Quantifying Mobile User Experience

Status quo, Implementation Challenges, and Research Agenda

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***Abstract*—In the last years, mobile applications (apps) have spread out to all parts of everyday life and the app market is growing rapidly. As developers and providers of mobile applications need to stay competitive in this environment, measuring the user experience (UX) of mobile applications is crucial in developing and maintaining mobile apps. In this context, methods for measuring user experience have to be applied to specific characteristics of mobile apps, such as context awareness, instable internet connections, small displays and alternative operating concepts. Against this background, this paper provides an overview of recent methods for measuring the user experience in the context of mobile applications and thus reveals research needs in this topic. We conduct a literature survey on UX related studies in the context of mobile applications of the last five years, taking into account generic methods that have been directly applied to the mobile context, methods that had been adapted, and new, mobile specific approaches. Furthermore, we propose a research agenda for the topic of mobile UX measuring.**

Keywords–User Experience (UX); Mobile User Experience; Human Computer Interaction (HCI); Mobile Applications; User Centered Design

I. Introduction

In the last years, mobile applications (apps) have been expanding to all parts of everyday life, including education, health, games, travel, shopping and work. The growing global app market is predicted to reach a total spend of over six trillion USD in 2021, which means an increase of almost four times its value [1]. According to a recent global study by the research agency App Annie, on a global average, one person uses nine apps per day and installs at least one new app per month [2]. Not only have mobile apps become an integral part in our everyday lives, but also the number of apps in the app stores is increasing. For every need, there are several alternative apps, and good user experience is needed to stay competitive. Moreover, smartphones as well as apps are becoming more complex, and challenge developers and publishers of mobile apps to sustain a good user experience. In this context, user experience does not only cover the usability of apps, but reaches out to emotional and motivational aspects of use. In order to generate a good user experience, user (experience) research needs to be a part of the conception, development and maintenance of a mobile app. Also, user analysis allows for insights in the users' habits and preferences. To reach this aim, there is a growing number of varying user experience evaluation methods for assessing different types of user experience data. Existing methods for user experience research are applied and adapted to the context of mobile applications, but there are also new approaches that have been developed specifically for this area.

Against this background, the main contribution of this work is on the one hand to provide an overview of recent methods for measuring the user experience in the specific context of mobile applications on smartphones and on the other hand to reveal research needs in this topic.

This paper is structured as follows: In Section II, the theoretical background of this work is outlined, covering general user experience models and models for measuring user experience. Section III focuses on the user experience in the context of mobile applications and smartphones. In Section IV, the results of the literature survey are presented. In Section V, the implications are discussed and challenges as well as research needs are pointed out based on the study findings. Section VI summarizes key findings and concludes this work.

II. Theoretical Background

User experience (UX) in the field of human computer interaction describes end users' experiences on interacting with a system or service. The concept of user experience can be seen from different perspectives, as a phenomenon, a field of study, or a practise. According to Roto et al. [3], the field of study investigates the experiences a person can make and how they develop. The ways to design systems in order to create a particular UX and methods for assessing UX are also subject of this research. In [4], several definitions of UX from industry and academia have been collected. Based on this work, Roto et al. [3] have developed the following definition:

"The field of UX deals with studying, designing for and evaluating the experiences that people have through the use of (or encounter with) a system. This use takes place in a specific context, which has an impact on, or contributes to, the UX."

This definition underlies the work that is presented in this paper. In order to approach this topic, we will first give an overview of different user experience models and based on that introduce models for measuring user experience.

A. User Experience Models

There is a variety of user experience models, such as [5]–[8]. In this Section, we will give a brief overview of two models from user experience practise and the description of UX in an ISO standard. The standard EN ISO 9241 describes guidelines of human computer interaction. Following

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this standard, user experience, as described in EN ISO 9241-210, can be applied to three phases of interaction: previous to the interaction, during the interaction, and after the interaction. Furthermore, EN ISO 9241-11 describes usability as one aspect of user experience that is located in the phase during the interaction.

In [7], Garrett introduces his model "*the elements of user experience*". According to this model, user experience comprises five levels –*strategy, scope, structure, skeleton, and surface*– that together form every digital product and, during the development process, have to be taken into account successively. At the first level of *strategy*, the purpose and goal of a product, as well as user requirements are specified. On the *scope* level, functional specifications and content requirements are determined. After that, the general *structure* is defined, comprising the information architecture and the interaction design that forms the background of the product's *skeleton*. On this next level, information, navigation and the interface are designed. At the top level, the *surface*, the sensory design of the product is made. While the first levels are rather abstact, the top levels are concrete and at all levels, the users' needs have to be taken into account.

Another, more comprehensive model is given by Stern [8]: The CUBI model conceptualizes user experience as four overlapping circles – *content, user goals, business goals,* and *interaction* (CUBI). Each of the circles is specified in five additional layers representig aspects that have to be considered for dealing with the particular field. The intersections of each two circles represent the four steps of a process that describes a user journey: *attraction, reactions, actions* and *transactions*. The intersections where three circles overlap are called *experience factors* and constitute primary factors of an effective user experience: *branded experience, comprehensive experience, useful experience* and *usable experience*. While the first model is more practically oriented and addressed to people who plan or develop products, the second one is theoretical and more suitable for business processes. However, both models have in common that UX is a concept that consists of several aspects where content, interaction, the users' needs and the goals of a product or service are closely intertwined. Each of these different aspects can be measured in order to assess different aspects of user experience.

B. Models for Measuring User Experience

There is a large variety of metrics and methods for measuring user experience, that are comprehensively described in user experience literature [9][10]. Prominent research in this field was done by Vermeeren et al. [11], who collected 96 methods from industry and academia and described how to use them. Though unified models for quantifying user experience are missing, there are several approaches to organize and classify existing evaluation methods. Vermeeren et al. [11] classify them regarding certain properties, such as the type of the collected data, the study type, or the development phase that the method can be used in.

Likewise, Albert and Tullis [9] established a categorization for different types of UX evaluation methods, distinguishing five types: (1) methods for assessing the performance, comprising task success, task completion time, occurring errors, efficiency, and learnability of the system; (2) issue-based methods, i.e., usability methods; (3) self-reported methods, such as rating scales and questionnaires; (4) behavioral and physiological methods, for example eye tracking, emotion tracking, heart rate and skin conductance; (5) combined methods. Our literature survey on UX evaluation methods aligned to the specifities of mobile apps and smartphones presented in the following sections will be oriented towards this classification.

Though Vermeeren et al. continued research in the field of UX measuring, as Law et al. [12], their work does not indicate, if the methods can be applied to the context of mobile applications on smartphones. However, this is a key issue for measuring UX, since mobile user experience differs from desktop user experience.

III. MOBILE USER EXPERIENCE

To our understanding and in the scope of this work, mobile apps are application software to run on mobile devices, such as smartphones, with which the functionality given by hardware and operating software can be applied to solve user-specific problems. Typically, mobile apps consist of programs and data that will be installed by the end users themselves to the devices and thus are also an important element of handset personalization. One main characteristic of mobile applications compared to classic desktop software is that they are smaller and more specific. Different from mobile web usage, mobile apps can integrate a broader spectrum of smartphone hardware functionalities and interfaces, such as taking pictures with the camera, scanning a bar code or sending voice messages using the microphone. Another characteristic of mobile applications is that its sensoric functions can contextualize the usage situation with regard to current location, phone orientiation or other ambient conditions.

Hart [13] summarizes characteristics that distinguish mobile devices from desktop computers: Mobile phones have smaller screens with fewer pixels and therefore can display less information in a less detailed way. Also, smartphones are equipped with slower processors, making them less performant, and have access to less bandwidth than desktop computers. Rather than a mouse, they have a touch-based input and a small, hard to access keyboard, making them less precise and more challenging for text input. In addition, mobile phones often provide no or only limited multitasking, meaning that it is difficult to work with more than one app at once. Different from desktop browsers, with mobile phones websites can be run in browser applets inside an app, which leads to different functionalities and views while interacting with a web page. The portrait screens are another challenge for mobile application design, since they are unfavorable for displaying more than two colums or showing overly-wide elements. Thus, navigation in mobile apps is rather guided along the top than the side. Lastly, users are using mobile devices differently, in different settings, locations and situations that desktop computers, which has a crucial influence on the UX of mobile applications.

Due to these specifics, practitioners and academics in UX often differentiate between desktop UX and mobile UX, e.g., in [14]–[18]. There are several studies that are approaching the differences between desktop and mobile UX: Selke [19] points out that due to the smaller displays, reduced bandwidth and touch technology, users feel less comfortable while using smartphones or tablets than they do with desktop computers. Furthermore, mobile usage leads to different user behavior, such as a different search behavior, a lower rate of exploration in browsing, finishing different process steps in a task, and receiving, reading and understanding a different amount of information [19]. Additionally, the UX with using mobile web and mobile apps also differs. According to Maurer et al. [20], users prefer native apps over mobile websites, and likewise Serrano et al. [21] conclude that native apps provide a richer and more solid user experience.

Against this background, content and functionalities for mobile apps need to be designed differently in order to meet these specific challenges and create a good user experience. As a result, the methods for assessing the user experience in mobile app usage also need to be suitable for this context, in order to capture the mobile UX adequately. One of the challenges for mobile UX measuring is the mobile context of use ”in the wild”. We assume that not all methods for measuring UX can be directly applied to this context. And since there is no overview on methods for measuring mobile UX up-to-date, we conducted an initial literature survey that provides an overview of the current status quo of academic user experience evaluation methods for mobile applications on smartphones.

IV. Literature Survey

The literature survey focused on academic research papers listed in Google Scholar, as this is one of the most comprehensive and publisher-independent scientific literature databases available. As we are focusing on a smartphone-based understanding of mobile applications for our analysis, we excluded publications older than five years (before 2012) from our study. The UX evaluation methods we found in the literature were divided into three groups: (1) methods that have been directly applied from classical desktop UX scenarios to mobile applications without modification (*generic methods*); (2) methods that are adapted in order to be applicable to mobile applications (*mobile adapted methods*); (3) new approaches that have been developed for measuring UX specifically in the context of mobile applications on smartphones (*mobile specific methods*). For each of these three groups, we searched for methods of the five categories defined by Albert and Tullis [9]: Performance methods, usability methods, self-reporting methods, behavioral and physiological methods, and combined methods.

TABLE I. CATEGORIZED NUMBER OF UX STUDIES ON MOBILE APPS

	Generic Methods	*Mobile Adapted Methods*	*Mobile Specific Methods*
Performance Methods	0	0	2
Usability Methods	2	0	4
Self-Reporting Methods	4	1	0
Behavioral and Physiological Methods	0	0	6
Combined Methods	1	0	2
Sum	7	1	14

An overview on our results is displayed in Table I. In total, 22 studies were found. For a list of all studies that were used in the literature survey, see the Appendix. Though almost two thirds of the methods that we found –14 out of 22– were new approaches, there were seven methods that have been directly applied to the mobile context without being changed. There was only one approach that had been adapted to the context of mobile usage. In the following subsections, a qualitative description provides a deeper insight in the studies that were found.

A. Generic Methods

Whereas we found no example of performance methods that were directly applied or adapted to mobile apps, there are several usability studies that prove that issue-based methods work out fine for mobile apps as well. In [22], a classical usability lab study is conducted, supported by the use of two non-standardized questionnaires. Likewise, Habermann et al. [23] evaluated a public transportation app regarding its usability by observing users while they are solving prototypical tasks.

Dhir and Al-kahtani [24] used three standardized self-reported UX methods to evaluate a mobile app, i.e., the AttrakDiff questionnaire [25]. These methods have been directly applied to the mobile context without modification. Likewise, the standardized System Usability Scale (SUS) has been applied to various objects by Kortum and Bangor [26], but is also proven to be feasible for mobile apps in [27], using the questionnaire with ten mobile apps on smartphones as well as tablets while gaining meaningful results. Additionally, Ferreira et al. [28] used different self-reporting methods for mobile app UX evaluation: In the Expressing Experiences and Emotions (3E) method, as well as the Empathy Map (EM), users have to draw or write their feelings on a sheet of paper. Using Method of Assessment of EXperience (MAX), the participant has to sort cards on a board. In addition, the Self Assessment Manikin (SAM) questionnaire and Think Aloud were used. The methods were used to evaluate UX for apps on smartpones. However, all the studies were conducted in lab environments with no further consideration of the impact of a mobile usage situation. This might be the reason why none of them required particular adaptation for the mobile context.

As one example for a comprehensive combined approach, Yao et al. [29] conducted a mobile application user study in a lab setting, collecting task performance data, self-reported data, EEG data and skin conductance data. The results showed that these methods can be generically used in the context of mobile apps. Nevertheless, since all of them have been used in a lab study, their applicability depends on the mobility of the sensors that are used. We have no information about their operational capability in a real mobile context of use.

B. Mobile Adapted Methods

While several questionnaires and self-reported methods have been directly applied for mobile apps, there is also one study where an adapted method was used: The goal of Kujala and Miron-Shatz [30] is capturing the user experience from the actual context of smartphone use. In a long-term study, users have to fill out an initial questionnaire and two follow-up questionnaires after 2.5 and five months. They use a version of the Day Reconstruction Method (DRM) questionnaire, that is adapted to the context of the actual product use by adding new questions. In doing so, the users had to reconstruct and report

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the most important episodes of their day and their experiences and emotions during the episodes of smartphone use.

Apart from that, no studies on mobile adapted methods from the fields of performance, usability, behavioral and physiological methods, and combined methods could be found.

C. Mobile Specific Methods

Regarding the field of performance methods, there are some new approaches. Ravindranath et al. [31] introduce a new tool that monitors performance of mobile apps in the wild and helps diagnosing problems. Likewise, Liang et al. [32] developed a cloud service that traces mobile app performance and helps reducing crashes and performance bugs.

For measuring the usability of mobile apps, several new approaches have been introduced. Inspired by existing usability models, Harrison et al. [33] create People At the Center of Mobile Application Development (PACMAD), a model that conceptualizes usability particularly for the context of mobile applications. Igler et al. [34] show a framework that enables usability evaluation in the actual context of use instead of a lab setting. Olsina et al. [35] follow a novel holistic quality approach for the evaluation of usability and user experience of mobile applications. Furthermore, Hoehle and Venkatesh [36] developed a survey instrument based on a concept for mobile app usability that they derived from Apple's user experience guidelines.

In the field of behavioral and physiological methods, different mobile specific approaches have been developed. Yang et al. [37] use the front camera of smartphones to track the users' face expressions in order to enable facial aware applications. In [38], a software for mobile face tracking is presented, that analyzes emotions with an accuracy of 86 percent. Regarding brain activity measurement, there are some new approaches [39][40]. Both of them use a cap with EEG sensors that can be worn outside a lab scenario, while only Stopczynski et al. [39] combine it with open source software in order to visualize brain activity during smartphone use. However, both studies show the potential that lies within this method. Paletta et al. [41] and Kassner et al. [42] both used mobile eye tracking devices and their own software for collecting gaze data during smartphone usage. Paletta et al. [41] introduce the Smartphone Eye Tracking Toolbox (SMET), a software that i.a. records screencasts and collects data during an experiment. In their setting, eye tracking glasses are used, whereas Kassner et al. [42] developed a headset-like device for mobile eye tracking, that can not only be used for studies with mobile devices, but also for interaction with everyday objects.

In the field of combined methods, Maly et al. [43] introduce a new tool including usability measurement as well as skin conductance and heart rate in real mobile usage contexts. Participants are asked to walk along a pre-defined route in a building while assessing comprehensive data on their interactions, movements, stress level and physiological state. Noldus et al. [44] use both movement tracking and logging for automatically assessing mobile user experience. In their study, participants could move freely, while their movements were logged.

V. Discussion

The literature survey provided us with an overview of generic as well as mobile specific methods for evaluating the user experience of mobile applications. Though almost two thirds of the methods that we found were new mobile specific approaches, almost one third of the methods was directly applied to the mobile context without being changed. We found only one approach that had been adapted to the context of mobile usage.

The new approaches show that regarding performance measurement, evaluations of mobile apps often take place in lab settings and that for field studies with mobile devices, novel approaches are required. Though we identified several of these new methods, the topic still needs more coverage.

Regarding usability methods, the literature we found showed that usability methods have been directly applied to the mobile context, as far as they take place in a lab setting. For collecting usability information "in the wild", different and combined new approaches have been developed.

In the field of self-reporting methods, most of them have been directly applied to the mobile context without being modified, while there is no example for a new approach. One explanation may be that existing self-reported methods and questionnaires are standardized and seem sufficient for all contexts of use, since the only restriction for using them is the interaction with a system that is given with both desktop systems and mobile apps. In addition, questionnaires and reports can be filled in online and therefore are location-independent. Also, it lies within the nature of these methods that they are mostly carried out after the episode of interaction and therefore, the application exactly during the use of an app is not crucial for the use of these methods. One challenge in this field is constituted in those self-reporting methods that need moderation or guidance, since they require that both persons –moderator and participant– are in the same room, and often involve desk-bound actions like writing, drawing or sorting. To solve theses issues, new approaches for self-reported methods should be taken into account.

The behavioral and physiological methods that were found involved unexceptionally new, mobile specific approaches. The reason for that might be that all of the approaches in this topic are quite new, since the topic itself was only recently discovered in the context of user experience measurement and so far there are no established standards for this kind of methods. The fact that existing mobile hardware for measuring physiological conditions, such as caps with EEG sensors or eye tracking glasses, are fit for use in the mobile context, is clearly a chance for this field. On the other hand, these kind of measurements have to cope with a high amount of influences from the environment that makes the collected data hard to interpret. Thus, Maly et al. [43] point out that "*such an approach brings numerous methodological challenges as researchers do not control the environment setting and parameters [...]*". To our knowledge, to this point there is no solution to solve this issue.

Regarding the last field, we found only few studies with combined methods – one that could be directly applied to mobile context and two new approaches. The one that was directly applied to smartphone use was set in a controlled lab environment, so that under these circumstances, the mobile context is not given anymore. We therefore assume that there is a demand for comprehensive combined UX evaluation methods in the context of mobile applications.

VI. Conclusions and Further Research

In this paper, we have presented a literature survey on user experience evaluation methods for mobile applications on smartphones. We identfied academic research papers from five categories of UX methods and assigned them to three groups – generic methods, mobile adapted methods, and mobile specific approaches. As key findings, we can conclude that classic UX evaluation methods have been applied directly to the mobile context, as long as they are used in a lab setting, and that the main challenge of measuring mobile is data aquisition "in the wild", in the actual context of use. Based on our literature survey, we can furthermore identify several research needs for mobile UX research: (1) New approaches for self-reported methods should be taken into consideration; (2) new approaches for behavioral and physiological methods should be further developed towards standardized methods; (3) methods and frameworks for coping with physiological data collected via studies in uncontrolled environments are required.

Appendix

TABLE A.1. STUDIES USED IN THE LITERATURE SURVEY

Authors	*Classification*
Wei et al. (2015)	Generic methods - Usability
Habermann et al. (2016)	Generic methods - Usability
Dhir and Al-kahtani (2013)	Generic methods - Self-reporting
Kortum and Bangor (2013)	Generic methods - Self-reporting
Kortum and Sorber (2015)	Generic methods - Self-reporting
Ferreira et al. (2016)	Generic methods - Self-reporting
Yao et al. (2014)	Generic methods - Combined
Kujala and Miron-Shatz (2013)	Mobile adapted methods - Self-reporting
Ravindranath et al. (2012)	Mobile specific methods - Performance
Liang et al. (2014)	Mobile specific methods - Performance
Harrison et al. (2013)	Mobile specific methods - Usability
Igler et al. (2013)	Mobile specific methods - Usability
Olsina et al. (2014)	Mobile specific methods - Usability
Hoehle and Venkatesh (2015)	Mobile specific methods - Usability
Yang et al. (2012)	Mobile specific methods - Behavioral
Suk and Prabhakaran (2014)	Mobile specific methods - Behavioral
Stopczynski et al. (2014)	Mobile specific methods - Behavioral
Kranczioch et al. (2014)	Mobile specific methods - Behavioral
Paletta et al. (2014)	Mobile specific methods - Behavioral
Kassner et al. (2014)	Mobile specific methods - Behavioral
Maly et al. (2013)	Mobile specific methods - Combined
Noldus et al. (2014)	Mobile specific methods - Combined

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