International Journal of Innovative Research in Computer Science & Technology (IJIRCST)
ISSN: 2347-5552, Volume-6, Issue-2, March-2018
DOI:10.21276/ijircst.2018.6.2.2

# Requirements of mHealth-Based Medication Management Systems

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**Abstract— Medication error is one of the healthcare challenges which effects 10 percent of individuals around the world and medication management is a complicated process including multiple activities. One of these activities is medication intake which is handled by patients. Technologies, specifically mobile health technologies are potential solutions for medication error and medication nonadherence. Moreover, designers need to be familiar with system requirements which are inducted from user's goals. Therefore the interaction design method is an appropriate method to design the medication management systems. According to the importance of medication management, the researches performed a review study about mHealth-based medication management systems in order to extract the system requirements and usable technologies in this area to help the designers to design efficient system.**

**Index Terms—Medication Adherence, Medication Management, Mobile Application, Mobile Health.**

## I. INTRODUCTION

Any preventable event which is caused by taking the medications in an inappropriate way, is called medication error. Medication errors are one of the challenges in healthcare [1] which affect 10 percent of people [2] and according to the severity, may have limited impacts on the patient's health or could cause conditions which require more examinations and interventions. Moreover in more dangerous situations, the medication errors could result hospitalization, surgery, long term damages, disability and even death [3]. Medication management is a complicated process which includes all activities from medication prescription to medication intake by patients [4] and improves the patients' safety [5]. Designing the protocols, guidelines and policies for medication management in all aspects of this process could prevent the medication errors[6].

Manuscript Received March 15, 2018
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[7]. The communication and information technologies have an important role in healthcare and quality of life for patients [8].Moreover, many researchers have been performed One of the effective solutions for this problem is application of medication management systems. They are planned systems consisting of processes and behaviors which determine the manner of medication intake for patients which show the positive impacts of technologies on medication adherence [9]. Specifically, mobile health is a potential solution for medication management which can be effective in three levels of clinics, pharmacies and individuals including patients and caregivers [10]. Moreover, the extensive use of smartphones and mobile applications, is another reason which make the mhealth based solutions more feasible [11]. According to the fact that success in designing of an efficient digital product depend on the designers' perception of users' needs, interaction design could be an appropriate method for these kinds of products. One of the important concepts in interaction design is "persona" which is a fictional user. Definition of personas helps the designers to identify the users' goals. The needed data which are necessary to define the personas could be gathered from different sources. Literature and previous studies are one kind of these sources [12]. The data which are presented in the previous researches in the field of medication management systems include the system requirements. These requirements could be divided into functional and user requirements [13]. Furthermore, the other information that could be extracted in literature review process is the technologies that are employed in the medication management system. Therefore, the aim of this study was to review the literature and extract the system (functional and user) requirements, employed technologies in the mhealth-based medication management systems and research gaps in this area, in order to help the researchers to design and develop efficient and effective medication management system to improve the medication adherence among patients.

## II. METHODS

The current study was a descriptive study which was performed on four databases including PubMed ScienceDirect, Embase and Scopus. In order to search these databases, the researchers designed a search strategy implemented by a conjunction of two concepts of medication management and mobile health. The concept of medication management was created by disjunction of "drug management", "medication management" and "medication intake". Moreover, the disjunction of "mhealth", "mobile health", "smartphone", "mobile

 

assistive technologies", "mobile assistive technology", "mobile application", "iPhone application", "iOS application" and "android application" made the concept of mobile health. No time limitation was applied to search strategy. In the results of the database advanced searches, 99 papers were extracted. In the first step, irrelevant papers were removed by the title/abstract skimming. In the next step, the conference abstracts which their full text papers were not available, non-English papers, review papers and unavailable papers were omitted from study. In the last step, the full text of other papers were studied by researchers and the papers which had not presented a new system and had discussed other systems excluded. Then the descriptive study was accomplished on 15 papers which were included. Then the system requirements, employed technologies and research gaps were elicited from papers.

**Table 1: Functional requirements which applied to medication management systems**

| Study | Medications list, dose, frequency and instruction | Medication Information (side effects) | Medication regimen | Reminders and alerts | Medication refill | Medication identification | Informing a person when the patient forgets multiple doses | Location of pharmacies | Medication recommendations | Medication errors handling | medication intake report | Experienced side effects | Medication tracking |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Davos et al. [14] | ✓ | | | | | | | | | | ✓ | | ✓ |
| Haynes et al. [15] | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | | | | |
| Ferreira et al. [13] | | | ✓ | ✓ | | | | ✓ | | ✓ | ✓ | ✓ | |
| Silva et al. [16] | ✓ | ✓ | ✓ | | | | ✓ | | | | | | ✓ |
| Abbey et al. [17] | | | | ✓ | | ✓ | | | | | | | ✓ |
| Neubeck et al. [18] | ✓ | ✓ | | | | | | | | | | | |
| Sarzynski et al. [19] | ✓ | ✓ | ✓ | ✓ | | | | | | | | | ✓ |
| Ong et al. [20] | | | | ✓ | | | | | | | ✓ | | |
| Shellmer et al. [21] | ✓ | | | ✓ | | | | | | | | | ✓ |
| Suzuki & Nakauchi [22] | | | | ✓ | | | | | ✓ | | | | ✓ |
| Buis et al. [23] | | | | ✓ | | | | | ✓ | | | | |
| Ebner et al. [24] | ✓ | ✓ | | | ✓ | ✓ | | | | | | | |
| Schreier et al. [25] | | | | | | ✓ | | | | | | | |
| Morak et al. [26] | | | | ✓ | | | | | | | | | ✓ |

## III. RESULTS

*A. Functional Requirements*

As mentioned above, the system requirements were divided in two main groups. The functional requirements are the ones that users consume the system to achieve them. Across the fifteen papers which included in this study, one of them which has been performed by Klein and colleagues[27], considered the factors of behavior change as the most important feature of the system and has not presented any other requirements. Therefore the functional requirements extracted from other fourteen researches, are presented in table 1. 13 functional requirements are extracted from included researches. The frequency of each functional requirement shows the importance of these requirements. Therefore, the reminders and alerts are the most important one. After that, medication tracking and medication list, dose, frequency and instruction are the most frequent ones.

*B. User Requirements*

In addition to functional requirements which are mentioned in previous section, another group of system requirements

 

ISSN: 2347-5552, Volume-6, Issue-2, March-2018
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were considered in the included medication management systems. User requirements are important because they aim to improve the users' experiences when they use the system. They were extracted by researchers and classified in six main groups: User account

**Table 2: Classification of extracted user requirement**

| Class Name | User Requirements |
|---|---|
| User Account | – Registration process [18]<br>– Password change or restoration after forgetting the password [18]<br>– Profile picture [18]<br>– Customization of user setting [18] |
| Consistency to target group | – Avoidance of filling the screen by small sized contents and icons [13]<br>– Appropriate size of compartments (if there is a medication box in the system) [17] |
| Increasing the possibility of effective use of system | – Being proper for all users even the users who don't have much tendency to use the system [13]<br>– Customization of contents [13]<br>– Sending motivational messages [18]<br>– Using games in order to find the cognitive situation of patients [15]<br>– Using psychology theories [18], [22], [27]<br>– Minimizing the activities in order to achieve each task [18]<br>– Utilization of push notification [19] |
| Contact with users to improve quality | – Measuring the users' satisfaction by evaluation of system usability [19]<br>– The users' feedback about the system and the experienced bugs [18] |
| Displaying the scales of system efficacy | – Definition of trackable goals and easy mechanism to check if the user achieve the goal or not [18]<br>– Displaying the percentage of adherence [20]<br>– Displaying the variation of users' medication intake reports and prescribed instructions [20] |
| User friendliness | – Providing the interaction between touch and speech in order to facilitate the situation [13]<br>– Tangible layout and navigation [19]<br>– Informing the users by daily language instead of technical language[13]<br>– Help page [18],[19]<br>– Accepting the terms in the first login [18]<br>– Using the medications images [16] |

Requirements, consistency to target group, increasing the possibility of effective use of system, contact with users to improve quality, displaying the scales of system efficacy and user friendliness. Each one of these groups includes some more detailed user requirements. In addition to classified user requirements and functional requirements, reliability, validity [13] and portability [17] are the other features that should be considered in these systems. This classification and the details of these requirements have been stated in Table 2.

*C. Technologies*

The presented systems in the included researches, have employed smartphones and different technologies (technology-based methods) in order to implement the functional requirements. The requirements which have been implemented by extra technologies in addition to smartphone, are medication identification, medication tracking and reminders and alerts. These technologies would be introduced in this section.

RFID (Radio Frequency Identification), is a technology to identify objects [28] and is a wireless technology which makes the computers able to read the low cost tags from distance without any battery [29]. The system that is presented by Schreier and colleagues in their research work, used the RFID tags in order to identify the medications. In this research, a smartphone with NFC (Near Field Communication) is used to read the RFID tags which would be attached to the medication containers. Furthermore, the barcode scanning is another method to identify the medications which is employed in this system [25]. The researches which have been performed by Silva and colleagues[16] and Sarzynski and colleagues[19] are the other ones which utilized the barcodes as identifiers. The system of Silva and colleagues, could register the medications by smartphone's camera according to the access to medication database in a web-based infrastructure

 

[16]. In Sarzynski's study, the developers have employed Universal Product Code (UPC) scanners in addition to barcode scanner. Moreover, the Optical Character Recognition (OCR) is another method which is used in this research to identify and register the medication [19]. Most of the mhealth-based medication management systems which were included in this study, have implemented reminders and alerts with smartphone's potentiality like alarm manager, but there are two researches that used other methods to implement this functional requirement. Buis and colleagues used Short Messages Service as reminders. This approach has an advantage that does not depend on kind of cell phone that users have but the other approaches rely on smartphones [23]. In addition to Buis, the system which is developed by Abbey and colleagues employed another technology too. The alerts of this system are managed by microcontroller and LEDs in a way that the LED which is attached on a specific medication compartment would be turned on in programmed time. This visual alert is synchronized by smartphone's alerts [17]. The text generation methods are the other technologies which could be employed to convert the text contents to natural language to provide audio alerts. Ferreira and colleagues, used the mentioned method in their system [13].Medication tracking is another requirement which could be important for the patients who forget their medication doses. Morak and colleagues, designed a special blisters comprising of microcontrollers, aluminum covers and tags. The blisters could detect the medication removal and the data could be transferred via NFC infrastructure to smartphone [26]. There are other methods that could handle the medication tracking. Suzuki and Nakauchi, used image processing methods which are implemented by equipped medication box and smartphone's camera. The technologies and technology-based methods which are used in medication management system, are summarized in Table 3.

**Table 3: Usable technologies for mhealth-based medication management systems**

| Technology | Implemented Functional Requirement | Description | Study |
|---|---|---|---|
| RFID | Medication Identification | Using RFID tags as identifiers | Schreier et al. [25] |
| NFC | Medication Identification | Utilization of NFC smartphones | Schreier et al. [25] |
| | Medication Tracking | Employing blisters comprising NFC tags and a microcontroller, in order to track the medication intake and transferring data to smartphone | Morak et al. [26] |
| Barcode Reader | Medication Identification | Using smartphone's camera, in order to read the barcodes which are used as identifiers | Schreier et al. [25] Sarzynski et al. [19] Silva et al. [16] |
| Universal Product Code Scanning | Medication Identification | Using smartphone's camera to detect the UPC according to the stored data in database | Sarzynski et al. [19] |
| Optical Character Recognition | Medication Identification | Using smartphone's camera and Optical Character Recognition algorithms to read the medication names. | Sarzynski et al. [19] |
| LED | Reminders and Alerts | Employing LEDs as medication alerts on the medication compartments (the programmed microcontroller turns the LEDs on and off) | Abbey et al. [17] |
| Short Message Service | Reminders and Alerts | Sending short messages to remind the medication doses. | Buis et al. [23] |
| Speech Generation | Reminders and Alerts | Speech generator system, converts the text to natural language in order to create a user friendly alert. | Ferreira et al. [13] |
| Using a box with mirrors and smartphone camera | Medication Tracking | Using a medication box which is equipped by mirrors, smartphone's camera, and image processing methods to identify if the medication is taken or not. | Suzuki & Nakauchi [22] |

## IV. CONCLUSION

Current study represents mhealth-based medication management system requirements and the feasible ways to implement these requirements in order to help developers to design and develop medication management systems based on mhealth technologies. The requirements of the system, were divided in two main groups called functional

 

requirements and user requirements. 13 functional requirements were extracted from included studies and user requirements were classified in six classes. Among extracted requirements, the most important ones (medication identification, medication tracking and reminders and alerts) were the requirements which could be implemented by employing different technology in addition to smartphone. RFID, NFC, OCR, UPC scanner, barcode scanner, image processing methods, using LED, SMS and speech generation were these technologies. According to Table 1, there was not any system which has considered and applied all the requirements. Therefore according to interaction design which is a user centered method, this area is a field that needs future researches. Moreover, the studied systems were not designed for users with cognitive impairment while they are the users with more possibility to encounter polypharmacy and experience more challenges in medication management.

## ACKNOWLEDGMENT

The study was performed as a part of master thesis project in medical informatics department in School of Allied Medical Sciences in Tehran University of Medical Sciences. The authors would like to thank all professions who helped the authors in this work.

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