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A Review on Usability, Security and Privacy for Mobile Health Applications

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***Abstract*— Mobile health applications, or mHealth, deal with health issues or medical supported by smartphones. mHealth applications are able to improve both the safety of the patients and the quality of medical services. It is considered to be a recent field with great potential that appeal to the interests of the stakeholders and the developers. By adopting the systematic literature review method, this paper presents a broad review of usability, security and privacy for mHealth applications. Specifically, we discussed the limitations as well the recommendations of USP characteristics in mHealth applications. It is crucial to learn and understand to overcome the conflict between usability, security and privacy in mHealth applications.**

Keywords — Mobile healthcare, privacy, security, usability, mHealth, applications

I. INTRODUCTION

Mobile health or mHealth is regarded to be a sub-segment of e-health and its domain is the medical or public health practice supported by mobile device [1]. Apple App Store has more than 20,000 mHealth applications as compared to Google Play store which has about more than 8,000 medical related applications [2]. According to the Mobile Health Market Report 2013–2017 [3], around 500 million people will have adopted medical applications by 2015. Many healthcare organizations are starting to incorporate medical mobile applications [4] [5]. The accessibility and possibility of these new technologies have been recognized as monitoring, diagnosing and treating diseases and chronic conditions [6][7]. The term mHealth usually used for medical practice supported by mobile devices [8].

A mobile application usually comprises a number of application quality factors and characteristics such as user satisfaction, usability, security, privacy, flexibility, maintainability, etc. A general study reports that different application quality factors are strongly correlated; for example flexibility improves in better maintenance, and reliability results in augmented user satisfaction. However, there are some characteristics of mobile applications cannot be linked with others such as usability conflicts with security and privacy. A common review reveals that increasing usability usually results in decreased security and privacy [9][10].

This paper examines the relation between usability, security and privacy (USP) in mobile health application. Furthermore, it describes a review of current issues and guidelines for investigating the relationship between the USP characteristics. The main contribution of this paper is to identify the current and practiced guidelines for the developers to create mobile health applications with improvement of USP.

Thus, to determine the detailed understanding of mHealth, this paper presents a broad review of usability, security and privacy for mHealth applications. This paper is organized as follow: Firstly, we describe the background of USP in healthcare in Section II. Section III presents the methodology of conducting the review on USP for mHealth applications. The current issues for USP in mHealth applications are discussed in Section IV. Then, Section V highlights the limitations and the recommendations of USP in mHealth. We conclude and summarize the review in Section VI.

II. USP IN HEALTHCARE

This section presents a background review of usability, security and privacy and followed by the related work from previous researchers.

High performance smartphones and ubiquitous access to the Internet, are representing most recently an unparalleled through in all aspects of life. Healthcare industry is one of the areas expecting a tremendous growth in terms of mobile application development and usage [11].

The mHealth field has become known as a sub-segment of eHealth. Mobile applications and services can include video conferencing, remote patient monitors, personal healthcare devices, online consultations, wireless access to patient records

and prescriptions. As yet, no uniform definition of mHealth has been recognized. The World Health Organization (WHO), the Global Observatory for eHealth described mHealth as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices".

Health applications provided medical information through a mobile device, mobile wellness applications, and the applications designed to access electronic health records (EHR) and personal health records (PHR) and also serve many other different purposes. [12] studied several healthcare applications for smartphones which are recorded on MedLine by classifying the users and functions of the health applications into three main types as shown in Table 1 below.

Table 1. Classification of user and functions in mHealth applications

User	Function
Healthcare professionals	disease diagnosis, medical training, medical calculators, clinical communication, drug reference, literature search, hospital information system client applications, and general healthcare
Medical or nursing students	medical education
Patients	disease management with chronic illness and other conditions

According to mHealth App Developer Economics 2016, follow-up monitoring and seeking healthcare information are features of mHealth apps which are expected to have the greatest impact on the patient journey over the next five years from 2015 [13]. Figure 1 shows the mHealth application categories for highest market potential in the next five years since 2015. The highest ranking was remote monitoring followed by diagnostic applications.

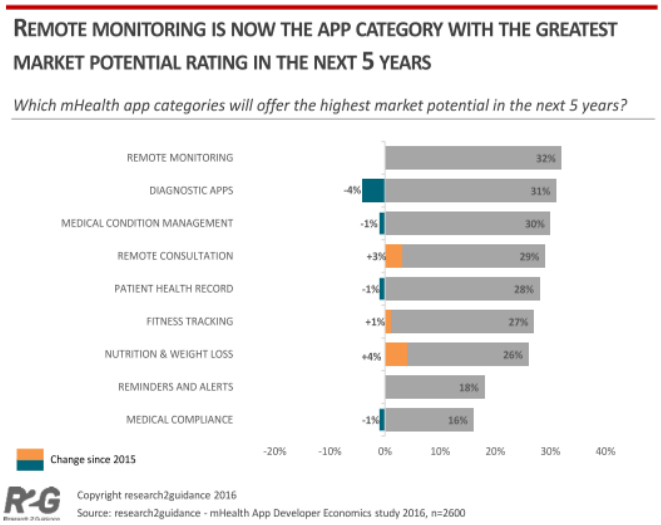

Figure 1. mHealth App Categories For Highest Market Potential in the Next 5 Years [13]

It is very important to categorize the user and the purpose of the health applications as it will increase the specific quality factors such as usability, security and privacy.

The security and usability are not fundamentally at chances with each other. A mobile application which is more secure is more controllable, more reliable, and more usable on the other side, therefore a more usable system reduces conflict as more likely to be secured. In common, security aspects and usability aspects both want the application to properly perform tasks what the user wants [14].

Usability of mHealth app

Usability is defined as a target accomplished by the user in the terms of effectiveness, efficiency and satisfaction. This term is refered from the International Organization for Standardization (ISO) standard ISO- 9241 [15]. Usability is a main component in mHealth applications, such as for elderly people who may find it difficult to interact with smartphones, PDAs and many more.

According to [16], there are five qualities criteria that define usability; learnability is about learning and getting used to the interface of the system to get maximum benefits from using it. A second criterion is efficiency of a system is said to be efficient if the usage of the system is probable to have a good level of productivity. Next is memorability, if the users who have experience with the system but have not used it for some time is able to return to the system and use it successfully then the system is said to be memorable. Low error rate is whenever the users fail to perform a task, the user gets an error.

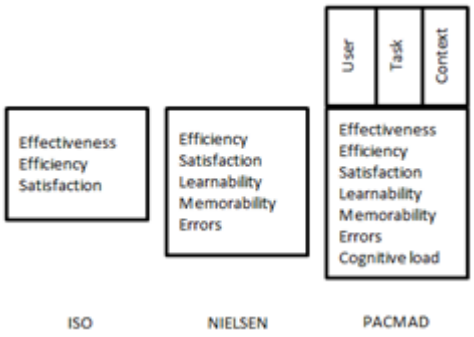

Figure 2. Comparison of Usability Model [17]

The system should be able to withstand errors. The users may give up on the system if they encounter too many errors or if errors are managed badly. This quality component is not only about number of errors, but also about severity of errors and how easy it is for users and the system to recover from errors. The last criteria are the satisfaction of the users plays an important role regarding the usability of the product. A user is satisfied if he/she is able to get expected benefits from the system and if the design is perceived as pleasant to use.

According to [17], major usability attributes are time to learn, speed of performance, time taken to recover from errors, error rate by the users and satisfaction. Figure 2 shows the comparison of usability models which have been designed by [15][16][18].

Even many technologies or applications are developed, if they cannot be used by anyone, they will lose their significance [19]. Usability is defined as the ease of use of technical artifact used by the users to fulfill an objective [20][21]. Usability is a critical part of design and development of mHealth applications as it aims to diminish the risk of users having difficulty in using the application [20] and as one of the attributes that control the success of the applications in the market [22].

Security and privacy of mHealth

mHealth applications have become linked into the field of consumer health informatics as tools that maintain a patient-centered model of health care by allowing consumers to monitor their health-related problems, understand specific medical conditions and attain personal fitness goals. However, mHealth apps may comprise significant risks to the privacy and security of consumer's protected health information.

Developers of smartphone applications have to make many privacy-related decisions about what data to collect about end users, and how that data is used. [29] discovered the way of application developers make decisions about privacy and security. Additionally, they have investigated any privacy and security behaviors are related to attributes of the application development concerns.

It was observed that privacy and security breaches have already go through every phase of user activities and living environment including health care, financial, voting, e-commerce, military and many more [30]. Thus, there is a persuasive requirement for the architectures development guaranteeing privacy and security that are vital to safeguarding confidential information wherever it digitally exist in.

Recently, there are many researchers have been actively involved in mHealth research. [24] reviewed articles about the design, development and evaluation of mHealth applications and discussed the differences between apps for patients, healthcare professionals, medical and nursing students, while [25] reviewed the most prevalent health conditions in the Global Burden of Disease list provided by the World Health Organization.

[26] developed a taxonomy to explore the privacy-related threats to mHealth technologies and discuss the technologies that could support privacy-sensitive mHealth systems. It is a requisite to reflect privacy in the design and implementation of any mHealth system, given the sensitivity of the data collected. From the threat taxonomy proposed by [34], it is important to adapt health applications based on the users' needs, particularly at the combination of the three components: usability, privacy and security in mHealth applications, which these three criteria are the upmost factors to be considered in the design and the development phases.

[35] developed a conceptual mHealth privacy framework and discussed the technologies that support privacy-sensitive mHealth systems through an extensive survey of the literature. [28] investigate the scenario and the patterns of patients' privacy concerns where they share their health information, in which these are collected from mHealth devices with their family, friends, third parties and the public. It was reported by [37] that it is imperative for the mHealth vendors to make improvements in the way the apps communicate and store data.

The importance of considering the types of mHealth applications with respect to information security and privacy, instead of treating them as generally the same technology (monolithic), was discussed by [38]. The study cultivates awareness of information security and privacy implications of mHealth apps for practical audiences.

III. Review Methods

In the previous section, we described the background of usability, security and privacy in mobile health application. In order to understand the relation between the USP characteristics for mobile health applications, we adopt a systematic literature review based on [29] to review the current issues and to determine the needs for a comprehensive guidelines that includes the developers' requirements for build-up mHealth application. We focus on articles published between 2010 until 2016 which discuss the roles of usability, security and privacy in mHealth applications.

Research questions

Three research questions were defined in order to accomplish the goal of this review. These research questions and their motivation are shown in Table 2.

Table 2.Research Question and Motivation

No.	Research question	Motivation
RQ1	What attributes are used when considering USP in mHealth applications?	To identify the different attributes that studied in the selected articles.
RQ2	What are the issues of USP found in existing research?	To examine the current research trends in mHealth applications with particular focus on the issues that relate to USP.
RQ3	What are the limitations and recommendations to improve the USP in mHealth applications?	To identify the guidelines for adapting mHealth applications applications according to developers' requirements.

RQ1: What attributes are used when considering the USP of mHealth applications?
This research question was established to identify the several attributes that typically used when considering the USP of mHealth applications. The answers to this question present evidence and data for the USP model.

RQ2: What are the issues of USP considered in existing research?
The second research question was examined to provide information about the particular focus on the issues that relate to USP based on the current research trends in mHealth applications.

RQ3: What are limitations and recommendations to improve the USP in mHealth applications?
This third research question was established to identify limitations and recommendations of USP in mHealth applications application.

The three research questions were answered by analyzing the literature on mHealth applications. The range of literature on the domain of mHealth applications is so broad, thus it is important to limit the literature review to the most recent and relevant publication interval to articles published between 2010 until 2016.

Search Strategy

The search strategy involves the selection of the search resources and the identification of the search terms. A set of automated search engines from the most relevant sources in software engineering and health were chosen to conduct the search for target papers: (1). The MEDLINE database covering life sciences and biomedical journal through the PubMed search engine; (2) the Web of Science (WoS) service, indexing cross-disciplinary research in sciences, social sciences, arts and humanities; (3) the ACM Digital Library covering the fields of computing and information technology; (4) the IEEE Xplore library of technical literature in engineering and technology; and (5) the Scopus database offering access to the fields of science, technology, medicine, social sciences, and arts and humanities of scientific journals, books and conference proceedings. The rationale behind this selection is to cover both medical and technical literature and provide a broader view of researchers' efforts in a wide but relevant range of disciplines. The summary of the process that was used to conduct the systematic literature review is shown in Figure 3.

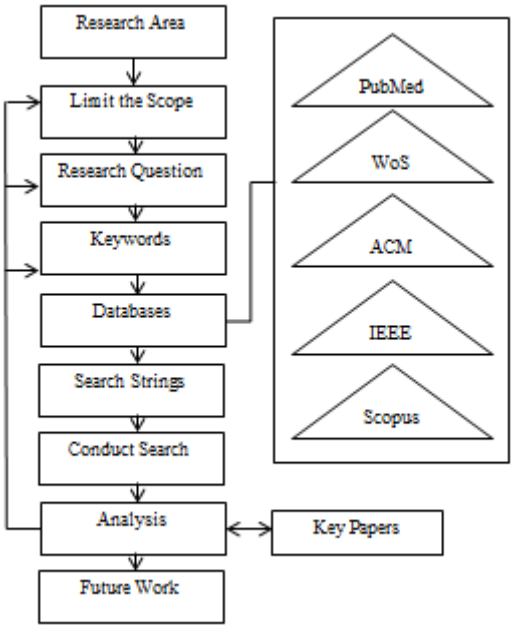

Figure 3.Search Strategy and Process

The search string (as shown in Table 3) should provide the maximum coverage to be of a manageable size. The terms used, which are based on the research questions, have been selected by using five different scopes as a starting point: 1) smartphones as the target devices; 2) the software scope of which the applications consist and the most popular mobile OS: Android and iOS; 3) health as the specific field of the applications studied; 4) usability, security and privacy as the topic under study; and 5) the research type that is related to empirical studies.

The Boolean OR is used to join alternate terms and the Boolean AND is used to join two major parts. We selected articles published in the year 2010 until 2016 and used a mix of keywords that contained "healthcare", "medical", "smartphones", "mobile", "apps", "usability", "security" and "privacy" in different variations, combined by the "OR" operator.

Table 3.Search string

Scope	String
Mobile context	(smartphone OR mobile phone OR mobile) AND
Software	(application OR app OR android OR OS) AND
Health	(health OR medical OR healthcare) AND
USP topic	(usability OR security OR privacy) AND
Research Type	(empirical OR method OR approach OR study OR framework OR prototype OR survey)

Eligibility criteria

Each study recruited from the initial search process was evaluated to decide whether or not it should be admitted as one of the selected studies. The papers that conformed to all of the following criteria were included:

IC1. The paper is focused on smartphones or tablet devices.
IC2. The paper provides information about usability, security and privacy.
IC3. The paper must be a full or short paper (not an abstract).

The papers that conformed to at least one of the following criteria were excluded:

EC1. The paper is not written in English.
EC2. The paper was published before 2000.
EC3. The paper was published after March 2017.
EC4. The paper is focused on a PDA or a feature phone.
EC5. The paper evaluates an internal feature of the smartphone but not any applications that are intended for final users like patients or doctors.

Data collection process

Data collection process is based on the research questions presented in Table 2 is therefore extracted in order to answer them. The process was carried out by completing a data extraction form.

Study Selection

The study selection process took place in January 2017. A total of 942 papers were obtained in the search phase, as shown in Figure 4.

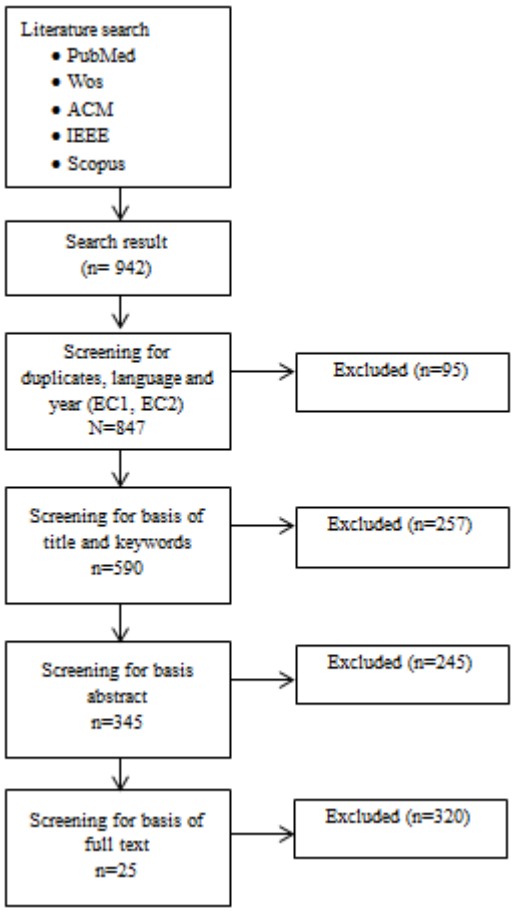

Figure 4. PRISMA flow diagram

From the 942 papers, 95 were identified as duplicates, and after applying EC1, two papers were discarded because they were not written in English while seven were discarded after applying EC2 because they had been published before the year 2000. The remaining 847 articles were evaluated by considering their titles and keywords. Two hundred fifty seven articles were excluded in this phase. Next, 245 articles were excluded after an examination of their abstracts. The full texts of the remaining 345 articles were investigated, 320 papers were discarded and 25 were finally selected after applying EC4 and EC5.

IV. Current Issues in USP of mHealth Applications

This section describes the current issues related to the USP of mHealth applications. It also highlights the usability, security and privacy concerns in healthcare.

Usability

Previous studies emphasized the drawbacks in using smartphone applications because of the additional engaged complexity and the limited usability as compared with the traditional platforms such as PCs [30]. For example, complexity is introduced to individuals by the need to manage a mix of mobile devices, personal applications, and applications they use for healthcare purposes, each with its own learning curve, possible financial costs, and security and privacy concerns.

The usability challenges in mHealth discussed are classified into two main categories: the part of the application and the challenges of the side of the device, which can be classified as shown in Figure 5. Here explained the results of each of these categories in details.

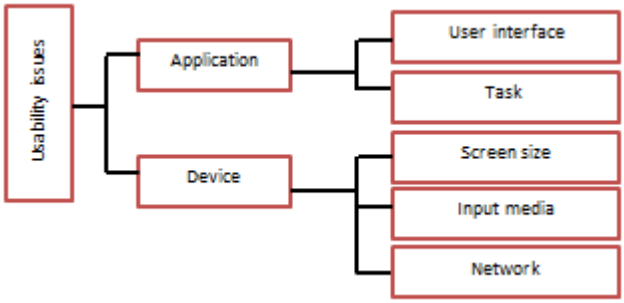

Figure 5. Classification of Usability Challenges [30]

Several scholars have proposed context of use theory which showed that there are extra variables that affect usability [31][32][33]. Traditional usability evaluation proved insufficient, or even inappropriate, when usability issues were addressed in situational contexts of everyday use. Mobile applications can be developed for different contexts. To address the usability needs when it comes to mobile phones, traditional HCI researchers have determined for a new example that considers environmental issues and context of use as important factors [34][35].

Usability for the most part includes the design of the products or system as the user should be able to perform tasks with the system efficiently. Users require interacting with interactive systems which are simple, interesting and satisfying. Users do not show much interest in complex interfaces [16]. Involving users in the development process of a system with the ambition of developing a system according to their requirements is an area where usability has proved to be an efficient approach and tool. Frank [36] reviewed 70 software products in different magazines and got 784 comments about the usability issues of the software as example to show the importance of usability as a way of engaging users in design discussions.

Usability of the applications must be taken into account from the start and measured during the development process for people to get motivated to use these applications, to minimize usability problems when the applications reach the market. From the range of different usability definitions that have been identified from previous work, we were adopting the definitions from ISO-9241 and [16] which are efficiency, effectiveness, satisfaction and learnability. An application which is interactive will be successful, only if the users are able to perform the intended tasks successfully in an efficient

manner. Even if the functionalities of the application perform well, but the users have issues with inefficient and ineffective when using the application, feel dissatisfied and not easy to learn the application, then the mobile interface is not be good and usable. These issues have led developers and designers of applications to focus on usability and this has resulted in that usability is important in developing an application.

Security and privacy

Security and privacy of patients data are also a major and relevant issue for smartphone apps [30], and has been often brought up by researchers [37][38][39][40]. [39] stated the non-compliance of medical applications with the Health Insurance Portability and Accountability Act, unlike the traditional EHRs. Additionally, there are security risks for less experienced users who might be trapped to download apps which offer them with uncertain medical information and advice or contain malware [37].

[41] examined the security issues and threats and security requirements to the mHealth system. They proposed a taxonomy of recent security protocols for mHealth system followed features supported and possible attacks, communication and computation cost. The taxonomy presents the advantages and weaknesses of recently proposed security protocols for the mHealth system. They identified some of the challenges in the area of security protocols for mHealth systems to enable cost-effective, secure and robust mHealth systems that still need to be addressed in the future.

In addition, [42] stated that the lack of standard application development guidelines have increased the security issues in mHealth apps. Consumers' security is at great risks due to mobile payment when they directly debit their health service accounts or bills payer. Fraud and identity theft caused from security breaks could also lead to mistrust among consumers and healthcare providers. A secure mHealth environment needs to build trust among consumers and healthcare service providers by adopting standard guidelines to increase security and protect from any unauthorized attacks.

Due to the mHealth applications portability and weaknesses in management and design, they are still at risk to a wide range of security threats. However, mHealth users are more concerned of the security and privacy issues related to their personal healthcare information. [43] reviews the security and privacy issues in current mHealth systems and their impact, which include discussion on the most recent threats, attacks and recommended methods to countermeasure in order to support secure sensitive mHealth systems. The next section covers the limitations and recommendations for USP in mHealth.

V. LIMITATIONS AND RECOMMENDATIONS

Weak Areas/limitations of USP in mHealth applications

Developers should consider the users' technical abilities, and the size of the mobile device display and the type of data being collected as the user interface design is concerned. Developers could conduct design and usability studies, referring to the users by way of aiming an easy-to-use application development [44]. Developers also need to improve the usability of mHealth applications such as an application for low back disorders [45] or an epilepsy patient monitoring system [46]. The mobile platform selected by the developers allows database and networking support and fundamental technologies to be provided throughout the applications. Specifically to iOS [47], the operating system is qualified with various libraries concerning animation and graphics. Mobile software architecture in mainly 2D/3D visualization technology and general may improve the accessibility of mHealth applications [47].

mHealth applications' developers mainly have to do with the design process as well as considering the user interface design choices and features specification made during developing process. Security is supposed to be a challenge when data are collected on mobile devices. Developing a strategy to ensure data are only accessible to those authorized to access the data is essential in any clinical study. Developers are expected to overcome the numerous technical challenges of conflicting data and data loss [48][44]. Consequently, developers have to fulfill the requirement by using all software and hardware means available for the automatic detection of data loss episodes [49].

Recommendations of USP

There are different researches identified with a number of recommendations and guidelines that can be followed in order to reduce the conflict between usability, security and privacy in mHealth applications.

Medical applications providers and also individual developers are needed to implement evidence-based principles and standards of app development [50]. They are also need to involve patients and physicians in a similar way in the app development process. Training is necessary in order to help users get the most out of applications, particularly for older adults [30]. Another ways are developers are recommended to improve content quality through the same essential measures leading the quality of information on the web, including the medical professional involvement in content preparation; the provision of authorship information; the disclosure of application sponsorship or other commercial funding arrangements; attribution of all references or sources of content; and any potential conflicts of interest [51].

VI. CONCLUSION

Mobile technology can assist much-needed, comprehensive change in healthcare systems worldwide and in turn bring significant social and economic benefits. Nevertheless, mHealth is still a work in progress and is growing and changing along with healthcare needs.

mHealth have the potential to replace some traditional healthcare services and practices and lower the cost of providing healthcare by taking advantage of the mobility, computing and sensing capabilities of smartphones and other handheld devices.

In spite of this also comes with additional usability, security and privacy risks that are lacking from traditional healthcare

approaches. In this review, we discussed the usability, security and privacy issues in mHealth application. Specifically, we discussed the weak areas or limitations and guidelines of USP in mHealth application.

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