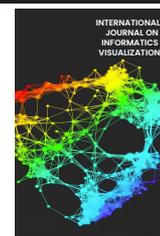




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## Identifying the Requirements of Visually Impaired Users for Accessible Mobile E-book Applications

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**Abstract**— Books are a medium for communicating information and in recent years have taken the electronic form called e-books. This shift has opened new opportunities for the visually impaired in overcoming their struggles with books in the traditional paper format. Yet, the National Federation of the Blind (NFB) claimed that many e-book applications do not meet needs of the visually impaired. Very few studies had investigated this subject matter hence paving the way for this current study to address the above research gap. As a result, equitable access to e-books for the visually impaired is still limited. Hence, there is now a necessity to design usable and accessible e-book interfaces for the visually impaired. To achieve this goal, it is important to identify the e-book requirements of the visually impaired into their e-book applications. An online survey was conducted involving seven visually impaired students at a local Malaysian university. The target participants' ages are between 21 and 27 years old. The outcomes of this study identified ten requirements for accessible e-book applications for the visually impaired. Among these requirements are features that enable users to zoom, read aloud, and search for book contents. Besides that, screen reader strategy and text-to-speech are also mandatory. Other requirements include clear text and sound, ease of navigation, high contrast, and high brightness. These requirements will involve the field of Human-Computer Interaction design which is applied particularly in the development of usable and accessible mobile e-book applications for the visually impaired.

**Keywords**— Accessible; e-book; requirements; visually impaired.

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### I. INTRODUCTION

An accessible electronic book (e-book) allows the visually impaired to read the book and achieve the same intended benefits as normal sighted people with approximately the equal amount of effort [1] (Texas School for the Blind and Visually Impaired, n.d.). E-books are progressively being used on mobile devices, which significantly benefits those with visual impairments [2]. There are multiple definitions for the disability term that covers several types of impairments. The disability may be presented since childbirth or may have occurred during a person's lifetime. The United Nations Convention on the Rights of Persons with Disabilities (UNCRPD) defines persons with disabilities as cited in [3] as: "Those who have long-term physical, mental, intellectual or sensory impairments which in interaction with various barriers may hinder their full and effective participations in society on an equal basis with others" (p.1). Many people with disabilities are excluded from normal daily life activities. Following the enforcement

of the UNCRPD's definition, disability is now increasingly understood as a matter of human rights. With increasing evidence, disability is also an important development issue, whereby people with disabilities experience more poverty and lower socio-economic outcomes as compared to people without disabilities [4]. In the world of Human-Computer Interaction (HCI), disabilities are often divided into three categories: perceptual disabilities (hearing and vision impairments), physical disabilities (limited use of the hands, arms, and speech) and cognitive impairments [5]. These categories are built on functional requirements related to computer outputs and inputs, whereby individuals with perceptual impairments will be affected by computer outputs and those with physical impairments will be affected by computer inputs [5]. With the different types of disabilities, there are certainly different needs for each type.

This study focuses on the requirements of the visually impaired in accessing and using e-book applications as they must be able to navigate and use e-books in a manner equal to sighted people [6]. Mobile devices and e-book reading

devices are used by the visually impaired to access the Internet and read electronic books [7]. E-books offer better features than Braille books and large-print books, which lack literature and are bulky [8],[9],[10]. Nevertheless, the National Federation of the Blind (NFB) claimed that many e-books do not meet the needs of the visually impaired. Equitable access to digital resources for the visually impaired is still limited and complicated [11],[12],[13]. Therefore, there is a need to deeply understand and gather the requirements of the visually impaired before attempting to design any mobile applications for them. Requirement gathering is a method used to discover the requirements, i.e., features or behaviours of the system by one or more stakeholders [14]. Unfortunately, few existing e-book studies did not consider gathering the requirements of the visually impaired nor examining them during evaluation. Therefore, by means of an online survey, this study aims to identify the main needs of the visually impaired in accessing and reading e-books.

The term “visually impaired” has been used in the literature to identify people with vision impairments. There are many different terms used to describe people with vision problems including visually disabled, blind, partially paired sighted, and non-sighted [13]. Visual impairment is a general term that is widely used to describe patients who have trouble seeing regardless of the severity of the impairment [12]. Vision impairment is classified by The International Classification of Diseases 11 (2018) as either distance or near vision impairment. Distance vision impairment is categorized as mild, moderate, severe, and blindness. Near vision impairment represents near visual acuity that is worse than N6 or M.08 in the near eye chart with existing correction [15]. Moderate vision impairment combined with severe vision impairment are grouped under the term “low vision”. Low vision taken together with blindness represents all vision impairments [16],[13]. Low vision people have visual acuity in the range of less than 6/18 and greater than or equal to 3/60 [17]. Blind people have a visual acuity that falls in the range of less than 3/60 to no light perception. People with a visual field of less than 10° are classified as blind, even if the central acuity is not impaired [13]. Visual field is the area from which one can perceive visual information when one’s eyes is in a standing position and is looking straight at an object [18]. According to [4] there are more than two billion people with vision impairment, whereby 36 million are blind and the rest have low vision [15],[16]. Internationally, the main reasons for vision loss are uncorrected refractive errors, cataract, diabetic retinopathy, age-related macular degeneration, glaucoma, corneal opacity, and trachoma [19],[17].

Visually impaired individuals rely on assistive technology (AT), which has aided learning for many people with several types of impairments [20],[21]. According to the Assistive Technology Act of 1998, as cited in [22] AT consists of “any item, piece of equipment, or product system, whether acquired commercially, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities” (p. 99). The main AT for the visually impaired consists of mobility aids, utilization of information and communication technology (ICT), and control of the surroundings [23] AT allows disabled people

to carry out their everyday chores comfortably and experience a higher quality of life. Due to differences in the degrees and types of visual impairment, there are different types of reading aids such as screen reading technology, literacy software and hardware, magnifying technology, speech recognition software, and peripheral devices [24],[20],[21]. AT reading tools comprise hardware, software, and other devices intended to make text-based resources easy to access and read for people who struggle with reading such as the visually impaired, and to strengthen their overall reading skills [25],[26]. For example, screen reading technology allows the visually impaired to navigate electronic resources by listening to the text on the screen as it reads aloud to them; it also converts text into Braille output [27],[28],[5],[29]. Job Access with Speech, or popularly known as JAWS, is an example of a screen reader that allows the visually impaired to navigate and access computer applications. Fortunately, mobile device systems have been developed to address the accessibility functions. VoiceOver on iOS and TalkBack for Android devices are two examples of screen reader applications [30]. Likewise, magnifying technology aids persons with low vision to zoom in or out the interface for comfortable viewing [30],[31]. Visually impaired consumers of electronic devices depend on the ability of assistive technologies to interact well with digital interfaces [32]. However, these assistive technologies will not function correctly if the format of the electronic content is not accessible [33],[11],[34],[13],[16],[35]. Additionally, disabled users may only be able to use websites that are designed to be compatible with assistive technologies [36]. Besides the ability to access electronic contents, the user should also be able to use the interfaces to access information with minimum effort [32]. It is very clear from the available literature on the usability and accessibility of e-resources that visually impaired users are still not qualified to use the existing resources due to lack of proper guidance and accessibility issues [11],[9],[13],[37].

Requirement gathering is a method used to discover features or behaviors of a system by one or more stakeholders [38]. Many research methods serve as requirement gathering methods by adopting or modifying interviews, questionnaires, observations, prototyping, task analysis, brainstorming, and laddering [39]. Interviews and questionnaires are the most used methods of system and software engineering to gather qualitative and quantitative data. Such data can be grouped into three basic types: structured, semi-structured, and unstructured. The most valuable method for requirement identification is the unstructured interview [40].

[29] studied the usage pattern and user requirement of e-book applications in terms of interface and functional requirements for visually impaired users. This study aimed to develop an e-book application that was suitable for both visually and non-visually impaired readers with the use of the same content and environment. The researchers conducted a survey to obtain data on user requirements in terms of service, interfaces, and functions. The study conducted two focus group meetings involving four blind and four non-blind accessibility experts to improve the interface design and accessibility functions. There are limited studies on e-book requirement gathering. However,

other studies on HCI have been conducted that focused on requirement gathering for usability and accessibility of websites, mobile devices, and applications [41],[31],[42]-[47]. These studies used literature reviews, observations, interviews, and experiments. Consequently, the current study will contribute more insights in identifying and discovering the requirements of different visually impaired users of mobile e-book applications in a local Malaysian university.

This paper has four main sections. The first section presents an introduction to the topic. The second section highlights the material and method used, and the third section presents result and discussion. Finally, the paper draws an overall conclusion to the study.

## II. MATERIAL AND METHOD

This study attempted to identify the requirements that are typically needed by the visually impaired in using mobile e-book applications. This phase began with an online survey containing open-ended questions. The authors sent the questions by electronic means because traditional distribution methods such as by paper was quite challenging [42]. The survey questions were sent to eight students with vision disabilities studying in a local Malaysian university; however, only seven students responded. This response rate was still acceptable as there were similar studies with only five participants [48]. The students were identified as visually impaired by the Student Support and Services Unit of the chosen university. This method would ensure that the requirements needed by the visually impaired were included.

The study adopted and adapted survey questions from [42] and [49]. Other questions were added to cover other issues related to reading print books and e-books. Examples of the questions are: "Are you able to navigate and understand the flow of the e-book content easily? Do you think visually impaired people need a special e-book application or they can use normal e-book applications? What do you think are important aspects to be included in a mobile e-book application, especially for blind or low vision users?" The researchers tested these questions with a yes or no close-ended option and rewrote the questions to find out more about the how and what [50].

A purposive sampling technique was used in selecting the participants. It is a non-probability sampling technique widely used to find people who are available and willing to provide information based on their knowledge and experience. This form of sample is often used when working with very small samples of 5–25 participants [51],[52]. After the requirements were gathered from the survey questions and comments, the comments were analyzed using the NVIVO software. The written transcriptions were examined, and the relevant statements were put into relevant nodes to represent the requirements. In this study, the researchers built the nodes based on their knowledge background of accessibility guidelines for the visually impaired [53]

## III. RESULT AND DISCUSSION

In this study, the collected data were both quantitative and qualitative. The quantitative data, such as age and years of experience using computers and mobile devices, and the qualitative data were derived from the open-ended questions.

The age of the participants ranged from 21 to 27 years old, whereby all the students were undergraduates except one who was a postgraduate student. Four participants were male and three were female. Table 1 summarized the demographics of the participants.

Table 1 shows the demographic information of the participants. Out of the seven students, one was born blind, three had low vision, and three were blind on one eye. Three had had the impairment since birth, while the others mentioned different reasons such as optic nerve inflammation, hereditary, and childhood incident. Overall, all the students had experience in using mobile devices as well as computer devices. The interviewees were asked to share the experiences and obstacles they faced with mobile application usage in general and e-book applications. The researchers also conducted an online interview with one of the blind students through WhatsApp application to obtain more information from her. The student used a screen reader to read the researchers' questions and responded using the WhatsApp voice message function. Table 2 below shows the major requirements that have been identified.

This study found ten requirements as shown in Table 2. It was found that the low vision participants used text enlargement and zooming features as AT to help them use mobile applications and read their content. In fact, zooming and text enlargement are core requirements for low vision users [7],[13],[35],[54],[47],[48],[55]. Sadly, most e-books for students are in PDF format, which is rigid and does not permit the text to be altered and reflowed to any screen size, thus creating another challenge for low vision users (Walton & Hailey, 2015). The participants with low vision agreed that reading e-books took a long time and caused eye pain, with difficulties navigating the book content. However, they valued the portability, space-saving, low-cost aspects of e-books, and the ability to change the text format to their preferences in reflowable formats.

They also valued the TTS feature, which converts written words to spoken words [56],[35],[54]. Numerous applications provide the TTS feature that addresses the accessibility limitations of written books [57],[58]. TTS improves comprehension especially for struggling readers such as the visually impaired [59]. However, TTS is a computer-based speech tool that at times is difficult to understand [33].

As a result, many settings associated with TTS have been introduced to increase its benefits. One of them is the ability to adjust TTS voice speed and volume, which are important because different users have different levels of listening ability [60]. The low vision participants also declared that they used the high contrast feature for more accessible usage on mobile phones. This requirement was consistent with the findings in previous studies [61], [62], [54], [44], [47], [48],[55].

In contrast, the blind participant depended more on the screen reader but also valued the feature of brightness adjustment as she could sense light. However, she experienced difficulties with PDF readers because of their nature and limitations; for instance, a mere scanned image could render it unsearchable and unreadable by a screen reader.

TABLE I  
DEMOGRAPHICS OF THE SURVEY PARTICIPANTS

No	Gender	Age	Type of vision impairment	Years of experience using computers	Years of experience using mobile devices	Cause of impairment
P1	Male	24	Low vision	1 to 5 years	1 to 5 years	Optic nerve inflammation
P2	Female	25	Blind one eye	> 5 years	> 5 years	Not provided
P3	Male	23	Low vision	> 5 years	1 to 5 years	Since birth
P4	Male	21	Blind one eye	> 5 years	> 5 years	Since birth
P5	Female	23	Blind one eye	> 5 years	> 5 years	Incident from childhood
P6	Female	27	Blind	Not provided	1 to 5 years	Since birth
P7	Male	22	Low vision	1 to 5 years	> 5 years	Hereditary

TABLE II  
USABILITY REQUIREMENTS FOR ACCESSIBLE E-BOOK APPLICATIONS GATHERED FROM SURVEYS ON THE VISUALLY IMPAIRED

Requirements	Comments
Compatible with the screen reader	<b>P1:</b> Mostly use laptops with the screen reader software to do their assignments. <b>P6:</b> Uses VoiceOver screen reader on her iPhone as she is blind. <b>P7:</b> An important aspect to include in an e-book for the visually impaired is to provide a screen reader.
Easy to navigate	<b>P1:</b> An important aspect to include in an e-book for the visually impaired is easy navigation. <b>P6:</b> E-book is good, but it depends on how it works. If it is easy to navigate from one page to another, it should be all right.
Easy to search for book content	<b>P6:</b> An important aspect to include in e-books for the visually impaired is to have a search menu and anything to help them navigate from one part to another.
High brightness High contrast	<b>P6:</b> She uses high brightness features. <b>P1:</b> The feature that he normally uses in his mobile phone is increasing contrast.
High-quality sound	<b>P2:</b> An important aspect to include in e-books for the visually impaired is clear sound of the typed words to facilitate and speed up reading resources. <b>P3:</b> An important aspect to include in e-books for the visually impaired is the sound of the words.
Clear text Text enlargement	<b>P5:</b> Blind-friendly whereby people can easily see the e-book notes. <b>P1, P3, P7:</b> The feature that they normally use in their mobile phones is text enlargement.
Text-to-Speech (TTS)	<b>P1:</b> An important aspect to include in e-books for the visually impaired is the ability to read the text as a screen reader does. <b>P7:</b> An important aspect to include in e-books for the visually impaired is a voice reader.
Zooming	<b>P3, P7:</b> They need to zoom in on the pages of PDF files to read them.

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 menus and icons [63]. Therefore, each interface element has to include a brief description (accessible name) to be read aloud by the screen readers [63],[64]. Besides, the users should be able to use interfaces that provide information with minimum effort [32]. Therefore, a good design in this context entails user-friendly navigation that facilitates the visually impaired, particularly in learning [65],[29]. Learners must be able to read not just in a sequential manner, but also to move instantly over the content [41].

Blindness in one eye is a type of visual impairment [66]. Nevertheless, the participants with such impairment in the current study considered themselves as a normal-sighted person and faced no problems using mobile applications. This was because they had had this impairment since early

childhood and had developed their own skills over time living with just one functioning eye. However, it has been shown that adults who lose sight in one eye have reduced abilities to effectively follow moving objects, sense depth, and determine distances. This means that they have to learn how to actively use one eye and their other senses to collect information [67]. Therefore, the WHO classification of vision impairment may be the best basis for participant selection in any accessibility study involving the visually impaired [13].

#### IV. CONCLUSION

This study identified ten basic usability requirements for accessible mobile e-book applications for the visually impaired, namely compatibility with the screen reader, ease of navigation, ease of book content search, high brightness, high contrast, high-quality sound, clear text, text enlargement, TTS, and zooming. As there are different types of vision

impairments, there are also diverse user requirements. Developers must be aware of all these requirements and ensure that they are addressed in the early design stages to reduce an iterative process of application development and to increase the number of application users among the visually impaired. In this study, the participants were from a developing country and had less exposure to the usage of e-book applications. Therefore, the results of this study may be affected and the number of collected requirements may not be enough. In addition, a single requirement gathering technique is insufficient, leading to the essential implementation of a combination of techniques to solve different types of requirements [39],[38], the study suggests implementing other requirement gathering techniques in future research, such as a case study, literature review, and experimentation, as well as increasing the number of participants.

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