

Usability Evaluation Factors in Acquiring Knowledge through Mobile E-Book Applications by Visually Impaired Users

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ABSTRACT

People read for various purposes, for example, to find data, interpret text, and acquire new knowledge. Electronic book (e-book) provides new opportunities to the visually impaired (VI) to read and learn and acquire knowledge at the same time as sighted people do. The e-book is an alternative to the traditional reading methods for the VI because it provides features like text enlargement and read aloud. However, the current mobile e-book applications are still not reaching their satisfactory level. Besides, usability evaluation studies for these applications are not clear in terms of factors used in the evaluation. Therefore, this study aims to identify the factors involved in a usability evaluation to evaluate e-book applications for the VI. Hence, the study applied a literature review to identify the usability factors that may use in the evaluation of e-book applications designed especially for VI. In total, 36 factors were identified but the study proposed six factors namely Efficiency, Effectiveness, Satisfaction, Learnability, Accessibility, and Navigation for the usability evaluation of accessible mobile e-book applications for VI to ensure that these applications are usable and accessible by them and will guarantee effectively acquiring knowledge.

Keywords: Acquiring Knowledge, e-book application, usability factors, visually impaired.

I INTRODUCTION

Currently, people are more dependent on their mobile phones which subsequently leads to an increase in the number of mobile applications (Hussain & Ferneley, 2008). Therefore, developers need to build high-quality applications with the intention of competition (Shitkova et al., 2015). The quality of an application for mobile devices comprises of several aspects; the important one is usability (Harrison et al., 2013). Another important factor of the application quality is accessibility whereby user interface (UI) and content may have limited access by users with different types of impairments or aged persons (Vieritz et al., 2013). Accessibility is the ability to access and control all information for all user categories (Billi et al., 2010).

As a result, accessible technology will provide equal ways of accessing the same transactions and content presented through any website or application (Lazar et al., 2015). Usability and accessibility are two rising factors in the design and evaluation of any product. Nevertheless, accessibility and usability cannot substitute each other but they can complement each other (Khowaja et al., 2019).

E-book is a book in digital support displayed on a desktop, notebook, mobile devices, or dedicated devices, but this puts out its most noticeable feature which is interactivity (Possatti et al., 2018). Whereby e-books, typically have in-use features such as search, annotations, and interactive tools which are overtime will continue to improve (Vassiliou & Rowley, 2008). The use of e-books has increased in recent years and they are fast becoming popular and their market share in e-publishing is growing (Gupta & Dhawan, 2019; Xin, 2018). The e-book has many advantages compared to traditional books and users find e-book useful and it influences their preferences over print books (Mune & Agee, 2015). E-book is quick to read, easy to manage formats, available anywhere anytime, with user-friendliness (Kumbhar, 2018). People read, for example, to find data, interpret text, and acquire new knowledge (Liesaputra & Witten, 2012). For disabled users such as VI people, e-book plays an important role to overcome their barriers to read paper books (Holanda et al., 2018; Schlünz et al., 2017). Consequently, it is considered as a chance for visually impaired to improve their knowledge.

There are different terms to describe visual disabilities: visually disabled, blind, partially sighted, and non-sighted (Kleynhans & Fourie, 2014), where the vision function is classified into four broad categories: normal vision, moderate vision impairment, severe vision impairment, and blindness (*Vision Impairment and Blindness*, 2017). Moderate vision impairment combined with severe vision impairment are grouped under the term "low vision": low vision taken together with blindness represents all vision impairment (Kleynhans & Fourie, 2014). Statistics show that about 253 million people live with vision impairment: 36 million are blind and 217 million have moderate to severe vision impairment, and 81% of them are aged 50 years and above

(Bourne et al., 2017). E-book offers new opportunities for people with vision impairments (Lenzi et al., 2013). However, e-book should implement accessibility principles, to be useful for the VI, which may be a built-in technology or compatibility with adaptive technologies (Dix, 2009).

Evaluation plays a critical role to address the usability problems of mobile applications. On one hand, general evaluation models and standards such as Nielson (1994), GQM (1994), and ISO 9241-11 seem to be ineligible to address the issues of a specific application type as they are generic and unable to clearly define the measurements for the usability evaluation (Abubakar et al., 2016; Khowaja et al., 2019). On the other hand, limited evaluation models for e-book consider the accessibility of e-book applications as the main factor (Sulaiman & Mustafa, 2019; Zhang et al., 2017). Moreover, evaluation models for e-book have either been developed for desktop software and websites or they do not consider accessibility. As a result, studies that evaluate mobile e-book applications usually depend on general usability measurements as in (Al-Qatawneh et al., 2019; Jardina & Chaparro, 2013, 2015; Mune & Agee, 2015) which are unable to address specific usability issues of a mobile e-book (Baharuddin et al., 2013; Dubey et al., 2012).

Therefore, this research seeks to address this gap by proposing factors that are involved in a usability evaluation model of accessible mobile e-book applications for VI users whereby an evaluation model of e-book can increase the usage of e-book and overcome technical barriers (Xin, 2018). The remainder of the article progresses as follows. The second section delivers the background and the related work on the topic addressed i.e., previous usability evaluation models in general and for e-book. The third section illustrates the research methods while the conclusion is further discussed in the last section, along with the potential research paths.

II BACKGROUND

This section will cover the previous work on usability in terms of models and standards. It will cover general evaluation models for desktops, mobile applications, and e-book. Usability evaluation is a significant pillar in the design of the UI (Greenberg & Buxton, 2008). Usability is defined by ISO 9241-11 (1998) as: “The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use”. Evaluation of usability is commonly done subjectively (Nayebi et al., 2012). The software systems have different candidate

audiences. Therefore, the definition of usability may have a different point of view for each of these audiences (i.e. end-users, software developers, and managers) (Abran et al., 2003). For the end-users, a usable application will allow them to perform the expected task faster and more efficiently (Abran et al., 2003). Yet, without a certain understanding of the end-user of the systems, considering and achieving the usability and learnability of the system becomes a significant quality obstacle for the designer (Abran et al., 2003). A variety of usability models and standards has been developed by the Human Computer Interaction (HCI) society, for example, Nielsen (1993) model and the GQM model by Basili (1994). These models and standards proposed different usability factors as summarised in Table 1.

Table 1. Comparison of Different Usability Standards, Models for Software Systems

| Model/ Standard | Usability Factors |
|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| (Nielsen, 1993) | Satisfaction, Learnability, Errors, Efficiency, Memorability |
| (Van Solingen & Berghout, 1999) | Simplicity, Accuracy, Time taken, Features, Safety, Attractiveness |
| (ISO 9241-11, 1998) | Effectiveness, Efficiency, And Satisfaction |
| (Seffah et al., 2006) | Effectiveness, Efficiency, Satisfaction, Productivity, Safety, Internationability, Accessibility, Learnability, Trustfulness, and Usefulness |
| (Dubey et al., 2012) | Effectiveness, Efficiency, Satisfaction, Safety, and Comprehensibility |
| (ISO/IEC 25023, 2016) | Appropriateness recognizability, Learnability, Operability, User error protection, User interface aesthetics, Accessibility |

Table 1 shows general usability models and standards for the evaluation of software systems or applications. Besides being general models, these models provide inadequate guidelines and consistency in applying these models for usability evaluation especially for mobile applications (Flood et al., 2013; Hussain et al., 2013). Additionally, metrics are also inadequately provided in supporting the derived factors except ISO 9241-11 (1998) and QUIM (2006) (Flood et al., 2013). While some models, for example, the model by Dubey et al. (2012) was not even tested and were ambiguous. Using these models may produce incomprehensive results especially when the model does not provide metrics. Such models, therefore, are difficult to be used by researchers and usability practitioners especially for applications that focus on VI or other special needs applications apart from QUIM, which is reliable for usability evaluation or design of independent model (Nathan et al., 2016, 2017).

The usability of mobile devices and their applications vary from other computer systems, as they have different characteristics. Users are looking for applications that are easily learned, take inconsiderable time to accomplish a particular task, and easy to use (Nayebi et al., 2012). Real user testing of mobile devices is equivalent to standard desktop studies. However, special care is required for recording equipment, room configuration, and even test participants. There are many usability evaluation studies introduced for mobile applications, these studies are presented in Table 2.

Table 2. Comparison of Different Mobile Usability Models

| Study | Usability Factors |
|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (Hussain, 2012) | Simplicity, Accuracy, Time taken, Features, Safety, Attractiveness |
| (Shamsudeen et al., 2012) | Understandability, Learnability, Operability, and Attractiveness |
| (Baharuddin et al., 2013) | Effectiveness, Efficiency, Usefulness, Satisfaction, Aesthetic, Intuitiveness, Learnability, Simplicity, Understandability, and Attractiveness |
| (Harrison et al., 2013) | Effectiveness, errors, Efficiency, Satisfaction, Learnability, Cognitive load and Memorability |
| (Nathan et al., 2017) | Effectiveness, Efficiency, Satisfaction, learnability, Understandable, and Accessibility |
| (Saleh et al., 2017) | Efficiency, Learnability, Effectiveness, Memorability, Satisfaction, Errors, Cognitive load, Simplicity, Interruptibility, |
| (Goel et al., 2018) | Speed, Interactive GUI, Error Tolerant, Less storage consumption, User friendly, Efficiency, Aesthetic, Battery Consumption, Performance, Effectiveness, Platform dependency |

Table 2 indicates models for mobile usability evaluation. Some of these models do not come with metrics to measure the exact factor (Baharuddin et al., 2013; Goel et al., 2018; Harrison et al., 2013; Shamsudeen et al., 2012). Besides the studies lack in providing appropriate descriptions of implementing the measures identified (Nathan et al., 2016). Moreover, the previous models do not consider any mobile usability factors for disable users except MAEHI which makes the models difficult to accommodate the usability of mobile e-book applications VI.

A. Usability Evaluation Models and Studies for E-book

The needs of the consumers are paramount for the look and feel of the book (Wilson, 2002). Therefore, there is a need for user testing to assess the interface because users have an open potential for describing the design of the interface in new and surprising ways. Audience clarity is the first footstep in evaluating the “usability” of an e-book (Wilson,

2002). It is important to discuss the usability of e-books as interactive applications must take into account the needs of the consumer. Several studies in the literature addressed the usability issues of e-book, some of these studies proposed evaluation models. This study analyzed the previous studies to summarise their finding in terms of measurement used for the evaluation See Table 3.

Table 3. Usability Evaluations Models and Studies of E-book in General and for VI

| | Study | Factors | Remarks |
|----------------------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Evaluation Model | (Lim et al., 2012) | Efficiency, Effectiveness, Satisfaction, Learnability | Accessibility not considered; the model also lacks valuation metrics |
| | (Haslinda et al., 2014) | Understandability, Learnability, Operability, Attractiveness | Accessibility not considered and only subjective metrics provided |
| | (Baker-Eveleth & Stone, 2015) | Efficiency, Effectiveness, engagement, Ease of learning | Accessibility not considered, and only subjective metrics provided |
| | (Wang & Huang, 2015) | Visibility, Ease, Efficiency, And Enjoyment | Accessibility not considered |
| | (Goel et al., 2018) | Efficiency, Aesthetics, Interactive GUI, and efficient | Accessibility not considered and lack of metrics |
| | (Sulaiman & Mustafa, 2019) | Efficient, Effective, Satisfaction, Accessibility, Learnability | Not provided evaluation metrics |
| | Evaluation Studies | (Siegenthaler et al., 2010) | Effectiveness, Navigation, Design, Orientation, Functionality, Handiness |
| (Jardina & Chaparro, 2012) | | Efficiency, Effectiveness, Satisfaction, Cognitive workload, Navigation | Simple accessibility metrics for normal vision users provided |
| (El-Glaly et al., 2012) | | Efficiency, Effectiveness, Error, Cognitive workload | Introduced a novel tactile way of reading for the visually impaired |
| (Jardina & Chaparro, 2013) | | Efficiency, Effectiveness, Satisfaction, Features, Accessibility, Engagements, Comprehensive, Cognitive workload, Navigation | Simple accessibility metrics for normal vision users provided |
| (Lenzi et al., 2013) | | Navigation, Accessibility | Enhanced ePub format evaluation study by blind users |

| | | |
|------------------------------|--------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| (Maatta & Bonnici, 2014) | Accessibility, Physical nature of the devices, functionality | Sighted participants are used to evaluate instead of print disability ones |
| (Jardina & Chaparro, 2015) | Effectiveness, Features, Navigation | Accessibility not considered |
| (Mune & Agee, 2015) | Accessibility, Features, Navigation | Sighted participants are used to evaluate instead of VI ones |
| (Lin, 2015) | Efficiency, Satisfaction, Error | Accessibility not considered |
| (Bartalesi & Leporini, 2015) | Accessibility, Navigation | Sighted and visually-impaired participants, Evaluation of content accessibility and usability |
| (Hussain et al., 2017) | Efficiency, Ease-of-use, visibility, and enjoyability | Accessibility not considered |
| (Shin et al., 2017) | Efficiency, effectiveness, Satisfaction, Accessibility | VI participants |

The above table shows that the most proposed factors are efficiency, effectiveness, learnability, and satisfaction. Other factors only appear once in each model even though they are very important such as accessibility. In addition, studies that focus on the usability of e-book for VI are more into evaluating the accessibility and the ability to navigate the e-book. Moreover, the learnability of e-book application from VI user's perspective had not been examined thoroughly.

III METHODOLOGY

This study used Literature Review (LR) to discover the factors that are typically used to evaluate mobile e-book applications in general and especially for those having vision disabilities. A comprehensive analysis of usability models in general and mobile applications from 1990 to 2019 has been done. Besides, current work on e-book evaluation for both sighted and VI users from 2010 to 2019 has been reviewed. Based on the reviewed papers (See Table 1,2, and 3), a total of 36 factors were identified however, based on the frequency referred to and used in the literature, only 16 factors were selected. In this review, the factors are identified based on the number of counts that exist in the usability evaluation literature in general as well as for mobile e-book usability evaluation, and evaluation of e-book usability from VI concerned. A count that is more or equal to three is taken into the factors list, the same method of identification used by Baharuddin et al., (2013) and Nathan et al. (2017).

Table 4 presents the usability factors that were identified.

Table 4. Frequently Used Factor in Reviewed Studies

| Factor | Freq. | Factor | Freq. |
|---------------|-------|-------------------|-------|
| Efficiency | 19 | Simplicity | 5 |
| Effectiveness | 17 | Cognitive Load | 5 |
| Satisfaction | 15 | Attractiveness | 5 |
| Learnability | 13 | Safety | 4 |
| Accessibility | 10 | Understandability | 3 |
| Navigation | 7 | Memorability | 3 |
| Error | 6 | UI aesthetic | 3 |
| Features | 6 | Operability | 3 |

Table 4 shows that Efficiency, Effectiveness, Satisfaction, Learnability, and Accessibility are the most frequent factors used to evaluate usability (cited by 19, 17, 15, 13, and 10 studies respectively). These results are similar to the findings of previous studies (Coursaris & Kim, 2006, 2011; Weichbroth, 2020, 2018). A total of 16 factors to be used in the evaluation of the application for VI are thought extremely much for any model development and therefore summarization is mandatory (Harrison et al., 2013). Thus, the most appropriate factors will be carefully chosen by considering the more relevant used factors and the requirements, while some are omitted because they are not relevant to e-book applications for VI. The study followed the summarization method used by Coursaris & Kim (2011) to ensure only the essential elements are included in the study (Baharuddin et al., 2013). This assures reliable evaluation of mobile e-book applications for VI. Consequently, the study proposed the initial evaluation factors for evaluating the accessible mobile e-book applications to ensure that VI can access the application. Figure 1 shows the factors proposed for the evaluation.

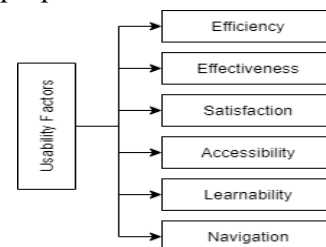


Figure 1. Usability Evaluation Factors for Evaluation Accessible Mobile E-book Applications for the VI

IV CONCLUSION

The word usability is constructed of two nouns: "use" and 'ability'" which indicated the ability to use the application easily. That means the ability to operate, navigate, and learn the application interface with no errors (Weichbroth, 2020). The usability of the e-book for VI indicates the ability to read, access,

and navigate the application interface as well as the content. In parallel with the findings found from similar studies as (Coursaris & Kim, 2006, 2011; Weichbroth, 2020, 2018), the findings are consistent in the extent of the top three main factors for any application, which concern Efficiency, Satisfaction, and Effectiveness (See Table 4). Moreover, an increased interest in learnability and accessibility can also be noticed. On one hand, learnability is about how easy can new users learn the application. This factor is more challenged when the user has any kind of disability and needs to give more attention to evaluators. On the other hand, the accessibility factor is the core factor for designing an application for the disabled whereby if the application is not accessible it is simply not usable. As a result, this study proposed Effectiveness, Efficiency, Satisfaction, Learnability, Accessibility, and Navigation as usability evaluation factors for accessible mobile e-book applications for VI users. In future work, metrics for each of these factors will be generated followed by expert review for verifying the proposed factors and metrics. Likewise, the proposed factors and metrics will be validated through a usability study.

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