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Research Article

Usability Dimensions for Mobile Applications-A Review

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Abstract: Usability has been increasingly recognized as a significant quality dimension to determine the success of mobile applications. Due to its importance, a number of usability guidelines have been proposed to direct the design of usable applications. The guidelines are intended particularly for desktop and web-based applications. Mobile applications on the other hand are different in many ways from those applications due to the mobility nature of mobile devices. To date, the usability guidelines for mobile applications are very limited. They in fact are isolated, which makes usability evaluation for mobile devices more difficult. This study aims to address this issue by proposing a set of usability dimensions that should be considered for designing and evaluating mobile applications. The dimensions are illustrated as a model that considers four contextual factors: user, environment, technology and task/activity. The model was proposed based on the reviews of previous related studies, which were analyzed by using content analysis approach. Twenty-five dimensions were found from the analysis. The dimensions however were synthesized and prioritized based on their importance towards designing usable mobile applications. As a result, ten most important dimensions were outlined in the model. The model can be used by practitioners and researchers as a guideline to design usable mobile applications and further research can be conducted in the near future.

Keywords: Empirical studies, evaluation, mobile applications, usability

INTRODUCTION

Mobile phones have become a popular device in people's daily life up to business. Statistics show that nearly 3.3 billion mobile connections exist worldwide and the number is increasing every day. Trends in the Information Technology (IT) and purchasing policies indicate that individuals use their personal phone for work (Sean, 2006). Mobility business has become mainstream and it is predicted that there will be more than 1.3 billion mobile workers by Stacy *et al*. (2011). This situation has caused mobile applications to emerge as corporate IT initiatives that need to support the organizational functions.

Activities in business shall be mobilized in order to maintain its sustainability and competitiveness (Azham and Kutar, 2009; Bahn *et al*., 2007). Multiple domains have gained benefits from the usage of mobile applications such as logistics, disaster, tourism, transportation and project monitoring and management activities (Chittaro and Zuliani, 2007; Holzinger and Errath, 2007; Chen and Zhu, 2010; Lee *et al*., 2011; Monares *et al*., 2011; Wang *et al*., 2011; Ochoa *et al*., 2010). As mobile applications support various spectrums of users including both technical and business, they ought to be not only useful but also usable.

Usability is defined as the capability of a product to be understood, learned, operated and be attractive to users when used to achieve certain goals with effectiveness and efficiency in specific environments (Bevan, 1995; Hornbæk and Lai-Choong, 2007; International Organization for Standardization, /IEC 9126-1, 9241-11, 2002). Usability of a product is normally demonstrated through its interfaces. To ensure software products could meet this quality, a number of usability guidelines and standards have been introduced. They however are generic rules to guide the design and implementation for web and desktop applications. Usability guidelines for mobile applications are still lacking and relatively unexplored and unproven (Azham and Ferneley, 2008; Gong and Tarasewich, 2004). Even several usability guidelines for mobile applications do exist, they are isolated and disintegrated. This issue is critical as existing usability guidelines are insufficient to design effective interfaces for mobile applications due to peculiar features and dynamic application context in mobile (Glissmann *et al*., 2005; Holzinger and Errath, 2007; Azham and Ferneley, 2008; Chittaro, 2011).

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This study is intended to review existing studies on usability for mobile applications in order to identify and prioritize the usability dimensions based on importance. The review could act as a starting point to introduce more appropriate guidelines for mobile applications. The study is organized as follows:

- **Background:** Discussion on related work concerning usability
- **Methodology:** Describe the method used in this study
- **Results and findings:** Explain the results of the study
- **Discussion:** The discussion and contribution
- **Conclusion:** Conclude the study with a summary of the main findings and future work

Thus, this study represents comprehensive review on usability guidelines for mobile application.

LITERATURE REVIEW

Usability has been an important quality in the development of application as well as product (Seffah *et al*., 2006; Bahn *et al*., 2007). Various definitions of usability can be found in the literature, as listed in Table 1.

Usability is also discussed from a broader perspective. Nielsen (1994), visualized usability as a good and usable user interface, which grounded all possible usability issues. He proposed several usability guidelines such as user friendliness, ease of navigation, learn ability, well integration of functions, consistency and simplicity of design as guidance for designers. From engineering perspectives, usability is defined from 2 aspects which are hardware (physical) and software (system) (Han *et al*., 2001). The physical aspect refers to the physical characteristics of product such as screen display, button and indicator. It also refers to the performance achieved in order to fulfill user satisfaction.

Coursaris and Kim (2006) have attempted to produce a roadmap for future usability research. This is to fill in the gap of different definitions and operations of usability between research efforts and practitioners of mobile products. They adapted the framework proposed by Han *et al*. (2001), which comprises a taxonomy of empirical usable mobile. They performed a qualitative review of 45 empirical usability studies that were published from year 2000 until 2006. The review revealed four elements: the contextual factors; the definitions and measures of core dimensions; the exploration of peripheral dimension; and key findings. The four contextual dimensions are user, environment, technology and task/activity.

Heo *et al*. (2009) research work has developed a framework for usability evaluation considering eight requirements to develop a multi-level hierarchical model. The study has concluded that fact-based, modularization, hierarchical, optimization, user-oriented, implementable, context-based and design oriented are the requirements for a good evaluation framework. The usability evolution discussed in the framework covers effectiveness, usefulness, efficiency, consistency, compatibility and understandability.

Biel *et al*. (2010) applied hybrid technique to identify usability issues in his research work. According to Biel, a usability evaluation should focus on the usage problems based on application and human errors. The evaluation task employed scenarios to measure interaction capabilities whereas mobile usage behavior used user profile and persona. Several techniques were used such as user interface walk-through on prototype to determine important interaction and visible usability problems; run analysis scenario to identify suitable scenarios which describe usability requirements and interactions; and the use case technique to evaluate components, interface and design patterns. The study proposed several dimensions, namely useful, error, understandable, learn ability, satisfaction and intuitiveness.

Kenteris *et al*. (2011) studied user experience towards mobile tourist applications. A task was given to the users, which was to download tourist information from infokiosk or via Internet into their mobile devices. The exercise was conducted in the laboratory and on field via Bluetooth and mobile adhoc network. There were 20 users with the age range from 20 to 53 years

Table 1: Usability definitions

Sources	Usability definitions
Bevan (1995)	"The capability to be used by humans easily and effectively"; "quality in use"
Hornbæk and Effie (2007)	"The effectiveness, efficiency and satisfaction with which specified users can achieve goals in particular environments"
ISO/IEC 9126-1	"The capability of the software product to be understood, learned, used and be attractive to the user, when used under specified conditions"
ISO 9241-11	"Usability refers to 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"

old and two usability specialists who employed heuristic evaluation. The study found that the usability dimensions that fit such applications are effectiveness, efficiency, learn ability, user satisfaction, simplicity, comprehensibility, perceived usefulness and system adaptability.

Holzinger *et al*. (2011) studied usability designs for mobile cancer systems using iPhone and iPad. The study started with project requirements, clinical context and environment, primary end-user (patient), secondary end-user (medical professional) and stakeholders (hospital manager). The User Centered Design (UCD) method was used to identify four main user requirements: user usage for the patient; sufficient data control function on minimizing error; transfer questionnaire into mail application; and easy manual. It applied four stages of application development: paper mock up studies, low-fidelity prototype, hi-fidelity prototype and development system testing. The study has identified a few guidelines which are learn ability, ease of use, functionality, easy manual, useful, usable, enjoyable, safety, security, efficiency, effectiveness, satisfaction, aesthetic and minimalist and simplicity.

Raita and Oulasvirta (2011) have discovered an interesting aspect of usability evaluation. The empirical study tested on the expectation aspect. For objective usability, task success and task completion were measured while subjective usability used task-specific and post-experiment. The study indicated that user expectation strongly influences usability rating that may overshadow good performance. This implies that usability evaluation is discovering not just usability problems but also revealing how future users will experience and perceive the product in their daily life. The usability dimension highlighted by this study is attractiveness.

Previous studies indicated the existence of high correlations between simplicity and usability compared to other dimensions. For example, Choi and Hye-Jin (2012) investigated the impact of simplicity towards user satisfaction. Simplicity comprises three dimensions: aesthetics, information architecture and task complexity. To validate the relationship, scenario-based tasks were performed as a survey that involved 205 users. The findings of the study have shown that a simple interface design contributes to positive user satisfaction.

There are studies that investigated the relationship between aesthetic and usability. Tuch *et al*. (2012) defined aesthetic as beauty, classical expressive and hedoaestheticsty. The empirical results show that hedonic does not affect usability. Furthermore, beauty is usable only when aesthetic enhances the perception of usability. Similarly, Moshagen and Thielsch (2010) studied aesthetic to measure the critical effects towards satisfaction and pleasure.

Mobile applications use interactive interfaces, which are apparently complex and often faced with usability issues such as information overload, screen clutter, lack of task support and limited interaction mechanisms (Wesson *et al*., 2010; Ali *et al*., 2012). This complexity can be seen from mobile devices' features. They are equipped with a quality miniaturized sensor with highly diversified interaction styles and connected through high bandwidth network (Ali *et al*., 2012). Despite these advantages, their limitations are in terms of small screen size, different input styles, small keypad, small memory and short battery life (Holzinger and Errath, 2007). Therefore, existing interface design principles and guidelines requires customizations before they could be adopted into mobile applications (Heo *et al*., 2009).

As a summary, a number of usability dimensions were introduced by previous studies to measure usability of mobile-related applications. Each model measures different aspects of usability and emphasizes on different levels of priority. In order to ensure a holistic usability design and evaluation of mobile applications can be executed, the findings from those isolated studies need to be integrated as one unified model as described in results and findings section.

METHODOLOGY

The purpose of this study is to provide a practical usability guideline that could help researchers and practitioners to design and measure usability of mobile applications. The guidelines contain a set of usability dimensions that are important to design and measure the usability of such applications. The guideline was proposed by reviewing previous studies on mobile usability. In general, this study aims to answer the following Research Questions (RQs):

What are the necessary usability dimensions for mobile applications?

How these dimensions can be viewed as one unified model?

The reviews were performed based on multiple databases to minimize the omission of relevant studies. The studies considered in this study were journals from high-rank publications concerning the field of usability. The keywords used in the searching were "usability", "mobile" and "evaluation" for articles that were published from year 2000 until 2012. The data were analyzed to determine the usability dimensions measured in these empirical mobile usability studies. They are clearly defined as usability dimension as

Table 2: Usability dimensions for mobile applications

Dimension	Count	(%)
Effectiveness	5	55
Efficiency	5	55
Satisfaction	5	55
Usefulness	5	55
Aesthetic	5	55
Learn ability	4	44
Simplicity	4	44
Intuitiveness	3	33
Understandable	2	22
Attractiveness	2	22
Accessibility	1	11
Memorability	1	11
Acceptability	1	11
Flexibility	1	11
Consistency	1	11
Adaptability	1	11
Operability	1	11
Reliability	1	11

The list is based on 9 empirical studies: Coursaris and Kim (2006) Heo *et al*. (2009) Biel *et al*. (2010) Kenteris *et al*. (2011) Moshagen and Thielsch (2010) Holzinger *et al*. (2011) Raita and Oulasvirta (2011) Choi and Hye-Jin (2012) and Tuch *et al*. (2012)

described in previous studies. Next, all dimensions are grouped according to the frequency of being tested. The results of this analysis are shown in Table 2 in the next section.

This study focuses only on empirical studies, as these dimensions have been proven in real settings rather than in theory. In total, there are nine empirical studies considered in this study. One of the studies also reviews previous studies from year 2000 up until 2006 (Coursaris and Kim, 2006). In this study, Coursaris and Kim (2006) review the findings from 45 empirical studies that have been analyzed and synthesized with the findings from eight recent studies (year 2006-2012). Coursaris and Kim (2006) adapted the taxonomy of empirical usable mobile proposed by Han *et al*. (2001). As a result, the proposed guidelines in this study have originated from those two significant studies.

RESULTS AND FINDINGS

Different dimensions of usability should be highlighted in designing and evaluating a product. There are 4 contextual factors that should be considered within the usability dimensions: user, environment, technology and task/activity (Han *et al*., 2001). Identifying usability dimensions based on these contextual factors is seen as sufficient as they are comprehensive and support closely Human-Computer Interaction principles.

Mobile user: Most studies discover the user profiles as an important requirement for user evaluation. User profile and persona are used to analyze and determine requirements pertaining to user context and have become an established method in user centered design (Biel *et al*., 2010; Holzinger *et al*., 2011). According to Coursaris and Kim (2006), user characteristics can be obtained from demographic data, traits and intelligence, job or tasks and skill status either expert or novice.

Mobile task: A task can be visualized as a use case scenario based on product operation or application task. Biel *et al*. (2010) have categorized task as functionality, workflow, interactions, duration, type, complexity and dependency. Task difficulty can be measured in terms of product expectations (Raita and Oulasvirta, 2011).

Mobile technology: Device profile can be categorized by device characteristics and features, hardware, software and network connectivity (Biel *et al*., 2010). As this study concerns mobile devices, it covers the characteristics pertaining to mobile technology. Heo *et al*. (2009) defined mobile devices as portable, self-contained information to the communication system. Three main features of mobility: they use user's hands, operated without cables, support applications and connected through the Internet (Ali *et al*., 2012).

Mobile environment: The environment can be viewed as geographic location, environmental data such as temperature, noise, social conditions such as a group of users or event that take place. It also covers the stability of connections and the capabilities of device to collaborate with others (Biel *et al*., 2010).

In terms of usability dimensions for mobile applications, Table 2, lists the dimensions that were found from the related studies. The dimensions are ranked based on counts, that is, how many times they were found in previous studies.

This study employed the same summarization technique used by Cousaris and Kim (2006) in reviewing empirical mobile usability studies. Table 2 shows that the top 3 measurements remain the same. This indicates that even after 6 years (2006-2012), effectiveness, efficiency and satisfaction are still given the highest priority in usability studies concerning mobile applications. The 4th most frequent dimension however has been overridden by usefulness. In 2006, it was learn ability.

Originally, there were 25 dimensions found from the reviews. There are 7 dimensions, which are not listed in Table 2 as explain subsequently. Rather, they were combined with the more prominent dimensions that carry similar meanings. For example, error is

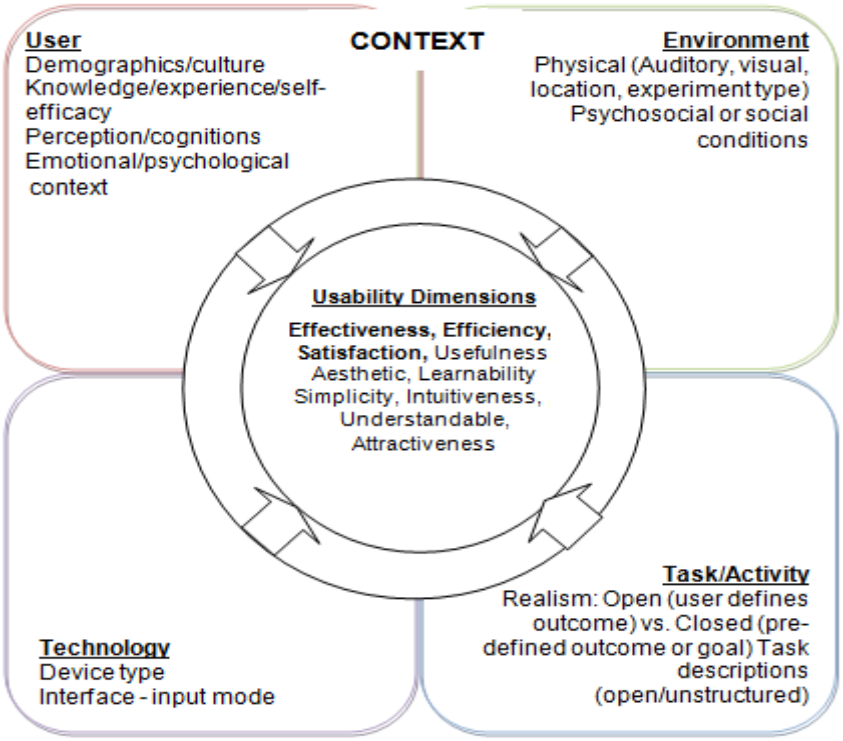

Fig. 1: Model of usability dimension base-on four context factors

considered as effectiveness and attitude as satisfaction (Coursaris and Kim, 2006). Compatible refers to the extent to which user interface is physically compatible with human abilities and limitations of input and output of information process. Hence, it can be combined under efficiency, which means the degree to which the product enables the tasks to be performed in a quick, effective and economical manner (Han *et al*., 2001). Similarly, comprehensibility is defined as completeness of jobs done. It thus can fall under effectiveness. Minimalist design means dialogs that contains non irrelevant information, which also entails simplicity. Enjoyable measures the feeling of a product. Therefore, enjoyable can be generalized under attractiveness, which refers to the degree to which a product is pleasing, charming and arousing interest (Han *et al*., 2001). Lastly, safety and security refer to data privacy and security, concern and assurance. Reliability is defined as a feeling that a product is dependable, fit to be trusted or confident. Consequently, safety and security can be generalized under reliability.

DISCUSSION

In order to answer the second RQ, the findings are discussed in the earlier section and illustrated as a model in Fig. 1. This model is based on Cousaris and Kim's (2006) qualitative review framework. This model represents 4 contextual factors, which are graphically drawn as 4 connected boxes. The usability dimensions considered in this model are the ones which were found at least twice (count = 2) in previous studies. Dimensions that appeared only once (count = 1) is seen as insufficient to justify the importance. Therefore, they were omitted. The final usability dimensions include the top 10 usability dimension in Table 2.

The profile of each contextual factor needs to be identified to illustrate the future potential application. In addition, the relationships between contextual factors need to be analyzed. User profile and demography are essential when applying UCD approach. It defines the characteristics of potential users and design the information required by them, which is normally within the context of task and activities. For example, the users of health mobile applications comprise medical practitioners and patients who are interested in health information such as food nutrition, food ingredient and medication. The information is more suitable to be presented in textual and figure forms, rather than pictorial. In contrast, tourist mobile applications require the information to be presented as graphics with more interactive tasks such as navigation of interesting places.

On the other hand, the environment context factor allows the ability to visualize the actual scenario when

using specific applications. Mobile applications are normally used in an unspecified environment where it can be in the public or private mode. Therefore, designers need to consider the possible situations and focus on the reliability of the data. Data won't be missing during interference when user is unable to finish the tasks.

Technology contextual factor is important especially during technology evolution. Each device has its own strengths and weaknesses. For example, the major difference between desktop and mobile devices is the size of screen. Websites that are meant for desktops are thus inappropriate to be browsed using mobile devices. Even though mobile devices equip with scroll feature, it tends to cause tiredness. Consequently, this will affect its usability. Designers therefore need to design dedicated web pages for mobile devices that consider their specific features and constraints.

It is believed that the usability dimensions of mobile applications are dynamic due to the mobility nature of mobile devices. Their levels of importance are strongly influenced by the four contextual factors. The dimensions depend on the types of user and devices used, where and how the devices will be used as well as its purposes. Designers have to fully understand those four factors before they could prioritize and determine which usability dimensions should be considered in the design process.

CONCLUSION AND RECOMMENDATIONS

This study has presented a set of usability dimensions, which is illustrated as a unified model for mobile applications. The dimensions in the model were proposed based on the reviews of previous studies. The model consists of ten usability dimensions and 4 contextual factors. The model can be used by researchers as well as practitioners as a usability guideline for mobile application. Practitioners can use the model to determine which usability dimensions should be considered when designing and measuring usability level for mobile applications. On the other hand, researchers may extend the study by investigating how these dimensions can be operationalised as specific measurements. As mobile devices vary, researchers may also need to empirically test these dimensions for specific mobile devices with predetermined usages.

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