Usability Evaluation Model for Mobile Visually Impaired Applications

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Azham Hussain(✉), Ahlam Mohamed Omar
Universiti Utara Malaysia, Kedah, Malaysia.
azhamuum@gmail.com

Abstract—The usability of the mobile applications is the most important factor in developing, so the key to develop successful mobile applications is usability, especially for users have specific needs such as visually impaired. However, developers do not focus on visually impaired users. Moreover, there are limited studies and usability evaluation models for mobile applications for visually impaired so developers use just a modified usability evaluation methods which are not enough and useful to evaluate mobile applications for visually impaired, or they use general usability evaluation models. Therefore, using these methods or models is difficult for evaluator and not useful for visually impaired users. This study conducts Systematic Literature Review (SLR) to identify usability dimensions that help mobile applications developers and evaluators to evaluate mobile application for users which have moderate and severe visual impairment. The result shows that,sixdimensions that have a significant impact on moderate and severe visually impaired users' satisfaction, who use mobile applications. These dimensions namely efficiency, effectiveness, satisfaction, errors, accessibility andunderstandability.

Keywords—Visually impaired people; Mobile application; Usability dimensions; Usability evaluation model.

1 Introduction

Users of internet, mobile devices and mobile applications grow every day more and more, Mary Meeker said that in 2018 the number of internet users has been more than half the world's population, and they are 3.6 billion.

According to the statistics the mobile phone users are 4.57 billion in 2018[1], including disabled people such as visually impaired. Also in annual report of App Annie, globally in 2017 there were 175 billion mobile apps downloads, this number makes 60% growth from 2015.

Moreover, in March 2017, there were 2.8 million available apps at Google Play Store and 2.2 million apps available in the Apple's App Store, the two leading app stores in the world.

Therefore, during a few last years mobile technology has been widely growing in human computer interaction area as well as it has been a main part of the every one social life. Especially with the features of this very useful device, therefore when mobile application is designed for HCI usability will be essential and crucial part to design better application with better usability quality[2].

Although developing of mobile devices and applications have been increased, the usability of the mobile applications with mobile advantages are the most important factor in developing [3], so the key to develop successful mobile applications is usability [4].

In these days the developers do not focus on special needs people who are visually impaired because they focus on people who can see. In additional the researchers do not focus on visually impaired user during their studies about usability evaluation for visually impaired because the most of these studies without visually impaired users, therefore these studies was not useful to help users and developers[5].

Therefore, usability definition has to be clear. First academic systematic definition of usability was by Shackel and Richardson in 1991, they found that a product to be important, it needs three positive sides utility, usability and likeability.

The meaning of utility is the functionality that agrees with users' requirement and need.

The meaning of usability is the success or goal achievement rate that helps user works with the product.

The meaning of likeability is the rate of suitability feeling that is resulted satisfaction (Kurosu, 2015).

Also, usability is defined as quality feature of a product, this definition indicates to how use and learn this product easily without any difficulty and mistakes, therefore usability as easily use earning is important base of any a new come out product (application or software) to users' complete acceptability and increasing reliability and satisfaction[6].

A large number of mobile applications do not cover requirements of visually impaired users because these applications do not accord with the guidelines of mobile accessibility. Therefore, it is difficult for visually impaired users in accessing and use mobile interface components (e.g., finding some buttons, interface navigation). At the same time these users need to learn new application, also sometimes features of application more than users' readiness to learning and discovering[7].

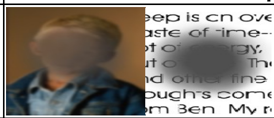
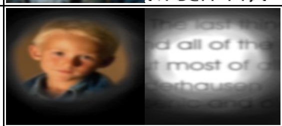
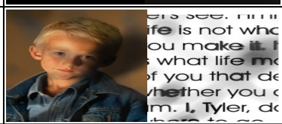
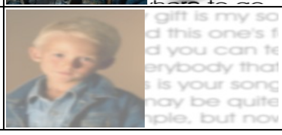
2 Literature Review

Usability and Human Computer Interaction have been central and main part to develop systems. HCI and usability improve and support the system services, also giving users their needs and necessities. HCI helps analysts, designers to identify the software needs to be successful, while usability helps to prove that the software has efficiency, effectiveness, safety, utility, learnability, memorability and usability to evaluate in really using, then finding the users' satisfaction. HCI and usability together help users to be satisfied and achieve their goals and tasks[8,9].

2.1 Visually impaired

WebAIM organization generally defined low vision as a condition in which a person's vision cannot be fully corrected by glasses, thus interfering with daily activities such as reading and driving. Low vision is more common among the elderly, but it can occur in individuals of any age, low vision divided to 4 types depend on the reason, these 4 types will be shown in the table 1 [10].

Table 1. The Low Vision Types

Low vision type	Description by picture
Macular degeneration	
Glaucoma	
Diabetic retinopathy	
Cataract	

TheWorld Health Organization according to the International Classification of Diseasesclassified function of vision in four broad categories: normal vision, moderate vision impairment, severe vision impairment and blindness[11], also World Health Organization presented distance visual acuity as view in the following table.

Globally, the number of people who have visual impairmentabout 253 million people, also the blind are about 14% of people have visually impaired while moderate to severe vision impairment is healthy problem for about 86% 0f the people have visually impaired, also International Classification of Diseases classified the vision function in four broad categories: normal vision, moderate vision impairment, severe vision impairment and blindness, so low vision is moderate vision impairment combined with severe vision impairment and low vision with blindness represents all vision impairment[11].

In a WebAIM survey in October 2017 about using screen readers, 88% of the 1792 valid responses used mobile screen reader in the mobile devices, also WebAIM reported that 69% of the responses commonly use VoiceOver and MobileSpeak was less using by 1.5%. To add more gave most problematic items in using as is shown in the figure 1[12].

Table 2. Distance Visual Acuity

Presenting Distance Visual Acuity		
Category	***Worse Than:***	***Equal to or Better Than:***
Mild or No Visual Impairment 0		6/18 3/10 (0.3) 20/70
Moderate Visual Impairment 1	6/18 3/10 (0.3) 20/70	6/60 1/10 (0.1) 20/200
Severe Visual Impairment 2	6/60 1/10 (0.1) 20/200	3/60 1/20 (0.05) 20/400
Blindness 3	3/60 1/20 (0.05) 20/400	1/60* 1/50 (0.02) 5/300 (20/1200)
Blindness 4	1/60* 1/50 (0.02) 5/300 (20/1200)	Light Perception
Blindness 5	No Light Perception	
9	Undetermined or Unspecified	

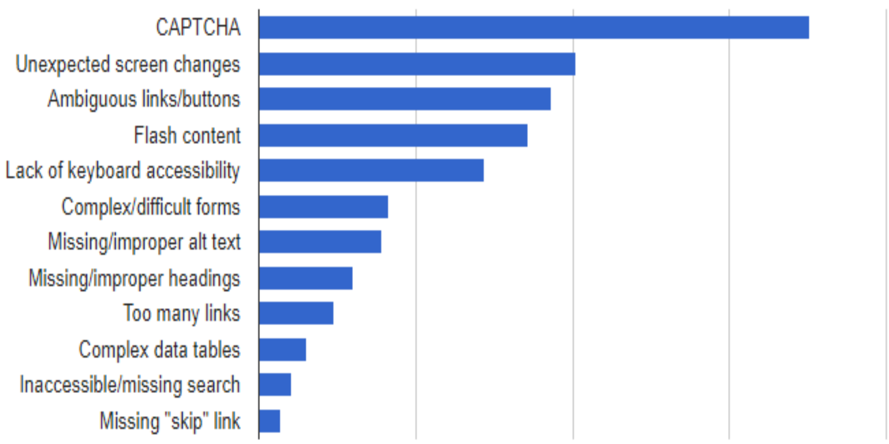


Fig. 1. Most Problematic Items

2.2 Usability evaluation

Right now a lot of usability evaluation models that used to evaluate the mobile applications have not been evaluated their accuracy, applicability and totally usefulness with real users in the real environment, then the result of this issue is losing user's confidence and in the other side the result of usability evaluation that uses these models not inclusive and righteous[6], thus a usability evaluation models for mobile applications are very general to evaluate usability of mobile applications for special need people[13]

2.3 Existing usability evaluation for mobile applications

PACMAD (People At the Centre of Mobile Application Development) was introduced as usability model for mobile applications, this model was consisted of seven usability attributes, these usability attributes were effectiveness, efficiency, satisfaction, learnability memorability, errors and cognitive load; after they found that as usual usability evaluation used three attributes: effectiveness, efficiency and satisfaction without important attributes that effect developing successful application such as cognitive load, so this model have the attributes of both ISO standard and Nielsen's model with three usability factors as a part of the model as will be shown in figure 2[14].However, this model does not offer metrics that related with usability dimensions[15], so it is difficult to use and not enough to evaluate mobile application

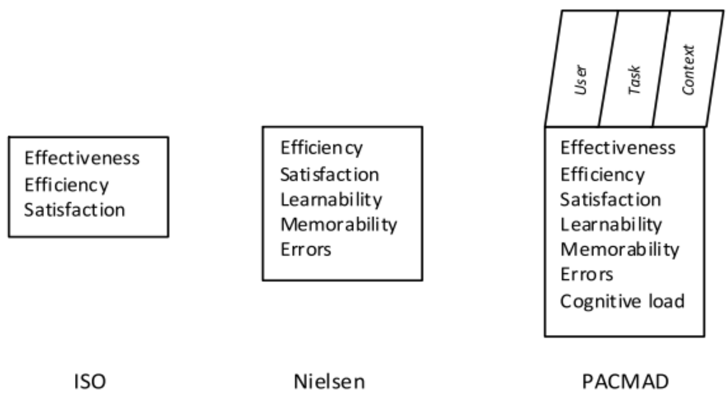


Fig. 2. Comparison of Usability Models

By following GQM approach also using SLR was provided usability evaluation model for mobile applications (mGQM) that started with three usability measures as main level: effectiveness, efficiency and satisfaction according to ISO 9241 (1998), then continued with three levels: goal, question and metrics. The goals were simplicity, accuracy, time taken, features, safety and attractiveness. Questions level that was contained of twenty twoquestions as criteria. Last level was metric that consisted of thirty seven objective and subjective metrics[16].However, as the author mentioned, this model need to add or drop some criteria and metrics, depending on the application and users needs, so it is not useful if drop some important criteria and metrics, also if Ignore adding some important criteria and metrics especially for visually impaired.

Usability evaluation model for mobile applications consisted of 10 usability dimensions was presented, with 4 contextual factors: environment, user, technology and task/activity as will be shown in figure 3[17].However, this model did no tested to be sure that, the model is useful to evaluate mobile application. Also, no supporting by usability metrics related to usability metrics that were offered, so cannot use this general model to evaluate mobile application for visually impaired users.

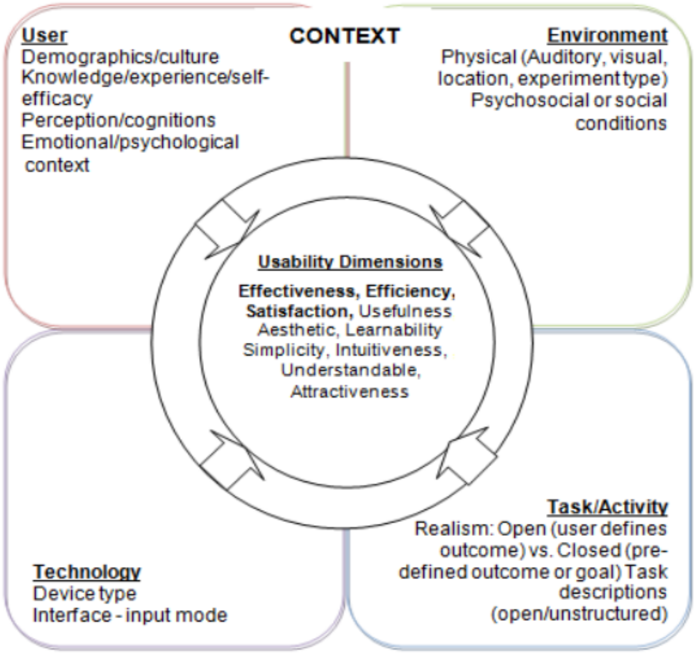


Fig. 3. Dimensions and Contextual Factors of the Model

Also in 2013 usability evaluation model to serve as a guideline for mobile companies,was presented how to collect data about the usability of their products and measure the usability. This model was included 9 main attributes of mobile applications, the main attributes were efficiency, effectiveness, satisfaction, productivity, learnability, safety, accessibility, generalizability and understandability, also 27 sub attributes and 63 sub goals. Moreover, they defined a set of 368 questions that can be used by mobile companies in usability evaluation [18].However, this model offered useful usability measures, generally for mobile application, not for mobile application for users with specific need such as visually impaired.

In a previous study nine attributes were presented as important usability attributes to evaluate the usability of mobile applications. Depending on seven usability attributes from PACMAD model and two attributes added. Beside the importance of the usability attributes, researchers focused on the relationships between usability attributes based on conception of users to offer their model with 9 attributes and 27 metrics, also the study found that satisfaction, errors, simplicity, cognitive workload, and interruptibility as the most important attributes for mobile application, also was found that the efficiency, effectiveness, learnability, memorability, errors, satisfaction, cognitive load, interruptibility, and simplicity were tied each other[4]. However, 9 attributes offered as the most important for mobile application for all users, not for disable users with specific needs, so it need to add more sub attributes and important metrics, which are important to evaluate the usability of mobile application for visually impaired.

Usability requirements catalog (USB-CAT) was proposed for health mobile applications, this catalog helps to evaluate existent application or develop successful new applications. This based on the ISO/IEC/IEEE 29148 (2011) standard and followed the SIREN methodology, also the usability requirements of this catalog are:

- Ease of use requirements.
- Personalization and internationalization requirements.
- Learning requirements.
- Understandability and politeness requirements.
- Accessibility requirements[19].However, previous requirements are important, though some are not very important for visually impaired users, such as internationalization.

Formobile banking applications proposed usability evaluation model, which including five usability evaluation dimensions: efficiency, effectiveness, trustfulness, learnability and satisfaction, also fourteen criteria that have number of metrics[6].However, using this model to evaluate mobile applications for visually impaired is not useful, because it presented important measures to evaluate mobile banking applications such as trustfulness, in the other side these measures not very important for visually impaired as users for mobile applications.

2.4 Usability evaluation for mobile applications for visually impaired

In previous study the researchers have analysed 100 empirical literature about mobile usability to find just two literature about users with visual impairment. Thus, the researches about these users have been limited and researchers did not focus on the limitation usage for disability users such as users who have many limitation in mobile services [20].

After systematic mapping of the literature which about usability evaluation methods with visually impaired users, researchers found few articles focused on visually impaired users. Also, the usability evaluation method although it was applied for mobile applications for visually impaired users, it was not enough to present clear information about how visually impaired users use their mobile applications, and what is more comfortable and easier for them. The reason of this fail is that the method was used just a modified method[5].

However, based on previous studies, the studies about the usability of mobile applications for visually impaired are limited, also there are not useful and accuracy usability evaluation models which help visually impaired users. Existing methods, metrics, and usability attributes that related to HCI were used to evaluate a proposed universal UI framework that was design for mobile for visually impaired users. The usability parameters that were used: attitude, intention to use, understandability and learnability, perceived usefulness, operability, ease of Use, system usability scale

(SUS), minimal memory load, user satisfaction and consistency, also every usability parameter had set of measurements[7]. However, this universal UI framework did not offer important usability dimensions for visually impaired users, such as accessibility and errors dimensions

Accessibility problems for visually impaired and normal vision users were compared after empirical study, researchers found that 514 problems reflect the low rate of successful tasks of mobile applications for visually impaired users, compared with normal vision users, especially with less assistive technologies for mobile (mostly in Android platforms) than that used in desktop computers, so this study pointed that it is important to develop accessible mobile application for visually impaired users. Also, have to examine deeply accessibility problems by visually impaired users[21]. However,evaluating application accessibility is important for all users, though for visually impaired users more important, because they have more accessibility problems than normal vision users.CLUE with 40 items was presented as checklist to guide researchers, practitioners and teachers for visually impaired children in usability evaluation. CLUE presented to evaluate multimodal video games which will impact the lives of children who are visually impaired, through helping them to developing their skills to be more independent in their daily lives and better integrated in their social lives [22]. However, this checklist just for multimodal video games for specific users, so not useful to use it to evaluate other mobile applications for other visually impaired users.

Some precautions to have a better system using for visually impaired users were suggested, that depends on sound, haptic and graphic interfaces. Researchers used usability criteria defined by Nielsen, to usability evaluation of a mobile navigation application for users who are blind. However, although precautions which were suggested useful for visually impaired users, usability criteria defined by Nielsen not enough to evaluate mobile application especially for visually impaired users[23].

3 Methodology

This study used Systematic Literature Review (SLR) method based on the guidelines as presented by Kitchenham[24]. The main goal of SLR was to discover usability dimensions that used in the literature and provide ideas that helped to identify usability dimensions for mobile applications for the visually impaired. In SLR as figure 3, there is three stage were used which are the first stage is planning of the SLR process, the second stage is applying the protocol determined in the planning stage and the final stage is analysing and reporting the findings.

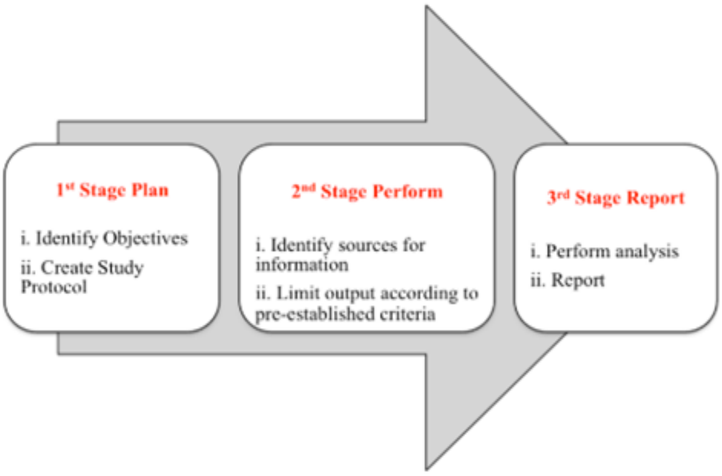


Fig. 4. Stages of Systematic Literature Review SLR[25]

4 Results

For proposed conceptual model chosen five usability dimensions to evaluate mobile application for visually impaired, Based on SLR which helped to find the most usefulness usability dimensions for visually impaired users. In literature there are different terms of usability dimensions with the same meaning[26], so suggested dimensions are without repeat same dimensions by other terms. Besides, proposed dimensions have to be helpful for visually impaired, not just useful to have good quality mobile application, without thinking about visually impaired requirement and needs.Therefore, accuracy and wisely are important to chose usability dimensions, which are useful and meet the users' needs as well as considering well application functionality.

General usability models including ISO models had some lacks [26,25],also not enough to use for mobile applications [28]. Beside, usability evaluation models for mobile applications are very general to evaluate usability of mobile applications for special need people [13].

Based on the above, visually impaired users needs the useful and accuracy usability dimensions, which will use successfully and effectiveness in evaluate their mobile applications.

First three dimensions are efficiency, effectiveness and satisfaction that were provided by ISO 9241-11[29], also were used in a lot of previous usability evaluation models and studies [46,14,15,16,17,25,29].Also there are three dimensions important for mobile applications, which will be used by visually impaired users; these dimensions are understandability [7,17,18], errors [4,14,30,31,32] and accessibility [17,18,25,31,32]. All chosen dimensions explained in table3.

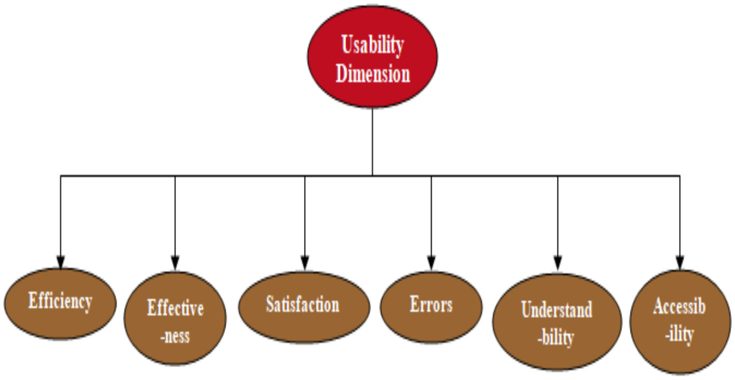


Fig. 5. Selected Usability Dimensions for Conceptual Model

Table 3. Description of dimensions

Dimension	Definition
Efficiency	Speed completing a task and achieving goals of the product, with the best productive by the application after learning it.
Effectiveness	Accuracy and completeness in achieve specified goals by users
Satisfaction	The level of user's pleasing and enjoying during using application.
Understandability	The user level in understanding application usage, and possibility learning it faster.
Errors	User faces fewer errors during using application, and can easily recover from them if there are errors, also application without catastrophic errors
Accessibility	The level of the user's usage regardless of the disabilities, and able to fully perceive application

5 Conclusion

This paper has discussed the existing usability evaluation models for mobile applications, also has focused on the existing usability evaluation and visually impaired, by using SLR method, to find usability dimensions as a part of conceptual usability evaluation model for mobile application for visually impaired. Chosen usability dimensions are more important than other usability dimensions for visually impaired users, but still need to add criteria and metrics to complete the model, and then will be evaluated by experts, finally will use the proposed model to evaluate a mobile application, by visually impaired users in real environment.

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7 Authors

Azham Hussain is the Associate Professor of Software Engineering at UUM School of Computing. He is the founder and head of Human-Centered Computing Research Group which is affiliated with the Software Technology Research Platform Center at School of Computing, Universiti Utara Malaysia. Assoc. Prof. Azham Hussain is a member of the US-based Institute of Electrical and Electronic Engineers (IEEE), and actively involved in both IEEE Communications and IEEE Computer societies. Azham is published in the areas of software evaluation and testing, user behaviours, group collaboration, and ubiquitous and mobile technology design. He has authored and co-authored more than 100 refereed technical publications, served as reviewer and referee

for refereed journals and conferences on computing as well as the examiner for more than twenty doctoral and postgraduate scholars in his research areas. Email: azhamuum@gmail.com

Ahlam Mohamed Omar is currently working in the department of School of Computing, Universiti Utara Malaysia, Kedah, 06010, Malaysia. Email: ahlam_ame@yahoo.com

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