still largely undefined for mobile applications (Di Gregorio et al., 2022). The term "mobile accessibility" refers to the process of creating mobile applications and mobile websites that are more accessible to users with disabilities (W3C, 2018). Guidelines on accessibility for people with disabilities and the elderly are available for several electronic systems. For instance, the IBM Human Ability and Accessibility Centre provides guidelines to help create accessible web, mobile, and desktop applications for people of all abilities (IBM, 2019). The accessibility checklist is based on the revised Section 508 standards, the EN 301 549 standard in Europe, the Worldwide Web Consortium (W3C) recommendations, and IBM Research best practices. In addition, Pernice et al. (2001) proposed a set of 75 guidelines for web accessibility. Many of these guidelines would make web designs accessible to everyone.

With the increasing use of mobile devices by the visually impaired, it is critical to create solutions and applications for this group (Ghidini et al., 2016). Most of the solutions found in the literature enable

accessible interactions by accepting gestures as inputs and providing speeches, audios, and regular tactical feedback as outputs (Piccolo et al., 2011; Power & Jürgensen, 2010). Based on participatory interviews, Kane et al. (2011) proposed a set of accessibility guidelines for touch-screen-based applications for both blind and sighted users. Nonetheless, it focused only on a common situation associated with selecting gesturing designs for visually disabled people (Siebra et al., 2016). Arroba et al. (2011) introduced a novel methodology and a set of guidelines for developing accessible touch-screen platforms for visually impaired users. In a research performed by Piccolo et al. (2011), a focus group session was conducted with the visually impaired (blind and partially sighted) to identify a set of guidelines for developing an accessible software solution. Buzzi et al. (2012) studied the accessibility problems faced by blind users, mainly when they are interacting with mobile learning applications using touch-screen mobile devices. The study discussed aspects that must be considered, such as using standard user interface elements and providing alternative interaction modalities. These studies addressed general mobile application guidelines and requirements that may enhance the usability and accessibility of mobile applications.

Mi et al. (2014) designed a general heuristic checklist for accessible smartphone devices; however, this study did not classify the types of disabilities to better frame their requirements (Siebra et al., 2016). To address the limitations of previous studies, Siebra et al. (2017) identified requirements associated with various categories of disabilities. In addition, Siebra et al. (2015) identified 13 requirements based on semi-structured interviews and a systematic literature review for accessible mobile applications for visually impaired users. These requirements were classified into six for blind users, six for low/limited vision users, and one for the visually impaired. In Siebra et al. (2016), these 13 requirements were classified into essential (9), desired (2), and not observed (2) based on an observation analysis. Kim et al. (2016) examined the interactions of camera-based mobile applications. They discovered that accessible applications for the visually impaired could be created by providing a simplified structure, maintaining consistent user interface layouts, and increasing configurable settings.

Ghidini et al. (2016) studied approaches to an interaction that could be used easily by visually impaired users. The outcomes indicated that mobile devices, particularly smartphones, must deliver proper

feedback, have a simple design for simple interaction, and have the ability to find the application's options and features. According to Alajarmeh (2021), mobile touch-screen devices can present persistent accessibility-related challenges to visually impaired users. These problems were examined to see if WCAG 2.1 sufficiently addressed them. According to the study, mobile apps and websites are still developing without considering crucial accessibility issues. WCAG 2.1 defined many of these problems, but some lack relevant success criteria or do not meet required conformance levels. While WCAG 2.1 contained several mobile-oriented guidelines, mainstream mobile content showed scant adherence to these guidelines despite their existence. As a result of these findings, WCAG 2.1 needs to be improved to better accommodate the needs of users with visual impairments using mobile touch-screen devices.

In a study by Di Gregorio et al. (2022), accessibility guidelines for all categories of disabled users were tested in 50 Android-based applications. It was found that most of the best practices were not implemented within applications. After conducting eight semi-structured interviews with 75 developers, the study showed that accessibility was considered necessary even though developers faced several socio-technical barriers that prevented them from applying the accessibility guidelines. Nevertheless, the study did not classify the guidelines according to disability types, which made it difficult for the developers to consider all the guidelines for one category of disability, like vision disability. People with vision impairments have unique requirements to be able to interact with mobile applications. It is possible for such a requirement to cause a gap between the ideas of developers and the needs of people with visual impairments. In this case, the applications were either not adopted or not enrolled (Senjam, 2021). Even though there are some recent studies that proposed accessibility requirements and checklists for mobile applications, they did not cover specific mobile applications, such as e-book applications for the visually impaired.

An accessible e-book for visually impaired users allows them to use the e-book and achieve the same benefits as individuals with normal vision with approximately the same effort (Texas School for the Blind and Visually Impaired, n.d.). Therefore, screen reader software should be able to read each element of e-book application interfaces, such as menus and icons. An accessible name (a brief description) must

accompany each user interface element (Ghidini et al., 2016; W3C, 2017). Another essential requirement is an accessible format. Screen readers will not function and read e-contents correctly if the format is inaccessible (Axtell et al., 2018; Bonnici et al., 2015; Maatta & Bonnici, 2014). There are two basic formats for e-books: fixed layouts, such as PDF files, and fluid formats, such as ePub, MOBI, and IBA (Walton & Hailey, 2015). Nonetheless, fluid formats are ideal for handheld devices (Zeng et al., 2016) and even preferable for users with visual disabilities (Axtell et al., 2018). Even so, concerns remain about the accessibility of content, including pictures without descriptive text and inaccessible PDF files (Southwell & Slater, 2012). In addition, if the content is not properly marked up, the e-book will remain unavailable (Lazar et al., 2015).

Numerous e-book applications provide a Text-to-Speech (TTS) feature, which addresses the accessibility limitations of written books (Attarwala et al., 2012; Munteanu, 2013). Besides, TTS can enhance the understanding of the visually impaired (Balajthy, 2005). Nonetheless, TTS is a computer-based speech that is sometimes difficult to understand (Axtell et al., 2018). For this reason, TTS has been configured in many ways to enhance its effectiveness. For example, the synchronisation of the highlighting of words being read helps in improving focus and comprehension (Balajthy, 2005; Biancarosa & Griffiths, 2012). Other features, such as TTS voice volume and speed adjustments, are also important because different users have different listening abilities that affect their comprehension (Curts, 2016; Power & Jürgensen, 2010). In addition, these TTS settings are frequently used by the visually impaired, namely voice pitch (45%), speed (75%), and volume (70%) (Shin et al., 2017). Furthermore, the customisation of TTS voice (such as male or female voice) must be available to suit the preferences of visually impaired users (Power & Jürgensen, 2010). Consequently, TTS improves the accessibility of e-books, and developers must be aware of the importance of such a feature for a more accessible e-book application for the visually impaired.

The production of accessible e-book applications for the visually impaired requires many accessibility features. Some examples include text enlargement, text and background selection, colour contrast, and support for different input techniques, such as voice commands (Axtell et al., 2018; Minatani, 2017). Additionally, the user interfaces

need to be as simple as possible to make accessing electronic content easy (Southwell & Slater, 2012). In this context, a user-friendly navigation design contributes to making the application easier to use for the visually impaired, especially when a learning process is involved (Minatani, 2017; Shin et al., 2017; Southwell & Slater, 2012). Learners must be able to read sequentially, move instantly over the content, and make annotations (Buzzi et al., 2012). Fortunately, e-books provide interactive features such as search, navigation, and editing tools. They also support hyperlinks, bookmarking, and annotations, which are advantages over print books (ChanLin, 2013). It is clear that e-books, as a specific type of application, have features and requirements that need to be clearly identified and reported.

Recently, several studies proposed usability requirements and guidelines for accessible mobile applications and declared them in terms of checklists, classifications, and guidelines. Unfortunately, few e-book studies thoroughly identified the usability requirements for accessible mobile e-book applications for the visually impaired (Shin et al., 2017). This outcome encourages the current study to perform a future analysis of the guidelines and requirements for mobile applications and e-book applications for the visually impaired and generate a list of accessibility requirements that cover both mobile and e-book accessibility requirements for the visually impaired. These requirements can be used to guide the developers and evaluators of these applications. The adoption of these requirements can lead to more usable and accessible e-book applications for people with vision impairments, which will increase the number of users of such applications. Literature that was analysed in deriving the usability requirements is listed in the Results Analysis and Discussion section.

METHODOLOGY

Identifying user requirements is very important, as they are critical in ascertaining user interface usability satisfaction for any application. This study reviewed the usability requirements of accessible mobile e-book applications designed for users with vision impairments. As a first step, the study conducted a literature review to summarise the current state of the art on the topic. This topic focuses on the usability requirements for accessible mobile e-book applications for the visually impaired. Following are the activities performed along these steps:

(1) Reviewing the literature: The current state of the art on the topic was summarised in this step. Papers were identified by searching academic and commercial databases (e.g., ACM Digital Library, Scopus, ScienceDirect, Google Research Databases, Research Gate). During this step, 50 scientific and technological articles were analysed from 2010 to 2022. The authors also used the snowball method to identify additional papers from existing articles' reference lists (Wohlin, 2014). The objective was accomplished by compiling a list of mobile usability guidelines and requirements for mobile applications for the visually impaired and mobile e-book applications. The study excluded any usability requirements of mobile as a device and any requirements related to operating systems, as the scope of this study was only on application interfaces. Besides, many assistive technology hardware solutions, such as Braille Keypads and Braille Displays, are available for visually impaired users. However, their usage is not common primarily because of their costs (Siebra et al., 2017). Therefore, this study excluded any requirements that depended on such external devices. Requirements regarding the creation of the book content were also excluded because the scope of the application was only the interface and functions.

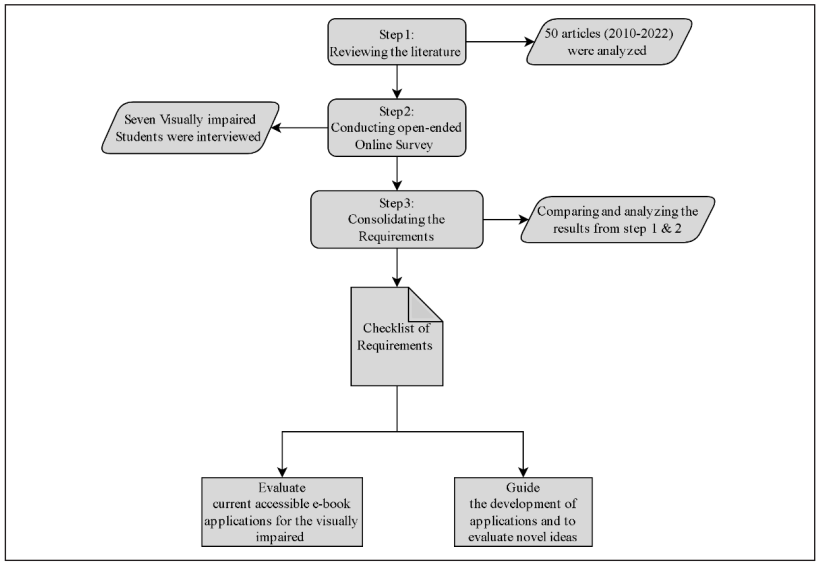
(2) Online survey: In confirming or extending the initial list, an online survey was used to collect information from real visually impaired users, as conducted by Piccolo et al. (2011). As part of the study, seven visually impaired students from a local university participated in an online survey. As similar studies had only five participants, this response rate was still acceptable (Siebra et al., 2015). Purposive sampling is employed when working with a small sample size, and it is widely used to identify available individuals to give information based on their experience (Saunders, 2012; Saunders et al., 2009). The survey contained open-ended questions sent electronically instead of using traditional distribution methods like paper, as it can be quite challenging. Some of the questions were adopted from Nathan (2017), and this study added the remainder to cover other reading issues related to print and electronic books. The instrument used in this study collected some demographics, such as gender, age, mobile experience, and degree of vision impairment. Additionally, open-ended questions, such as

mobile application usage and difficulties, e-book usability, and accessibility issues, were added to the survey. Content analysis software was used to analyse the comments and identify the usability requirements based on the survey answers and comments. The relevant statements have been grouped into nodes based on the written transcriptions to represent the usability requirements.

(3) Requirements Consolidation: The usability requirements from the papers and online survey were analysed together to generate conclusions about their use and significance. Finally, the requirements from the online survey were compared with the requirements from the literature to confirm or add new requirements. After this analysis, a checklist of usability requirements was developed, which can be used in two directions. As a first step, the checklist can evaluate current accessible e-book applications for the visually impaired to determine their level of usability. A second use of this checklist will be to guide the development of applications and evaluate novel ideas. Figure 1 shows the methodology of this paper.

Figure 1

Research Procedure



RESULTS ANALYSIS AND DISCUSSION

Visually impaired users depend on the power of information, communication, and technology (ICT) software to interact with digital interfaces (Southwell & Slater, 2012). As ICT software, e-books provide a new avenue for learning for the visually impaired. Therefore, addressing the requirements of the visually impaired for a usable and accessible mobile e-book application is essential. Based on the reviewed literature, this study identified 24 usability requirements that were considered important for developing easy-to-use and easy-to-access mobile e-book applications for people with vision disabilities. Table 1 summarises these requirements.

Table 1

The Usability Requirements of Visually Impaired Users for Accessible E-Book Applications

Req No.	Description	Source
R1	Compatible with screen reader	Hassouna et al. (2017), Khowaja et al. (2019), Mi et al. (2014), Siebra et al. (2016; 2017; 2015)
R2	Provide a meaningful alternative description to non-text interface elements	Di Gregorio et al. (2022), Hassouna et al. (2017), Siebra et al. (2015; 2017; 2016)
R3	When a character is tabbed, the application reads its name aloud	Di Gregorio et al. (2022), Mi et al. (2014), Siebra et al. (2016; 2015; 2017)
R4	Provision of a clear spoken, haptic, or even sound feedback for all actions/interactions	Mi et al. (2014), Siebra et al. (2016; 2017; 2015)
R5	Users can stop feedback	Ghidini et al. (2016), Mi et al. (2014)
R6	Support for easy usage of multiple device platforms	Shin et al. (2017)
R7	The applications must support customisations and prevent adjustments in user-defined settings	Buzzi et al. (2012), Siebra et al. (2016; 2017; 2015)

(continued)

Req No.	Description	Source
R8	The interface elements presented are standard, reasonable, and suitable for the small screen on mobile devices	Buzzi et al. (2012), Di Gregorio et al. (2022), Lanyi (2017), Shin et al. (2017)
R9	The application supports various input methods such as voice commands	Di Gregorio et al. (2022), Ghidini et al. (2016), McNaught et al. (2010), Shin et al. (2017)
R10	The user interface should employ various gestures to perform actions instantly	Buzzi et al. (2012), Mi et al. (2014), Piccolo et al. (2011), Shin et al. (2017)
R11	Users can navigate book contents randomly (i.e., by using a table of content, page number, forward and backward, or navigation bar)	Leporini et al. (2012), Mune and Agee (2015), Pearson et al. (2010), Piccolo et al. (2011), Richardson Jr and Mahmood (2012)
R12	Consider physical access to main features such as play and pause TTS	Piccolo et al. (2011)
R13	Provide navigation via shortcuts to frequent functions	Lim et al. (2012), Shitkova et al. (2015), Siebra et al. (2015)
R14	Support for various e-book file formats (pdf, txt, word, ePub)	Junus (2012), Shin et al. (2017)
R15	Text and background attributes can be customised (i.e., size, colour, font type, line spacing)	Axtell et al. (2018), de Oliveira et al. (2018), Di Gregorio et al. (2022), Mune and Agee (2015), Shin et al. (2017), Siebra et al. (2017)
R16	Zooming/Magnification tools	Mune and Agee (2015), Rogers and Draffan (2016), Siebra et al. (2015; 2017)
R17	In the case of a locked screen or unintentional termination of the application, continuous reading is carried out	Shin et al. (2017)
R18	Adjustable brightness and contrast	McLaughlin and Kamei-Hannan (2018), Ribeiro et al. (2019), Rogers and Draffan (2016), Siebra et al. (2017)

(continued)

Req No.	Description	Source
R19	Support TTS	Attarwala et al. (2012), McNaught et al. (2010), Munteanu (2013)
R20	Users can adjust the setting of TTS to their preferences (voice, volume, speed)	Curts (2016), Power and Jürgensen (2010), Shin et al. (2017)
R21	Synchronisation of the highlighting of the words being read	Axtell et al. (2018), Biancarosa and Griffiths (2012), Epp et al. (2017), Munteanu (2013)
R22	Users can search book contents	Jardina & Chaparro (2015), Mune and Agee (2015), Richardson Jr and Mahmood (2012)
R23	Users can make annotations (take notes, highlight, or bookmark)	Jardina and Chaparro (2015), Mune and Agee (2015), Zhang et al. (2017)
R24	Users can view annotations easily	Jardina and Chaparro (2015), Pearson et al. (2010)

It is clear from Table 1 that the usability requirements for the e-book interface for visually impaired users are mainly related to the needs to access the application interface, control the appearance of e-book content in a way that is perceived by the visually impaired, simulate the process of reading in paper books, navigate the e-book content easily, and provide accessible features for reading purposes. Accessibility features, such as text enlargement, compatibility with a screen reader, TTS, and high contrast, are among the essential features. Besides, like any ordinary book reader, visually impaired users need to use functions that facilitate the reading process, such as navigation, annotations, and search. Therefore, designers should consider these requirements and provide clear spoken feedback for all interactions, as specific mobile applications might be inaccessible at the usage level due to poor design (Ballantyne et al., 2018). The study conducted an online survey with seven students from a local university to confirm or extend these requirements. The study administered the survey via email or WhatsApp to the students. The study wrote the questions in a Word document so that the participants could change the setting of the text to suit their vision needs, and it could also be read by screen reader applications. Table 2 summarises the demographics of the participants.

Table 1

Participants' Demographic

No.	Gender	Age	Type of Vision Impairments	Cause of Impairment
P1	Male	24	Low vision (Severe)	Optic nerve inflammation
P2	Female	25	Blind one eye	Not provided
P3	Male	23	Low vision (Moderate)	Since birth
P4	Male	21	Blind one eye	Since birth
P5	Female	23	Blind one eye	Incident from childhood
P6	Female	27	Blind	Since birth
P7	Male	22	Low vision (Severe)	Hereditary

Table 2 shows that the age of all the students ranged from 21 to 27 years old. Three of them were male, and four were female. One student was born blind, three had low vision, and three were blind in one eye. Three of these individuals had had the impairment since birth, while the others attributed it to various causes, such as optic nerve inflammation, hereditary, and childhood incidents. All these students used mobile devices and computers. The interviewees were asked to describe their general experiences and challenges with mobile applications and e-books. The study also used the WhatsApp application to survey a blind student online to learn more information. Table 3 demonstrates the significant requirements that the participants had identified.

Table 2

Accessible Mobile E-book Apps Usability Requirements Gathered from Online Survey

No.	Requirements	Participant No.
1	Compatible with the screen reader	P1, P6, and P7
2	Easy to navigate	P1 and P6
3	Easy to search for book content	P6
4	High brightness	P6, P1, and P7
5	High contrast	P1
6	High-quality sound	P2 and P3
7	Clear text	P5
8	Text enlargement	P1, P3, and P7
9	Text-to-Speech (TTS)	P1 and P7
10	Zooming	P3 and P7

Table 3 showed ten usability requirements from the online survey. Low-vision participants (participants with moderate vision impairments) made use of features like text enlargement and zooming (R 16) to use mobile applications and read the content (Rogers & Draffan, 2016; Siebra et al., 2017, 2015; Woodward, 2014). Furthermore, the TTS (R 19) feature that converted written words into spoken ones (participants with severe vision impairments) was valued (Mune & Agee, 2015). The participants declared the importance of the clear sound of the reading text (TTS), which made the text accessible and understandable for them (Curts, 2016). Reading comprehension was improved by controlling the properties of TTS in terms of sound, speed, and volume, where different people had different levels of vision impairments. Therefore, different settings were needed (R 20) (Power & Jürgensen, 2010; Shin et al., 2017). Likewise, low-vision participants claimed they used the high contrast and brightness feature for easier mobile phone use (R18) (McLaughlin & Kamei-Hannan, 2018; Ribeiro et al., 2019; Siebra et al., 2017). Compared to the moderate vision impairment users, the blind participant and severe vision users relied more on the screen reader strategy (R1, R2, R3) and valued the brightness adjustment feature since they could still perceive light (R18) (Hassouna et al., 2017; Khowaja et al., 2019; Siebra et al., 2017). Despite this, PDF readers still present some challenges due to their nature and limitations; for example, screen readers may render unsearchable text and unreadable images (R14, 22) (Junus, 2012; Shin et al., 2017). The ability to navigate the e-book content was also stressed by the participants, whereby sequence navigation might add more difficulties and waste users' time, especially those who use screen readers (R 11, 12, 13) (Mune & Agee, 2015; Shitkova et al., 2015; Siebra et al., 2015). A comparison (mapping) between the requirements collected from the survey and the literature review is presented in Table 4.

Table 3

Mapping the Requirements from Literature Review and Online Survey

Requirements from Online Survey	Requirements from LR
Compatible with the screen reader	**R1)** Compatible with screen reader **R2)** Provide a meaningful alternative description to non-text interface elements **R3)** When a character is tabbed, the application reads its name aloud
Easy to navigate	**R10)** The user interface should employ various gestures to perform actions instantly **R11)** Users can navigate book contents randomly (i.e., by using a table of content, page number, forward and backward, or navigation bar) **R12)** Consider physical access to main features such as play and pause TTS **R13)** Provide navigation via shortcuts to frequent functions **R24**) Users can view annotations easily
Easy to search for book content	**R22)** Users can search book contents
High brightness High contrast	**R18)** Adjustable brightness and contrast
High-quality sound	**R20)** Users can adjust the setting of TTS to their preferences (voice, volume, speed)
Clear text Text enlargement	**R15)** In the case of a locked screen or unintentional termination of the application, continuous reading is carried out
Text-to-Speech (TTS)	**R19)** Support TTS
Zooming	**R16)** Zooming/Magnification tools

Based on Table 4, 14 requirements from the literature review were supported by the findings from the online survey. In contrast, ten requirements were still not confirmed, namely R4, R5, R6, R7, R8, R9, R14, R17, R21, and R23. The study believed that the main reason was that the sample was small. There is also a need for other evaluation

methods that are more effective than the online interview, such as the lab-based usability test, think-aloud exercises, and observation techniques (Álvarez et al., 2017). These techniques will enable the discovery of a larger number of problems that are related to the presentation, organisation, and behavioural requirements (Shera et al., 2021). In addition, the study found that even though one-eye blindness is a visual impairment (Abdullah et al., 2017), the participants in this study considered themselves normal-sighted, and they did not experience any problems with mobile applications because of such impairments. They had developed specific skills despite only having one working eye since they were very young. However, the loss of one eye can interfere with tracking moving objects, accurately determining distances, and sensing depth. They must learn to actively acquire information with one eye and other senses (Whitaker, 2013). Therefore, the study did not recommend considering such types of vision impairments in future studies since the feedback gained in this study was minimal. Since accessibility requirements cover different types of vision impairments, this result makes sense. Accordingly, sufficient participants representing different levels of vision impairment are needed to validate the proposed requirements.

CONCLUSION

Mobile devices, coupled with ongoing technological advancements, have led to a growth in mobile applications, including e-books. Despite the importance of usability for smartphone design, few studies have examined how mobile applications are accessible. This research aimed to advance the state of the art for accessible e-book applications by providing a verified usability requirement list. An analysis of the literature was conducted to determine the usability requirements for accessible mobile e-book applications for the visually impaired. The findings of the study identified 24 usability requirements related to appropriate accessibility for mobile applications and e-books for users with vision impairments. Seven visually impaired individuals were interviewed to confirm or extend the requirements collected. According to the results, accessibility was perceived as necessary.

Nevertheless, confirming certain requirements was impossible due to the small sample size and the need for multiple evaluation methods. The identified challenges should guide future research on this topic.

More participants, face-to-face interviews, lab-based usability tests, a survey of mobile e-book developers on accessibility challenges, and an assessment of how accessible mobile e-book applications implemented the identified requirements may be included in future research to gain more insight. Finally, this study focused on the usability requirements of the e-book application in terms of interacting with the application for ease of use and access during reading. Therefore, further research can identify other requirements regarding user experience, which may include many aspects, such as the interaction requirements for usable and accessible e-book content and other requirements for using external assistive devices or the physical needs of the mobile device.

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REFERENCES

Abdullah, N., Hanafi, H., & Hamdi, N. I. M. (2017). The rights of persons with disabilities in Malaysia: The underlying reasons for ineffectiveness of Persons with Disabilities Act 2008. *International Journal for Studies on Children, Women, Elderly and Disabled*, *1*, 127–134.

Abuaddous, H. Y., Jali, M. Z., & Basir, N. (2017). Quantitative metric for ranking web accessibility barriers based on their severity. *Journal of Information and Communication Technology*, *16*(1), 81–102. https://e-journal.uum.edu.my/index.php/jict/article/view/8219

Al-Megren, S., & Almutairi, A. (2019). Analysis of user requirements for a mobile augmented reality application to support literacy development amongst hearing-impaired children. *Journal of Information and Communication Technology*, *18*(1), 97–121. https://doi.org/10.32890/jict2019.18.1.6

Al-Qatawneh, S., Alsalhi, N., Al Rawashdeh, A., Ismail, T., & Aljarrah, K. (2019). To e-textbook or not to e-textbook? A quantitative analysis of the extent of the use of e-textbooks at Ajman University from students' perspectives. *Education and Information Technologies*, *24*, 2997–3019. https://doi.org/https://doi.org/10.1007/s10639-019-09912-4

Alajarmeh, N. (2021). The extent of mobile accessibility coverage in WCAG 2.1: Sufficiency of success criteria and appropriateness of relevant conformance levels pertaining to accessibility problems encountered by users who are visually impaired. *Universal Access in the Information Society*, *21*(2), 507–532. https://doi.org/10.1007/s10209-020-00785-w

Álvarez, T., Rusu, C., Álvarez, F., Benítez-Guerrero, E., & Esparza, A. (2017, September). Applying usability evaluation methods with blind users: A systematic mapping study. In *Proceedings of the XVIII International Conference on Human Computer Interaction* (pp. 1–4). https://doi.org/10.1145/3123818.3123829

Arroba, P., Vallejo, J. C., Araujo, Á., Fraga, D., & Moya, J. M. (2011, June). A methodology for developing accessible mobile platforms over leading devices for visually impaired people. In *Third International Workshop on Ambient Assisted Living (IWAAL 2011)* (pp. 209–215). https://doi.org/10.1007/978-3-642-21303-8_29

Attarwala, A., Baecker, R. M., & Munteanu, C. (2012, October). Accessible, large-print, listening & talking e-book (ALIT). In *Proceedings of the Fifth ACM Workshop on Research Advances in Large Digital Book Repositories and Complementary Media* (pp. 19–20). https://doi.org/10.1145/2390116.2390129

Axtell, B., Munteanu, C., Demmans Epp, C., Aly, Y., & Rudzicz, F. (2018, March). Touch-supported voice recording to facilitate forced alignment of text and speech in an e-Reading interface. In *23rd International Conference on Intelligent User Interfaces* (pp. 129–140). https://doi.org/https://doi.org/10.1145/3172944.3172984

Baker-Eveleth, L., & Stone, R. W. (2015). Usability, expectation, confirmation, and continuance intentions to use electronic textbooks. *Behaviour & Information Technology*, *34*(10), 992–1004. https://doi.org/10.1080/0144929X.2015.1039061

Balajthy, E. (2005). Text-to-speech software for helping struggling readers. *Reading Online*, *8*(4), 1–9.

Ballantyne, M., Jha, A., Jacobsen, A., Scott Hawker, J., & El-Glaly, Y. N. (2018, November). Study of accessibility guidelines of mobile applications. In *ACM International Conference Proceeding Series* (pp. 305–315). https://doi.org/10.1145/3282894.3282921

Bartalesi, V., & Leporini, B. (2015, August). An enriched ePub eBook for screen reader users. In *International Conference on Universal Access in Human-Computer Interaction* (pp. 375–386). https://doi.org/10.1007/978-3-319-20678-3_36

Biancarosa, G., & Griffiths, G. G. (2012). Technology tools to support reading in the digital age. *The Future of Children*, *22*(2), 139–160. https://doi.org/10.1353/foc.2012.0014

Bonnici, L. J., Maatta, S. L., Brodsky, J., Elaine, J., & Steele, J. E. (2015). Second national accessibility survey: Librarians, patrons, and disabilities. *New Library World*, *116*(9/10), 503–516. https://doi.org/10.1108/NLW-03-2015-0021

Buzzi, M. C., Buzzi, M., & Leporini, B. (2012). Investigating mobile learning and accessibility for blind users. *Mobile Learning for Visually Impaired People*, 26–40.

ChanLin, L.-J. (2013). Reading strategy and the need of e-book features. *The Electronic Library*, *31*(3), 329–344. https://doi.org/10.1108/EL-08-2011-0127

Curts, E. (2016). *Three text to speech tools and 5 ways your students can use them*. Control Alt Achieve. https://www.controlaltachieve.com/2016/01/text-to-speech-extensions.html

de Oliveira, B., Braga, J. C., & Damaceno, R. J. P. (2018, April). Application for the configuration and adaptation of the Android operating system for the visually impaired. In *Proceedings of the Internet of Accessible Things* (pp. 1–4). https://doi.org/10.1145/3192714.3192838

Di Gregorio, M. (2021, October). Accessible applications-Study and design of user interfaces to support users with disabilities. In *Proceedings of the 2021 International Conference on Multimodal Interaction* (pp. 832–834). https://doi.org/10.1145/3462244.3481281

Di Gregorio, M., Di Nucci, D., Palomba, F., & Vitiello, G. (2022). The making of accessible android applications: An empirical study on the state of the practice. *Empirical Software Engineering*, *27*(6), 1–37. https://doi.org/10.1007/s10664-022-10182-x

Epp, C. D., Munteanu, C., Axtell, B., Ravinthiran, K., Aly, Y., & Mansimov, E. (2017, September). Finger tracking: Facilitating non-commercial content production for mobile e-reading applications. In *Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services* (pp. 1–15). https://doi.org/10.1145/3098279.3098556

Fahmy, S., Haslinda, N., Roslina, W., & Fariha, Z. (2012). Evaluating the quality of software in e-book using the ISO 9126 model. *International Journal of Control and Automation*, *5*(2), 115–122.

Ghidini, E., Almeida, W. D. L., Manssour, I. H., & Silveira, M. S. (2016, January). Developing apps for visually impaired

people: Lessons learned from practice. In *2016 49th Hawaii International Conference on System Sciences (HICSS)* (pp. 5691–5700). https://doi.org/10.1109/HICSS.2016.704

Hassouna, M. S., Sahari, N., & Ismail, A. (2017). University website accessibility for totally blind users. *Journal of Information and Communication Technology*, *16*(1), 63–80. https://e-journal.uum.edu.my/index.php/jict/article/view/8218

IBM. (2019). *IBM accessibility checklist:Version 7.1*. IBM. https://www.ibm.com/able/guidelines/ci162/accessibility_checklist.html

Jardina, J. R., & Chaparro, B. S. (2015). Investigating the usability of e-textbooks using the technique for human error assessment. *JUS Journal of Usability Studies*, *10*(4), 140–159.

Junus, S. R. (2012). E-books and e-readers for users with print disabilities. *Journal of Usability Studies*, *48*(7), 25–38. https://doi.org/10.5860/ltr.48n7

Kane, S., Wobbrock, J., & Ladner, R. (2011, May). Usable gestures for blind people: Understanding preference and performance. In *Proceedings of the 2011 Annual Conference on Human Factors in Computing Systems - CHI '11* (pp. 413–422). https://doi.org/10.1145/1978942.1979001

Khan, A., & Khusro, S. (2020). An insight into smartphone-based assistive solutions for visually impaired and blind people: issues, challenges and opportunities. *Universal Access in the Information Society*, 1–34. https://doi.org/10.1007/s10209-020-00733-8

Khowaja, K., Al-Thani, D., Aqle, A., & Banire, B. (2019, July). Accessibility or usability of the user interfaces for visually impaired users? A comparative study. In *International Conference on Human-Computer Interaction* (pp. 268–283). https://doi.org/10.1007/978-3-030-23560-4_20

Khowaja, S., & Fatima, N. (2019). Awareness and use of electronic resources by visually impaired students at Aligarh Muslim University, Aligarh: A study. In *CALIBER 2019* (pp. 1–15). INFLIBNET Centre.

Kim, H. K., Han, S. H., Park, J., & Park, J. (2016). The interaction experiences of visually impaired people with assistive technology: A case study of smartphones. *International Journal of Industrial Ergonomics*, *55*, 22–33. https://doi.org/10.1016/j.ergon.2016.07.002

Lanyi, C. S. (2017). Choosing effective colours for websites. In *Colour design* (pp. 619–640). Elsevier. https://doi.org/10.1533/9780857095534.4.600

Lazar, J., Goldstein, D. F., & Taylor, A. (2015). Introduction to accessible technology. In *Ensuring digital accessibility through process and policy* (pp. 1–19). Morgan Kaufmann.

Leporini, B., Buzzi, M. C., & Buzzi, M. (2012, November). Interacting with mobile devices via VoiceOver: Usability and accessibility issues. In *Proceedings of the 24th Australian Computer-Human Interaction Conference* (pp. 339–348). https://doi.org/10.1145/2414536.2414591

Lim, C., Song, H.-D., & Lee, Y. (2012). Improving the usability of the user interface for a digital textbook platform for elementary-school students. *Educational Technology Research and Development*, *60*(1), 159–173. https://doi.org/10.1007/s11423-011-9222-5

Maatta, S. L., & Bonnici, L. J. (2014). An evaluation of the functionality and accessibility of e-readers for individuals with print disabilities. *The Electronic Library*, *32*(4), 493–507. https://doi.org/10.1108/EL-01-2013-0012

McGookin, D., Brewster, S., & Jiang, W. (2008, October). Investigating touchscreen accessibility for people with visual impairments. In *Proceedings of the 5th Nordic Conference on Human-Computer Interaction: Building Bridges* (pp. 298–307). https://doi.org/10.1145/1463160.1463193

McLaughlin, R., & Kamei-Hannan, C. (2018). Paper or digital text: Which reading medium is best for students with visual impairments? *Journal of Visual Impairment & Blindness*, *112*(4), 337–350. https://doi.org/10.1177/0145482X1811200401

McNaught, A., Evans, S., & Ball, S. (2010, July). E-books and inclusion: Dream come true or nightmare unending? In *International Conference on Computers for Handicapped Persons* (pp. 74–77). https://doi.org/10.1007/978-3-642-14097-6_13

Mei Kodama, E. I., Watanabe, Y., & Tomiura, Y. (2021). Usage of e-books during the COVID-19 pandemic: A case study of Kyushu University Library, Japan. *Diversity, Divergence, Dialogue*, *12646*, 475. https://doi.org/10.1007/978-3-030-71305-8_40

Mi, N., Cavuoto, L. A., Benson, K., Smith-Jackson, T., & Nussbaum, M. A. (2014). A heuristic checklist for an accessible smartphone

interface design. *Universal Access in the Information Society*, *13*(4), 351–365. https://doi.org/10.1007/s10209-013-0321-4

Minatani, K. (2017, July). A proposal for improvement of usability of browsing and playback systems for DAISY and ePUB: Using web technology to make accessible content more user-friendly. In *Proceedings of the 11th International Convention on Rehabilitation Engineering and Assistive Technology* (pp. 1–4).

Mune, C., & Agee, A. (2015, June). Ebook showdown: Evaluating academic ebook platforms from a user perspective. In *Creating Sustainable Community: The Proceedings of the ACRL 2015 Conference* (218–224).

Munteanu, C. (2013, August). An accessible, large print, listening and talking e-book to support families reading together. In *Proceedings of the 15th International Conference on Human-Computer Interaction with Mobile Devices and Services* (pp. 440–443). https://doi.org/10.1145/2493190.2494658

Nathan, S. S. (2017). *A usability evaluation model for hearing impaired mobile applications interfaces*. Universiti Utara Malaysia.

Nathan, S. S., Hussain, A., & Hashim, N. L. (2016). Studies on deaf mobile application: Need for functionalities and requirements. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, *8*(8), 47–50.

Patel, H., & Morreale, P. (2014). Education and learning: Electronic books or traditional printed books? *Journal of Computing Sciences in Colleges*, *29*(3), 21–28.

Pearson, J., Buchanan, G., & Thimbleby, H. (2010, October). HCI design principles for ereaders. In *Proceedings of the Third Workshop on Research Advances in Large Digital Book Repositories and Complementary Media - BooksOnline '10* (pp. 15–24). https://doi.org/10.1145/1871854.1871860

Pernice, K., Nielsen, J., Farrell, S., Mizobuchi, S., Ishida, N., Stover, U. A., Yohay, M., Franko, E., & Richardson, A. (2001). Usability guidelines for accessible web design. In *Evidence-based user experience research, training, consulting*.

Piccolo, L. S. G., De Menezes, E. M., & De Campos Buccolo, B. (2011, October). Developing an accessible interaction model for touch screen mobile devices: Preliminary results. In *Proceedings of the 10th Brazilian Symposium on Human Factors in Computing Systems and the 5th Latin American Conference on Human-Computer Interaction* (pp. 222–226).

Power, C., Freire, A., Petrie, H., & Swallow, D. (2012, May). Guidelines are only half of the story: Accessibility problems encountered by blind users on the web. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (433–442). https://doi.org/10.1145/2207676.2207736

Power, C., & Jürgensen, H. (2010). Accessible presentation of information for people with visual disabilities. *Universal Access in the Information Society*, *9*(2), 97–119. https://doi.org/10.1007/s10209-009-0164-1

Ribeiro, B., Pellegrini, F., Anjos, M., Florentin, F., Alves, V., Zandona, D., Levrero, T., Correia, W., Quintino, J., & Macêdo, J. (2019). Disabled user role on mobile accessible application development. In *International Conference on Applied Human Factors and Ergonomics* (pp. 250–259). https://doi.org/10.1007/978-3-030-19135-1_25

Richardson Jr, J. V., & Mahmood, K. (2012). eBook readers: User satisfaction and usability issues. *Library Hi Tech*, *30*(1), 170–185.

Rogers, N., & Draffan, E. A. (2016, April). Evaluating the mobile web accessibility of electronic text for print impaired people in higher education. In *Proceedings of the 13th Web for All Conference* (pp. 26–27). https://doi.org/10.1145/2899475.2899504

Saunders, M. (2012). Choosing research participants. In C. Cassel, & G. Symon (Eds.), *Qualitative organizational research: Core methods and current challenges* (pp. 35–52). https://books.google.com.my/books?hl=ar&lr=&id=RDWu5-gb7JEC&oi=fnd&pg=PA35&ots=dOpPkRpMc3&sig=_IW0E70HvGWqqgNEo3x505vkMmA&redir_esc=y#v=onepage&q&f=false

Saunders, M., Lewis, P., & Thornhill, A. (2009). Research methods for business students. In *Research methods for business students* (Fifth ed.). Prentice Hall.

Senjam, S. S. (2021). Smartphones for vision rehabilitation: Accessible features and apps, opportunity, challenges, and usability evaluation. In *Software Usability* (pp. 1–18). IntechOpen. https://www.intechopen.com/chapters/76654

Senjam, S. S., Manna, S., & Bascaran, C. (2021). Smartphones-based assistive technology: Accessibility features and apps for people with visual impairment, and its usage, challenges, and usability testing. *Clinical Optometry*, *13*(November), 311–322. https://doi.org/10.2147/OPTO.S352181

Shera, A., Iqbal, M. W., Shahzad, S. K., Gul, M., Mian, N. A., Naqvi, M. R., & Khan, B. A. (2021). Blind and visually impaired

user interface to solve aAccessibility problems. *Intelligent Automation and Soft Computing*, *30*(1), 285–301. https://doi.org/10.32604/iasc.2021.018009

Shin, H., Gil, Y.-H., Yu, C., Kim, H.-K., Lee, J., & Jee, H.-K. (2017). Improved and accessible e-book reader application for visually impaired people. In *ACM SIGGRAPH Asia 2017 Posters* (pp. 1–2). https://doi.org/10.1145/3145690.3145748

Shitkova, M., Holler, J., Heide, T., Clever, N., & Becker, J. (2015, March). Towards usability guidelines for mobile websites and applications. In *Proceedings of the 12th International Conference on Wirtschaftsinformatik, Osnabrück, Germany* (p. 107).

Siebra, C., Correia, W., Penha, M., Macêdo, J., Quintino, J., Anjos, M., Florentin, F., Silva, F. Q. B., & Santos, A. L. M. (2018, September). An analysis on tools for accessibility evaluation in mobile applications. In *Proceedings of the XXXII Brazilian Symposium on Software Engineering* (pp. 172–177). https://doi.org/10.1145/3266237.3266238

Siebra, C., Gouveia, T. B., Macedo, J., da Silva, F. Q. B., Santos, A. L. M., Correia, W., Penha, M., Anjos, M., & Florentin, F. (2017, January). Toward accessibility with usability: Understanding the requirements of impaired uses in the mobile context. In *Proceedings of the 11th International Conference on Ubiquitous Information Management and Communication* (pp. 1–8). https://doi.org/10.1145/3022227.3022233

Siebra, C., Gouveia, T., Macedo, J., Correia, W., Penha, M., Anjos, M., Florentin, F., Silva, F. Q. B., & Santos, A. L. M. (2016, September). Observation based analysis on the use of mobile applications for visually impaired users. In *Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct* (pp. 807–814). https://doi.org/10.1145/2957265.2961848

Siebra, C., Gouveia, T., Macedo, J., Correia, W., Penha, M., Silva, F., Santos, A., Anjos, M., & Florentin, F. (2015, November). Usability requirements for mobile accessibility: A study on the vision impairment. In *Proceedings of the 14th International Conference on Mobile and Ubiquitous Multimedia* (pp. 384–389). https://doi.org/10.1145/2836041.2841213

Southwell, K. L., & Slater, J. (2012). Accessibility of digital special collections using screen readers. *Library Hi Tech*, *30*(3), 457–471. https://doi.org/10.1108/07378831211266609

Sulaiman, W. N. A. W., & Mustafa, S. E. (2020). Usability elements in digital textbook development: A systematic review. *Publishing Research Quarterly*, 1–28. https://doi.org/10.1007/s12109-019-09675-3

Texas School for the Blind and Visually Impaired. (n.d.). *Accessibility of information in electronic textbooks for students who are blind or visually impaired*. Texas School for the Blind and Visually Impaired. Retrieved August 14, 2018, from http://www.tsbvi.edu/accessibility-items/1185-accessibility-of-information-in-electronic-textbooks-for-students-who-are-blind-or-visually-impaired#_1_8

Vigo, M., & Brajnik, G. (2011). Automatic web accessibility metrics: Where we are and where we can go. *Interacting with Computers*, *23*(2), 137–155. https://doi.org/10.1016/j.intcom.2011.01.001

W3C. (2017). *Accessible rich internet applications (WAI-ARIA) 1.1*. W3C. https://www.w3.org/TR/wai-aria/#dfn-accessibility-api

W3C. (2018). *Web content accessibility guidelines (WCAG) overview*. W3C. https://www.w3.org/WAI/standards-guidelines/wcag/

Walton, R., & Hailey, D. (2015). Evaluating the relevance of eBooks to corporate communication. *Communication Design Quarterly*, *3*(3), 12–19. https://doi.org/10.1145/2792989.2792991

Whitaker, D. (2013). *Learning to live with one eye*. DukeHealth. https://www.dukehealth.org/blog/learning-live-one-eye

WHO. (2021). *Blindness and vision impairment*. World Health Organization. http://www.who.int/en/news-room/fact-sheets/detail/blindness-and-visual-impairment

Wohlin, C. (2014, May). Guidelines for snowballing in systematic literature studies and a replication in software engineering. In *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering*, 1–10. https://doi.org/10.1145/2601248.2601268

Woodward, H. (2014). Ebooks and accessibility. In *Ebooks in education: Realising the vision* (pp. 35–49). Ubiquity Press. https://doi.org/http://dx.doi.org/10.5334/bal.e

Yan, S., & Ramachandran, P. G. (2019). The current status of accessibility in mobile apps. *ACM Transactions on Accessible Computing (TACCESS)*, *12*(1), 1–31. https://doi.org/10.1145/3300176

Zachariah, B., & Nonyelum, O. F. (2020). A comparative analysis of requirement gathering techniques. *IUP Journal of Computer Sciences*, *14*(2), 7–32.

Zeng, Y., Bai, X., Xu, J., & He, C. G. H. (2016). The influence of e-book format and reading device on users' reading experience: A case study of graduate students. *Publishing Research Quarterly*, *32*(4), 319–330. https://doi.org/10.1007/s12109-016-9472-5

Zhang, T., Niu, X., & Promann, M. (2017). Assessing the user experience of e-books in academic libraries. *College & Research Libraries*, *78*(5), 578–601. https://doi.org/10.5860/crl.78.5.578