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THE STATE OF THE ART OF MOBILE APPLICATION USABILITY EVALUATION

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ABSTRACT

Mobile devices and applications provide significant advantages to their users, in terms of portability, location awareness, and accessibility. A number of studies have examined usability challenges in the mobile context, and proposed definitions of mobile application usability and methods to evaluate it. This paper presents the state of the art of the evaluation and measurement of mobile application usability.

Index Terms—Usability, Quality, Software Measurement, Mobile, Human Computer Interaction.

1. INTRODUCTION

Complex computer systems are finding their way into everyday life, and with a much broader customer base. This has made usability more critical. As a result, companies are seeing the benefits of designing and developing their products with user oriented methods instead of technology oriented methods, and are endeavoring to understand both user and product, by investigating the interactions between them.

Mobile devices and their applications provide significant advantages to their users, in terms of portability, location awareness, and accessibility. Lower price points and improvements in the hardware and software capabilities of smartphones in particular, the so-called "handhelds," have led to tremendous expansion of the mobile and related markets. This has led to huge numbers of mobile applications ("apps") being developed over the past few years.

This vast and increasing number of mobile apps in the marketplace has challenged developers to develop apps of superior quality in order to compete [1]. There are many aspects to the quality of mobile apps, an important one being usability. Furthermore, the architecture of these applications must take into account a number of design constraints, such as limited resources, connectivity issues, data entry models, and the varying display resolutions of mobile devices.

The usability of mobile devices and their apps differs from other computer systems, because their characteristics are different. The software needs of handhelds, such as PDAs and mobile phones, affect the development process of mobile apps, as these are embedded in the phones during manufacturing or installed by customers from various mobile software distribution platforms, such as Apple's App Store and Google's Android Market. Users tend to choose mobile apps that are easy to learn, take less time to complete a particular task, and appear to be more user-friendly because they are less computer-oriented.

In the past, the usability of software systems was evaluated subjectively and the process was not well defined. Researchers would select the aspects of usability to evaluate and measure what they considered important. At the same time, usability measurement and analysis methods and methodologies were being developed. Lab experiments, field studies, and hands-on measurement are some of methodologies most often applied by researchers [2][3][4][5].

Every usability evaluation method has its advantages and disadvantages. Some are difficult to apply, and others are dependent on the measurers' opinions or instruments. In addition to these challenges, mobile devices and applications change very quickly, and updated methods of usability evaluation and measurement are required on an ongoing basis.

This paper presents an analysis of previous studies by considering: 1) up-to-date mobile technologies; 2) the challenges to defining mobile usability questionnaires; and 3) an inventory of measures for mobile usability measurement.

This paper is structured as follows. Section 2 presents some of the generic definitions of usability, as well as specific definitions of mobile usability. Section 3 presents the methodologies for evaluating mobile usability. Section 4 presents observations on the evaluation studies surveyed. Finally, section 5 presents a summary and a discussion on further work.

2. USABILITY DEFINITION

2.1 General definition of usability

It is important to consider the following three aspects of usability for all types of software:

- More efficient to use: takes less time to complete a particular task.
- Easier to learn: operations can be learned by observing the object.
- More user satisfaction: meets user expectations.

ISO 9241 defines usability 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" [6]. Abran *et al.* [7] consolidate the ISO 9241 [6], IOS 9126 [8], ISO 13407 [9], Dix *et al.* [10], and Nielsen *et al.* [11] usability models, and propose an enhanced one, referred to as the Consolidated Usability Model. This model defines usability as a combination of effectiveness, efficiency, satisfaction, learnability, and security, along with a recommended set of related measures.

More recently, ISO 25010 [12] breaks down the notion of quality-in-use into usability-in-use, flexibility-in-use, and safety-in-use. In addition, ISO 25010 defines satisfaction-in-use as:

- Likeability: satisfaction of pragmatic goals
- Pleasure: satisfaction of hedonic goals
- Comfort: physical satisfaction
- Trust: satisfaction with security

Also, it defines flexibility-in-use as context conformity-in-use, context extendibility-in-use, and accessibility-in-use.

2.2. Mobile usability definition

With the emergence and rapid deployment of mobile technologies, a number of additional studies have focused on the usability of mobile devices [2][3]: "Problems caused by physical restrictions of mobile devices and wireless networks imply that while designing and conducting usability studies for mobile applications, these issues must be carefully examined in order to select an appropriate research methodology and minimize the potential effect of contextual factors on perceived usability when they are not the focus of studies" [13]. For Zhang *et al.* [13] mobile usability includes some of the new mobility-related challenges, such as: Mobile Context, Connectivity, Small Screen Size, Different Display Resolutions, Limited Processing Capability and Power, and Data Entry Methods.

At the same time, mobile device manufacturers have been enforcing their own usability constraints. For example, the Apple iOS Human Interface Guidelines [14] states the iOS platform characteristics that should be considered during the application development process, such as: Interaction with Multi-Touch screen, Displays of different resolutions and dimensions, Device orientation changes and Gestures such as tap, flick, and pinch. In addition, Apple reviews applications submitted for the App Store based on these characteristics.

Concurrently, Google has developed Android user interface guidelines [15], which guide developers to take into account the following characteristics: Touch gestures, size and location of Icons and Buttons, Contextual Menus and their responsiveness, simplicity, size, and format of Text, and certain aspects of Messages. These guidelines also explain how these characteristics should be considered during the development and testing of Android applications.

In the next section, the methodologies presented in the literature that evaluate the usability of mobile apps are identified.

3. METHODOLOGIES FOR EVALUATING MOBILE USABILITY

Three types of evaluation methodologies are currently used in mobile usability studies:

- Laboratory experiments: human participants are required to perform specific tasks using a mobile app in a controlled laboratory setting.
- Field studies: users are provided with mobile apps and asked about their experience.
- Hands-on measurements: defined aspects of mobile apps are measured directly to evaluate usability.

3.1. Laboratory experiments

Usability laboratory experiments take place in a usability lab where the testing takes place. It is an environment in which users are studied while they interact with a mobile app to evaluate its usability.

By controlling the environment and giving predefined tasks to the users in a usability experiment, it is possible to ensure that they test all aspects of usability. The environment can also be controlled in such a way to isolate users from conditions that are not relevant to the experiment. These advantages make lab experiments useful for comparing different mobile designs and interfaces. In addition, it is possible to record users' activity while they use the mobile apps and analyze the data later.

However, isolating users from environmental factors that can affect usability may cause differences in the user experience, and the effect of environmental factors prevalent in the real world may not be felt. It is also reported that organizing lab experiments is more costly than other methodologies, because of the equipment required [13].

3.2. Field studies

A field study is a general method for collecting data about users, user needs, and product requirements that involves observation and interviews. Data are collected about task flows, inefficiencies, and the organizational and physical environments of users.

Investigators in field studies observe users while they are involved in an activity, taking notes and asking questions. The method is useful early in product development to gather user requirements. It is also useful for studying currently executed tasks and processes. The usability of a mobile app is measured based on participants performing tasks in a real environment. On the downside, sufficient control over users during a field study is not assured.

Some studies have been carried out to develop a questionnaire tailored to measure the usability of electronic

mobile products. For instance, the Mobile Phone Usability Questionnaire [MPUQ] was designed in [2] to help researchers evaluate the usability of mobile phones, in order to compare competing devices in the end-user market, and to make decisions among prototypes during the development process and among evolving versions during the iterative design process. Ryu *et al.* [2] group together factors that affect mobile usability, such as: ease of learning and use, the help and problem solving capability provided, emotional aspects and multimedia properties, commands and minimal memory load, control and efficiency, and typical mobile phone tasks. Additional questions are defined in [2] and linked to these factors.

3.3. Hands-on measurement

There are hands-on measurement methods designed to quantitatively measure the usability of a mobile application, and these require an approach defined by ISO 15939 [16]. This standard explains the measurement process for obtaining base measures using a measurement method, derived measures using a measurement function, and indicators resulting from the analysis of derived measures.

Gafni [3], for instance, in a study of mobile wireless information systems, has developed mobile device-specific usability measures, such as: display load, clarity of operation possibilities, completeness of operation menu, and display self-adjustment possibilities, their purpose and method of calculation. In addition, Gafni links these measures to three types of wireless mobile-related problems: network, device, and mobility.

Hussain *et al.* [4] define a usability metric framework for mobile phone apps, and use the Goal Question Metric approach to link usability goals, such as simplicity, accuracy, and safety, to questions and related metrics.

4. OBSERVATIONS ON THE STUDIES SURVEYED

In this section, we present our observations on the studies we identified that use either a field study or a hands-on measurement methodology. The evaluation studies in which measures and measurement methods are proposed for mobile usability are presented in *Table 1* for articles [2][3][4].

4.1 Limitations of the lab experiments

What Table 1 does not include is reference to evaluation studies based on laboratory experiments. All methodologies have advantages and disadvantages, and one of the most significant criteria is the cost of experimentation. Laboratory experiments need instruments and are therefore more costly than other methodologies. Duh *et al.* [17] compared laboratory and field test methodologies, and concluded the following: "There were many more types and occurrences of usability problems found in the field than in the laboratory. Those problems discovered tend to be critical issues regarding usability. Some of these usability problems are only related to the device being used in the field, which could not be found using conventional laboratory usability tests. With regards to the users' behaviors, users behave less positively and more negatively in the field than in the laboratory. Some behaviors can only be observed in the field. Users also take longer time to perform certain tasks and also present more negative feelings, such as dissatisfaction and difficult of use, to the use of the device in the field." This is the other reason why this methodology is not considered.

4.2. New mobile user interface needs

We observed in the literature that the questionnaires and hands-on methods developed for mobile usability measurement do not consider the user interface features provided in the newest mobile operating systems that are gaining popularity. The multi-touch gestures (e.g. the tap, flick, and pinch), device orientation changes, and location awareness are not examined.

4.3. Usability measures

The measures [16] discussed in the identified studies are often not properly defined. For example, it is not clear on what basis users are answering questions posed in questionnaires [2], such as, "Does the product have all the functions and capabilities you expect it to have?" This question is imprecise, and so the answer will be subjective and highly dependent on the user's judgment.

4.4. Measurement methods

Sometimes the measurement methods [16] are not properly explained for some of the hands-on data collected. For instance, it is not clear how what measurement methods were used to collect data such as: "Number of system resources displayed," "Number of voice assistance in a task" [4].

4.5. Single evaluation methodology

Published studies typically rely on a single methodology. However, a field study, along with hands-on measurement, could be more informative in mobile usability measurement studies. In this case, the field study is based on the experience of users, while hands-on measurement is performed by a measurement professional. Combining the two methodologies should provide more significant information for evaluation.

4.6. Mobile market rates

User given rates in app markets, such as Apple's App Store and Google's Android Market, are valuable resources for usability studies; however, the studies we examined did not consider mobile marketplace ratings.

Furthermore, there is as yet no standardized set of measures and corresponding measurement methods covering popular mobile operating systems, which can be used for benchmarking purposes to compare the usability of mobile apps.

Table 1: Summary of evaluation studies

Reference number	2	3	4
4.2. New mobile user interface needs	N	N	N
4.3. Usability measures	N	A	A
4.4. Measurement methods	N	A	P
4.5. Single evaluation methodology	N	N	N
4.6. Mobile market rates	N	N	N

A: available N: not available P: partially available

5. SUMMARY AND DISCUSSION

In this study, we looked at the mobile application usability evaluation and testing, and determined that there is no scientific research addressing the requirements of new mobile user interfaces.

We also surveyed the literature on the usability measures and measurement methods used in both field studies and hands-on measurement, and also determined the importance of mobile market rates. A study of the literature also revealed that there are no evaluation studies related to iOS mobile application usability measurement.

Future work is needed to investigate the following issues:

1) iOS Human Interface Guidelines aligned measures: a vast number of applications have been developed for this platform, and it is Apple's objective to review all applications before publishing them in their App Store. However, this is a time-consuming process, and self-review before submitting an application to the store is clearly needed.

2) A field study methodology is needed that takes the form of a questionnaire that can consider new mobile operating system needs, such as interaction with a multi-touch screen, displays of different resolutions and dimensions, device orientation changes, and gestures like tap, flick, and pinch.

3) A hands-on measurement methodology is needed that can be applied to the same application development process as considered in the field study.

Furthermore, it is necessary to define base and derived measures and their measurement methods for hands-on measurement. Defining these elements will give practitioners the ability to compare and more precisely benchmark the usability of the mobile applications.

4) Finally, there is a great deal of data on user satisfaction on the mobile application markets that can be used for analysis. In addition, these markets can help researchers collect user feedback from all over the world. At the same time, by distributing the developed applications in mobile markets, researchers can prototype and evaluate their research methodology.

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