A Review on Usability Requirements of Visually Impaired Users for Accessible E-book Applications

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ABSTRACT

An e-book is basically a book in electronic or digital format that is significant and beneficial for readers who cannot access print books, such as the visually impaired. An accessible e-book is one that allows the visually impaired to use it and achieve the same intended benefits as those who are normal. However, current e-book applications are not practical for users with vision disabilities. With the increased demand for e-books, it becomes even more important to design usable and accessible e-book interfaces for users with vision impairments. This paper hence aims to conduct a review on the usability requirements of accessible e-book applications for the visually impaired. For this purpose, the authors applied an intensive review of current works from 2010 to 2020 that focus on the development and evaluation of e-book usability and accessibility. This study also reviewed general accessibility requirements and guidelines for mobile applications. In total, 24 usability requirements were identified. As the main purpose of the usability evaluation is to determine whether the users' needs are met, and to identify the needs of the visually impaired that can guarantee that those needs are introduced into their e-book applications.

Keywords: Accessibility, visually impaired, e-book applications, usability requirements.

I   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). E-books are progressively used on mobile gadgets. This is mainly significant and beneficial for readers who cannot access print books, such as the visually impaired (Patel & Morreale, 2014). Concerns about easy access to digital resources for the visually impaired must be acknowledged and designers and evaluators must understand that accessibility does not routinely involve usability and vice versa (Khan & Khusro, 2020; Kleynhans & Fourie, 2014). However countless users with vision disabilities found mobile applications as inaccessible (Khan & Khusro, 2020; Mi et al., 2014). Moreover, the National Federation of the Blind (NFB) claimed that many e-books do not meet the requirements of visually impaired users. As a result, equitable access to digital resources for the visually impaired is still limited (Bartalesi & Leporini, 2015; Khowaja & Fatima, 2019; Kleynhans & Fourie, 2014).

Requirements are features or behaviours of a system as perceived by one or more stakeholders (Zachariah & Nonyelum, 2020). Identifying the requirements for the visually impaired to make an application more accessible and usable is essential and must begin at an initial stage of application development to guarantee benefits of the developed application and its continuous usage (Nathan et al., 2016). An evaluation plays a critical role in addressing usability problems and user needs. However, current usability evaluation models for e-books do not address accessibility issues for the visually impaired (Baker-Eveleth & Stone, 2015; Haslinda et al., 2014; Wang & Huang, 2015) and only suggested limited measurements on accessibility such as alternative text for non-text elements, change text size, and screen readers compatibility (Axtell et al., 2018; Bartalesi & Leporini, 2015; Minatani, 2017; Rogers & Draffan, 2016). However, these measurements are still not sufficient in offering a satisfying experience of a usable application for the visually impaired (Siebra et al., 2018).

The goal of this article is to review the usability requirements of visually impaired users for accessible e-book applications by conducting a literature review (LR). Literature that focuses on examining and developing e-books that reflects the perspective of visually disabled people are carefully reviewed to define the requirements. Besides that, the study also reviewed the current guidelines and requirements for general mobile applications to address the requirements more deeply. This paper consists of several sections. The first section presents a brief introduction. The second section covers the review of previous works, and the third section presents the methodology. The final section covers the discussion and conclusion.

II   LITERATURE REVIEW

According to Henry (2018), "accessibility means that people with disabilities can perceive, understand, navigate, and interact with the Web and that they can

contribute to the Web. Web accessibility also benefits others, including older people with changing abilities due to aging". Guidelines on accessibility for people with disabilities and the elderly are available for several types of 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, a set of 75 guidelines for web accessibility were proposed by Pernice et al. (2001). Many of these guidelines would make the designs accessible to everyone. However, the most important accessibility guidelines are related to the design (Pernice et al., 2001). A good design usually helps sighted users to increase their efficiency and complete tasks faster; but for visually impaired users, a good design is essential to make task accomplishment possible (Pernice et al., 2001). The following sub-sections will discuss the usability requirements.

A. Usability Requirements and Guidelines for Accessible Mobile Applications

With the growing adoption of mobile devices by the visually impaired, it is important to develop solutions and applications for this audience (Ghidini et al., 2016). Most of the solutions found in literature enable accessible interactions by accepting gestures as inputs and providing speeches, audios, and regular tactical feedbacks as outputs (Piccolo et al., 2011; Power & Jürgensen, 2010). In terms of gestures for touch screens, the study by McGookin et al. (2008) proposed general design guidelines to improve the accessibility of the interfaces for the visually impaired. Based on participatory interviews, the study by Kane et al. (2011) proposed a set of accessibility guidelines for touchscreen-based applications for both blind and sighted users. However, it focused only on a common situation associated with selecting gesturing design for visually disabled people (Siebra et al., 2016). Another study by 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. Mi et al. (2014) designed a general heuristic checklist for accessible smartphone devices; however, this study did not classify type of disabilities to better frame their requirements (Siebra et al., 2016). To address these limitations of the previous study, Siebra et al. (2017) identified requirements that are associated with various category 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 are classified into three: six requirements for blind users, six requirements for low/limited vision users, and one requirement 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 observation analysis.

Based on the findings of Kim et al. (2016) who examined the interactions of camera-based mobile applications, creation of accessible applications for the visually impaired can be achieved by providing a simplified structure, maintaining consistent user interface layouts, and increasing configurable settings. Ghidini et al. (2016) studied approaches of interaction that could be used easily by visually impaired users. The outcomes indicated that mobile devices, particularly smartphones, must deliver proper feedbacks, a simple design for simple interaction, and the capability to find the options and features of the application.

B. Usability Requirements of the Visually Impaired for Accessible E-Book Applications

An accessible e-book for a visually impaired user is one that allows them to use the e-book and achieve equal benefits as an individual with normal vision with approximately the same amount of effort (Texas School for the Blind and Visually Impaired, n.d.). Therefore, e-book application interfaces should be designed carefully to allow the screen reader software to read each element a user may interact with, such as menu and icons (Ghidini et al., 2016). Each interface element must include a brief description (accessible name) to be read aloud by screen readers (Ghidini et al., 2016; W3C, 2017).

Another important requirement is an accessible format. Screen readers will not function and read e-contents correctly if the format is not accessible (Axtell et al., 2018; Bonnici et al., 2015; Maatta & Bonnici, 2014). There are dual basic formats for e-

books: fixed layout such as PDF files, and fluid format as in ePub, MOBI, and IBA (Walton & Hailey, 2015). Nevertheless, fluid format is best suited for handheld devices (Zeng et al., 2016) and even more accessible for visually impaired users (Axtell et al., 2018; Bartalesi & Leporini, 2015). Still, there are concerns related to the accessibility of contents such as pictures devoid of descriptive text, and inaccessible PDFs (Axtell et al., 2018; Southwell & Slater, 2012). Also, if the content is not correctly marked up, the e-book remains unavailable (Lazar et al., 2015).

Numerous applications provide Text-to-Speech (TTS) which addresses the accessibility limitations of written books (Attarwala et al., 2012; Munteanu, 2013). TTS improves comprehension especially for struggling readers such as the visually impaired (Balajthy, 2005). However, TTS is a computer-based speech and at times difficult to understand (Axtell et al., 2018). Therefore, many settings associated with TTS have been introduced to increase its benefits. One of them is the synchronization of the highlighting of words being read which helps in improving focus and comprehension (Balajthy, 2005; Biancarosa & Griffiths, 2012). Other features such as TTS voice speed and volume adjustments are also important because different users have different levels of listening ability that affects their comprehension (Curts, 2016; Power & Jürgensen, 2010). In addition, these TTS settings are frequently used by the visually impaired specifically voice pitch (45%), speed (75%), and volume (70%) (Shin et al., 2017). Furthermore, the customization of TTS voice (such as male or female voice) must be available to suit preferences of the visually impaired users (Power & Jürgensen, 2010).

Likewise, many accessibility features are required in order to produce accessible e-book applications for the visually impaired. Examples of such functions are text enlargement, user selection of various attributes such as text and background, colour contrast, and support for different input techniques such as voice commands (Axtell et al., 2018; Minatani, 2017). Besides the ability to access electronic contents, a user should also be able to use the interfaces which provide information with minimum effort (Southwell & Slater, 2012). Therefore, a good design is represented by a user-friendly navigation design which makes the application easier to use by the visually impaired particularly for learning (Minatani, 2017; Shin et al., 2017; Southwell & Slater, 2012). Though e-books exist in more accessible formats, this alone does not ensure that it is easy to use in supporting learning. Learners must be able to read in a sequential manner and to move instantly over the content, along with the ability to 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 printed books (ChanLin, 2013).

From the above two subsections, it is revealed that several studies had proposed usability requirements for accessible mobile applications and declared them in terms of checklists, classifications, and guidelines. Unfortunately, e-book studies did not thoroughly identify the usability requirements for accessible mobile e-book applications.

III METHODOLOGY

Identifying user requirements is very important as they are critical in ascertaining user interface usability satisfaction for any application. This study aims to review the usability requirements of accessible e-book applications designed for the visually impaired. For this purpose, the authors applied a literature review approach on current works from 2010 to 2020 in the domain of development and evaluation of the usability and accessibility of e-books. The study also reviewed general accessibility requirements and guidelines for mobile applications. The authors searched the Association for Computing Machinery (ACM) Digital Library, Scopus, Science Direct, and Google Research Databases to find the relevant papers. The authors also used the snowball method to identify additional papers from existing articles reference list (Wohlin, 2014).

This intention was accomplished by compiling a list of mobile usability guidelines and requirements for mobile application and e-book application user interface. The study excludes any requirements of mobile as a device and any requirements related to operating systems as the scope of this study is only on application interfaces. Besides that, there are many assistive technology hardware solutions available for visually impaired users such as Braille Keypads and Braille Displays. However, their usage is not common mostly because of their costs (Siebra et al., 2017). Therefore, this study excludes any requirements that depend on such external devices.

IV RESULTS AND DISCUSSION

Applications that are not available or only partially accessible are an obstacle to users (Ballantyne et al., 2018). Visually impaired users depend on the power of information, communication, and technology (ICT) software to interact with digital interfaces (Southwell & Slater, 2012). E-books as ICT software offer a new chance for learning for the visually impaired. Addressing the requirements of the visually impaired for a usable and accessible e-book application is essential. Based on the reviewed literature, this study identified 24 usability requirements. Table 1 summarizes these requirements.

Table 1: The Usability Requirements of Visually Impaired Users for Accessible E-Book Applications

	Description	Source
R1	Interface elements can be read aloud by screen readers when touched	(Mi et al., 2014; Power & Jürgensen, 2010; Siebra et al., 2016, 2017, 2015; Woodward, 2014)
R2	Accessible e-book content	(Mi et al., 2014; Power & Jürgensen, 2010; Siebra et al., 2016, 2017, 2015)
R3	Provision of a clear spoken, haptic, or even sound feedback for all actions/interactions	(Arroba et al., 2011; Mi et al., 2014; Power & Jürgensen, 2010; Siebra et al., 2016, 2017, 2015)
R4	The application reads aloud the name of a character that is being tabbed	(Mi et al., 2014; Siebra et al., 2016, 2015, 2017)
R5	Users can select various attributes of text and background (i.e. size, colour, font type, line spacing, etc)	(Axtell et al., 2018; Crossland et al., 2014; de Oliveira et al., 2018; Minatani, 2017; Mune & Agee, 2015; Shin et al., 2017; Siebra et al., 2016, 2017, 2015)
R6	The applications must support customizations and prevent adjustments in user-defined settings.	(Buzzi et al., 2012; Siebra et al., 2016, 2017, 2015)
R7	Text enlargement/ Zooming	(Crossland et al., 2014; Kleynhans & Fourie, 2014; Mune & Agee, 2015; Rogers & Draffan, 2016; Siebra et al., 2017, 2015; Woodward, 2014)
R8	Provide meaningful alternative description to interface elements and images	(Buzzi et al., 2012; Lenzi et al., 2013; Power & Jürgensen, 2010; Siebra et al., 2016, 2017, 2015)
R9	Adjustable brightness/contrast/colour controls	(McLaughlin & Kamei-Hannan, 2018; Ribeiro et al., 2019; Rogers & Draffan, 2016; Siebra et al., 2016, 2017, 2015; Woodward, 2014)
R10	Support TTS	(Attarwala et al., 2012; McNaught et al., 2010; Munteanu, 2013)
R11	Users can adjust the setting of TTS to his preferences (voice, volume, speed)	(Curts, 2016; Power & Jürgensen, 2010; Shin et al., 2017)
R12	Synchronization of the highlighting of the words being read	(Axtell et al., 2018; Biancarosa & Griffiths, 2012; Epp et al., 2017; Munteanu, 2013)
R13	The application supports various input methods such as voice commands	(Ghidini et al., 2016; McNaught et al., 2010; Shin et al., 2017)
R14	The interface layout is perceivable and out of clutter (i.e., the interface elements presented are standard, reasonable, and suitable for the small screen on mobile devices)	(Buzzi et al., 2012)
R15	Does not include any information that relies exclusively on the use of colour and uses high contrast	(Lanyi, 2017; Power & Jürgensen, 2010; Siebra et al., 2015, 2017, 2016)
R16	Users can stop feedbacks	(Ghidini et al., 2016; Mi et al., 2014)
R17	The application interface employs intuitive gesture. The user interface should employ various gestures to instantly perform actions, for example, investigate or start screen items.	(Arroba et al., 2011; Buzzi et al., 2012; Kane et al., 2011; Mi et al., 2014; Piccolo et al., 2011)
R18	Users can navigate book contents randomly (i.e., by using table of content, page number, forward and backward, or navigation bar)	(Leporini et al., 2012; Mune & Agee, 2015; Pearson et al., 2010; Richardson Jr & Mahmood, 2012)
R19	Users can search book contents	(Jardina & Chaparro, 2015; Mune & Agee, 2015; Richardson Jr & Mahmood, 2012)
R20	Users can make annotations (take note, highlight, or bookmark)	(Jardina & Chaparro, 2015; Mune & Agee, 2015; Zhang et al., 2017)
R21	Users can select texts	(McNaught et al., 2010; Richardson Jr & Mahmood, 2012)
R22	Users can translate selected texts at their fingertips	(Mune & Agee, 2015; Richardson Jr & Mahmood, 2012)
R23	Users can delete annotations	(Liesaputra & Witten, 2012; Pearson et al., 2010)
R24	Users can view annotations easily	(Jardina & 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 need to access both the application interface and book content. Accessibility features such as text enlargement, compatibility with a screen reader, and high contrast are among the most important features. Besides that, visually impaired users as any normal book readers need to use functions that facilitate the reading process such as navigation, annotations, and search. Therefore, designers should take these requirements into account and provide clear spoken feedbacks for all interactions as certain mobile applications might be inaccessible at the usage level due to poor design (Ballantyne et al., 2018).

V CONCLUSION

This paper aims to reassess the requirements for usable and accessible mobile e-book applications for visually impaired users that are frequently overlooked by developers. This paper contributes by providing a list of usability requirements in designing accessible mobile e-books for visually impaired readers. However, the proposed list of requirements still needs to be validated i.e. a task that can be undertaken in future studies involving visually impaired users or expert reviews.

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