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DESIGN OF THE USABILITY MEASUREMENT TOOL FOR MULTIMODAL MOBILE APPLICATIONS

Ahmed Sheikh Abdullah Al-Aidaroos[a*], Ariffin Abdul Mutalib[b]

[a]Faculty of Engineering and Computer Science, Al-Ahgaff University, Hadhramaut, Yemen
[b]School of Multimedia Technology and Communication, Universiti Utara Malaysia, Kedah, Malaysia

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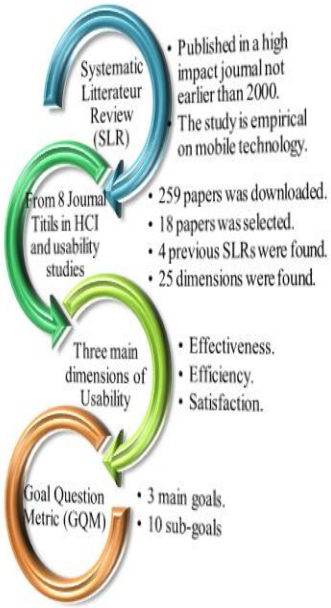
*Corresponding author
mr.alaidaroos@gmail.com

Graphical abstract



Abstract

Nowadays, mobile phones provide not just voice call and messaging services, but plethora of other services. Those computational capabilities allow mobile phones to serve people in various areas including education, banking, commerce, travelling, and other daily life aspects. Meanwhile, the number of mobile phone users has increased dramatically in the last decade. On the other hand, the usability of an application can usually be verified through the user interface. Therefore, this paper aims to design a measurement tool to evaluate the usability of mobile applications based on the usability attributes and dimensions that must be considered in the interface. To obtain the appropriate attributes, a Systematic Literature Review (SLR) has been conducted and the Goal Question Metric (GQM) has been used to design the tool. From 261 related works only 18 most relevant ones were selected, through four SLR. 25 dimensions were found through the SLR, but some of these dimensions are synonymous or a part of other dimensions. Consequently, three dimensions must be included in any usability evaluation instrument, which is broken down into ten sub dimensions.

Keywords: Usability tool, usability evaluation, multi-modality, mobile Apps

Abstrak

Kini, telefon mudah alih menyediakan bukan haya perkhidmatan panggilan dan penghantara mesej, malah pelbagai perkhidmatan lain. Dengan kepelbagaian tersebut, telefon mudah alih mempu melayan pengguna dalam pelbagai bidang termasuk pendidikan, perbankan, perdagangan, pelancongan, dan lain-lain aspek kehidupan harian. Sementara itu, jumlah pengguna telefon mudah alih sentiasa bertambah dengan pesat sejak sedekad lalu. Dalam hal lain, kebolehgunaan sesebuah aplikasi boleh diukur melalui antara mukanya. Justeru, kertas kerja ini mensasar untuk mereka bentuk satu alat bagi mengukur kebolehgunaan aplikasi mudah alih berdasar kepada dimensi dan ciri-ciri kebolehgunaan yang dibenam ke dalam antara mukanya. Bagi mendapatkan elemen-elemen yang sesuai, Pengkajian Karya secara Sistematik (Systematic Literature Review (SLR)) telah dijalankan, dan Metrik Soalan Bermatlamat (Goal Question Metric (GQM)) telah digunakan bagi mereka bentuk alatan pengukuran. Melalui 261 kajian lepas, hanya 18 yang paling berkaitan telah dipilih, melalui empat SLR. 25 dimensi telah ditemui melalui SLR, tetapi dimensi-dimensi tersebut mempunyai banyak persamaan. Hasilnya, tiga dimensi perlu dimasukkan dalam mana-mana instrumen kajian, yang diperincikan ke dalam sepuluh sub-dimensi.

Kata kunci: Alatan kebolehgunaan, penilaian kebolehgunaan, pelbagai kaedah, aplikasi mudah alih

1.0 INTRODUCTION

Today, mobile technology is applied in a wide range of our daily activities [1]. It is rare to get a person who does not have a cell phone [2]. In addition, the mobile devices are regarded as very flexible devices because they are easy to handle and to be used everywhere by the users [3]. According to [4], mobile phones have become powerful useful devices that can carry out professional services and applications such as Global Positioning System (GPS) functionalities, E-Banking, email clients, and web browser besides to the typical functions like contacts, calendar, diary, notepad, and voice recorder [5]. With such utilities, more than 3.3 billion mobile connections have been in place worldwide, and the number is increasing daily [1]. By employing the mobile applications, different interests can be gained in various domains such as health [6], tourism [7], education [8], transportation [9], logistics [10], disaster [11], and management [12, 13]. Since mobile applications support the requirements of various users, it is essential that the mobile applications are useful as well as usable in order to be successful [1].

Consequently, the usability of an application can usually be verified through the user interface [14]. Therefore, many usability methods (such as the semi-Automated Interface Designer and Evaluator (AIDE) [15] and Metrics for Usability Standards in Computing (MUSiC) [16]) and models (such as the Skill Acquisition Network (SANe) and the Diagnostic Recorder for Usability Measurement (DRUM) [17]) have been introduced, but all those methods and models still have a number of limitations and not focusing on mobile application. As a response to that, this study aims to design a measurement tool that is able to evaluate the usability of multimodal mobile applications based on the International Organization for Standardization (ISO) standards as well as the usability attributes and dimensions that must be considered in the application interface designing

After a brief introduction on the importance mobile technology in our daily life, this paper reviews some of the current methods and models that have been introduced to evaluate the application usability. The rest of this paper is organized as follows; section 2 gives a brief background about usability and ISO standards. Section 3 reviews some of the related studies in the field, while the methods and results were described in section 4. Finally, the conclusion and future outlook are discussed in section 5.

2.0 BACKGROUND

2.1 Usability

Usability is known as a quality attribute, which can measure how the User Interface (UI) is usable for various users' profiles [18]. Formally, the ISO defines the usability as "the capability of a product to be understood, learned, operated and be attractive to users when used to achieve certain goals effectively and efficiently in specific environments" [19, 20]. From the definition of usability, four factors can be extracted. Those factors which are users, tasks, environments, and technologies can strongly influence the usability of mobile applications [1]. The first factor is the variety of user profiles (novice users, knowledgeable intermittent users, and expert users) [14]. This means different skill levels can directly affect the product usability. In other words the previous experience with the product itself or similar product is likely to affect the usability of the product. In the other hand, it is clear that a product which is usable for the able-bodied users will not necessarily usable for disabled users [21].

The second factor in the definition of usability is task, which refers to steps to do in achieving objectives. In different cases, objectives require a set of steps. Some developers prefer to give the users the possibility to performing the task using more than a single way; they embrace all the possible ways to perform the task in order to be helpful to the users. But unfortunately, this causes chaos and overcrowding [22]. Three levels of task can be defined as frequent tasks, less frequent tasks and infrequent tasks, and the complexity of a task is indicated by the number of steps to complete that task successfully [14]. Frequent tasks can be performed in a single action by pressing a button or key and so on, but less frequent tasks involve two actions only, whereas infrequent task requires more than two or three actions [23].

The third usability factor is environment, which refers to the periphery or the conditions which the product uses in performing the user's task [24]. Also, it refers to the data and the device capabilities and connection's consistency [25]. It can be factors such as user's social conditions, noise, temperature, bandwidth, and network connectivity between the connected devices [1]. Finally the last usability factor is technology, which refers to the device's specifications and features, and software and hardware. For example the input and output mode of data have direct effects over usability.

2.2 ISO 9241-11 Standards

According to [1], more than 27 dimensions were found in previous studies of the mobile usability. Some of those dimensions can be referred to, combined, or considered as other dimensions. The most commonly used dimensions are effectiveness, efficiency, and satisfaction [1, 20, 22]. While the efficiency and effectiveness are clearly mentioned in the usability definition [14], satisfaction has been implicitly mentioned by using the word "attractive"[24]. Effectiveness refers to the extent of success of task. Also, effectiveness in some cases simply means success or failure of tasks. As an example, in a condition the user task is to play a sound file. It is successful if the sound file is started and the sound is audible. In contrast, it is a failure if it is not. Nevertheless in some cases, effectiveness of tasks could be measured by the percentage of the

achievement of a particular goal, for example in network if the sender's goal were to send 100 KB per second; as a result the effectiveness level is 90% if sender was able to send 90 KB per second.

Meanwhile, efficiency refers to the cost or the efforts required to perform required tasks or to achieve the goal. It is refers to the time spend to perform the task or the number of steps or errors to complete the task. In other words, it refers to the complicity of performing tasks. Generally, the greater number of errors or the more time taken reduces the efficiency. For example, when sending 100 KB or 90 per second, it is less efficient if the processor is reserved completely for the task only more than if the processor still can perform another task while performing the task [22, 26].

On a contrary, satisfaction refers to the user's comfortable feeling level when using a product and the users' acceptance of the product in terms of achieving their requirements and goals [21]. Higher than the effectiveness and efficiency, satisfaction is a more subjective aspect of usability and it is the most complicated to assess. There have been many cases where satisfaction is the most significant usability consideration, but the importance of satisfaction does not eliminate or reduce the importance of effectiveness and efficiency [22, 26].

3.0 PREVIOUS STUDIES AND RELATED WORK

Many studies have been conducted to develop models or frameworks assess the usability of mobile applications and determine it is contextual factors [1, 27-30]. One of those studies has adapted a framework which can be used to evaluate the usability of the mobile computing context. This study was conducted by Coursaris and Kim [28], where they reviewed about 100 empirical studies in the field of mobile usability in a qualitative meta-analytical review. The results show the usability contextual factors and it is dimensions. Another study conducted by Treeratanapon [30], he try to develop a framework to evaluate the usability of mobile applications which designed by the free developers in the various platforms. This study was adopted from Technology Acceptance Model (TAM) model and the ISO 9241 standard. This study relied on three dependent variables and two independent variables to measure usability. The dependent variables of the study were efficiency, effectiveness and satisfaction while the group of users and the mobile operating system were the independent variables. According to [30], he use the time required to finish the tasks to measure the efficiency and the correctness to measure the effectiveness while the satisfaction was assessed by asking the respondents about their satisfaction immediately after using the application and finishing the tasks. iOS and Android were the platforms conducting this study, whereas the participants in this study divided in to three groups: novice, experience, and expert.

Moreover, in 2013 three researchers from the Universiti Kebangsaan Malaysia had conducted a study aimed to propose a set of usability dimensions that should be considered during the mobile applications designing and evaluation processes [1]. In this study, the relevant previous studies were reviewed then analyzed using the content analysis approach. The analysis process found that there are twenty-five dimensions directly affect the usability of the mobile applications. Based on their importance, these dimensions have been prioritized and re-synthesized to select the most important ten to be used in the proposed model which can be used as guideline to develop a usable mobile application.

4.0 METHODS AND RESULTS

4.1 Systematic Literature Review (SLR)

SLR defined as a formal literature review of the high quality studies related to a specific research matter in order to identifying, appraising, selecting and synthesizing all the evidence relevant to that matter [31]. It is considered as a key element of the evidence-based studies in healthcare [32], but it is used other fields too such as information systems [33]. This study employed SLR in order to acquire the usability dimensions of mobile applications. [31] outlines that SLR consists of three main steps which are planning, conducting, and reporting the review.

Planning: In this study SLR has been conducted to address the usability dimensions of mobile applications. Therefore, the keywords "Usability", "Evaluation", and "Mobile" have been used to retrieve the relevant studies. Four criteria as the basis of selecting references are: (1) the study has been published in a high impact journal in Human – Computer Interaction (HCI) or Usability Studies (see Table 1) (2) published not earlier than 2000, (3) empirical study, and (4) on mobile technology.

Table 1 The List of Selected Journals Titles in HCI and Usability

Journal Title (Short Title)	Publisher	Candidate	Selected
Computers in Human Behavior (CHB)	Elsevier	52	6
Human-Computer Interaction (HCI)	Taylor & Francis	25	0
Interacting With Computers (IWC)	Elsevier	44	2
International Journal Of Human-Computer Interaction (IJHCI)	Taylor & Francis	82	5

Journal Title (Short Title)	Publisher	Candidate	Selected
International Journal of Mobile Human Computer Interaction (IJMHCI)	IGI Global	15	1
Journal of Usability Studies (JUS)	Usability Professionals' Association	17	2
Transactions on Computer - Human Interaction (TOCHI)	ACM	26	2
Total		**261**	**18**

Conducting the Review: This phase involves identifying, selecting, and evaluating the primary studies based on the research question that formulated in the first step, while the exclusion and inclusion of the studies was conducted according to the criteria of the review protocol that is developed in the planning phase. However, based on [34] in SLR before identifying primary studies there is a need to make sure that this work has not been done previously in order to avoid repetitions and waste time. Therefore, in this study performed a quick search about the previous meta-analysis and systematic reviews that addressed the same research question "the usability evaluation in mobile" by using the same protocol. In fact, four studies have been founded in which the same research question has been addressed by using the same research protocol [1, 27, 28, 35]. Accordingly, the research protocol time limit has been changed to retrieve the studies that have been published from 2013 up to now.

In order to minimize any omission of relevant studies, the reviews were performed based on multiple databases. 261 journal articles have been downloaded. These articles have been reviewed and 18 articles only were selected based on the criteria that have been defined in the planning phase as showed in Table 1.

Reporting the Review: In this step the 18 selected studies' have been analyzed carefully and summarized. This study focused on the measures that have been addressed in selected studies to measure and evaluate the usability. The Analysis process highlighted 25 measures have been circulated in the previous meta-analysis and systematic reviews that addressed the same research question in this study. Table 2 shows the usability measures that obtained from the previous SLRs.

Table 2 The Original List of Usability Measures in the Previous SLRs

No.	Measures	2006	2009	2011	2013	No.	Measures	2006	2009	2011	2013	No.	Measures	2006	2009	2011	2013
1	Effectiveness	√	√	√	√	2	Efficiency	√	√	√	√	3	Satisfaction	√	√	√	√
4	Errors	√		√		5	Attitude	√		√		6	Learnability	√		√	√
7	Accessibility	√		√	√	8	Operability	√		√	√	9	Accuracy		√	√	
10	Acceptability	√		√	√	11	Flexibility	√		√	√	12	Memorability	√		√	√
13	Ease of use		√	√		14	Usefulness			√	√	15	Utility			√	
16	Playfulness			√		17	Simplicity		√		√	18	Attractiveness		√		√
19	Safety		√		√	20	Intuitiveness				√	21	Aesthetic				√
22	Consistency				√	23	Adaptability				√	24	Reliability				√
25	Understandable				√												

The results of contents analysis showed that the selected studies focused clearly on the usability measurements defined by ISO 9241-11 which are effectiveness, efficiency, and satisfaction, while the other measures came independently or listed under these three measurements according to the nature of the study. However, some of these measurements are synonymous or a part of other measures. Therefore, the original list has been collapsed by combining the synonymous measures to each other under one name as well as incorporating the sub measures under the main measures. Figure 1 illustrates the usability main measures defined by ISO 9241-11 and it is sub-measures as well as the using percentage of each measure in the selected studies. Meanwhile the next paragraph explains how the 25 measures collapsed to ten sub-measures under the mean three measures.

From 18 selected studies 88.9 % of the studies used the effectiveness as one of the measures in the usability evaluation instrument, whereas efficiency and satisfaction were utilized in 77.8% of the selected studies. In the same context, rest of measures mentioned in the usability evaluation instruments of the selected studies by the following percentages: usefulness 83.3%, errors 44.4%, simplicity 94.4%, reliability 38.8%, ease of use 77.8%, safety 16.6%, flexibility 27.8%, accessibility 22.2%, attitude 66.6%,

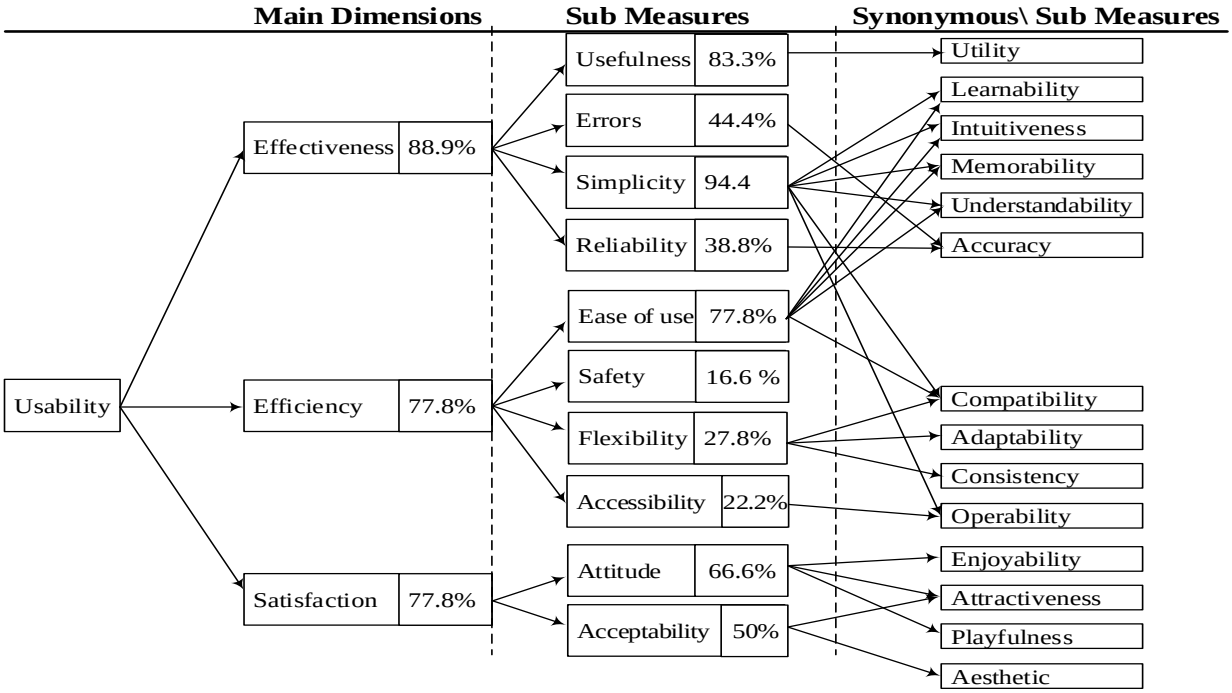


Figure 1 The Usability Measures in Mobile Applications

and acceptability 50%. However, according to [36], errors, usefulness, reliability, and simplicity can be collapsed with effectiveness. Similarly, [37] collapses utility, accuracy, and intuitiveness with effectiveness. In the other hand, the system must be learnable, understandable, memorable, and intuitive in order to be simple [38], whereas, reliability means accuracy [39]. Furthermore, efficiency means ease of use [40]. Meanwhile safety, flexibility, and accessibility can be collapsed with efficiency. Moreover, flexibility means consistency, adaptability, and compatibility [41], while accessibility means operability [42]. However, based on [43] satisfaction refers to attitude which means the user's comfortable feeling level when using a product. Whereas its means acceptability which means the users' acceptance of the product in terms of achieving their requirements and goals [44]. In the other hand, enjoyability, attractiveness, playfulness, and aesthetic are a part of satisfaction and all refer to the degree of the user's comfortable feeling when using the product [45].

4.2 Goal Question Metric Approach (GQM)

According to [46] GQM is an approach used to create usability metric and guideline as well as usability measurement instrument. GQM is a hierarchical structure form two steps begins with goals and ends with a set of questions able to measure those goals. Therefore, the first step is to determine the sub-goals of each goal, after that refining each sub-goal into several questions. In this study an instrument to evaluate usability of mobile apps is going to be developed, so each usability dimension is considered as a goal. One of those goals is efficiency which has sub-goals such as ease of use, safety, flexibility, and accessibility as explained in Figure 1. The instrument items can be adapted from previous instruments developed by HCI community that measure user interface satisfaction , usefulness and ease of use such as the Questionnaire for User Interaction Satisfaction (QUIS) [47], Perceived Usefulness and Ease-of-Use (PUEU) [48], Post Study System Usability Questionnaire (PSSUQ) [49], Software Usability Measurement Inventory (SUIMI) [50], Purdue Usability Testing Questionnaire (PUTQ) [51], and the questionnaire of Usefulness, Satisfaction, and Ease of use (USE) [52] as well as the instrument developed to evaluate usability specifically in mobile apps such as Usability Issues for Mobile Devices (UIMD) [53], Usability Questionnaires for Electronic Mobile Products (UQEMP) [54], and Usability Metric Framework for Mobile Phone Application developed by [35]. Therefore, the new instrument can used to measure the usability of mobile application in the crowded environments after selecting the appropriate items that related to the obtained measures depending on the nature of the study that will use the instrument.

5.0 CONCLUSION AND FUTURE OUTLOOK

This paper explains how to develop a usability evaluation instrument for multimodal mobile applications using GQM approach. Therefore, to obtain the appropriate measurements of this instrument, a SLR has been conducted on the empirical studies on mobile usability evaluation that

has been published in a high impact journal in HCI or Usability Studies not earlier than 2000. Four SLRs have been conducted previously in which the same research question has been addressed by using the same research protocol. Therefore, the research protocol time limit has been changed to retrieve the studies that have been published from 2013 up to now. In fact, 25 dimensions were found in the previous SLRs, but they were collapsed to ten dimensions under three main dimensions that must be included in any usability evaluation instrument. Finally, as future outlook the instrument items will be adapted from previous instruments developed by HCI community that measuring the obtained attributes from SLR and will be tested in terms of reliability and validity in a pilot study.

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