Conference Paper

Designing and Developing Android Application for Medication Reminder to Improve Treatment Efficiency of Stroke Patient

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Abstract

Stroke patients often experience problems of taking medications due to forgetfulness, a number of medications causing confusion to take, or even the side effects making the patients refuse to take medications resulting in ineffective treatment. In this study, the researchers study and develop information technology in the form of Android application in order to educate and remind the stroke patients to take medications by developing a prototype system called DCMed. The research finds that the stroke patients in the experimental group using DCMed system are more interested and complied with taking medications accounting for 42.86%. Moreover, the patients can take medications more timely than those in the control group at the significant level of 0.05.

Keywords: stroke patient, medication discontinuation, medication reminder system, Android application, web application, medication compliance, IMB Model

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1. Introduction

The major public health problem in the world or even Thailand is Cerebrovascular disease or Stroke [1]. Most of Thai people are familiar with the name "Paralysis" which is a common neurological disease and has been recognized as the number 3 cause of the death in the world for 50 years [2]. There are over 15 million stroke patients worldwide [1] and more than 5 million stroke deaths each year. Even though 5 million patients survive, but they become permanently disabled [3].

At present, the number 4 cause of the death in Thailand is stroke. It is found that a stroke patient occurs every 2 minutes, and the mortality rate increased steadily during

5 years (2008-2012), from 20.8 to 30.7 per 100,000 populations [1]. Therefore, it indicates that both domestic and global stroke situations are particularly concerned. The number of patients and deaths from stroke increases potentially due to the population aging especially in developing countries. It has also been estimated that the number of patients who die of stroke will double from the comparison between 1992 and 2020 [1].

In addition to health issues, the direct cost is 1,489.78 baht per day for inpatient services, and 1,010.22 baht per day for outpatient services. Moreover, the opportunity cost due to absenteeism and disability is 101,681.20 baht, and loss due to death is 15,766.66 baht. On average, total cost of illness from stroke is 162,664.97 baht per year [4].

One of the factors that can reduce the mortality rate and recurrence of stroke is to take medications continuously and timely according to the medical suggestion [5]. However, most stroke patients have long-term physical, mental, and psychological impairments so that they need help from the caregivers for doing their daily activities. As a result, it may be difficult for the patients to take the medications correctly and continually [6]. Moreover, the patients might forget to take medications, or a number of medications might cause the patients to refuse taking medications [7]. These factors are the common causes of ineffective treatment.

Nowadays, the role of mobile phone technology in people's lives has increased. At present, mobile phone has been evolved to function variously rather than just dialing-in and finally become 'smartphone' which works better and more efficiently than a typical mobile phone. Kantar World panel, the famous marketing-research company, has recently released the report on the market share of smartphone operating systems from users around the world in April 2016 [8]. It is found that Android is the operating system that people used the most. Moreover, the previous research developed mobile Health (mHealth) to provide health care service widely. mHealth is also a part of eHealth, i.e. using mobile computer and commuting with health care and public health technology, which can cause behavioral changes of the patients and deal with chronic disease [9]. However, it is found that even though there are several mobile phone applications for medication reminder [10], the system is not appropriately developed to meet the needs of patients directly. For example, the research "Don't Forget Your Pill! Designing Effective Medication Reminder Apps That Support User's Daily Routines" highlights the features of the medication reminder system that should be included by compiling features from 229 current applications and survey from 1,012 users, and

then offers reminder assistant feature based on users' daily activities [11]. Furthermore, the research "Safer Virtual Pillbox: Assuring Medication Adherence to Elderly Patients" studies and presents the design of assisting system for the elderly to take medication regularly by adopting the concept of User Center Design and considering usability, fit-for-elderly, as much as possible [12]. Another research is "UbiMeds: A Mobile Application to Improve Accessibility and Support Medication Adherence" which realizes the problem of access to medication information so that the idea of application which is easy to access to the patients' medication information is emerged, focusing on elderly and partially disabled people [13]. From the previous research and preliminary survey, it is found that most of the reminder applications are mainly designed for elderly. There is still no reminder application for stroke patients nowadays. Moreover, the applications in the market are not designed based on IMB Model which is seen as the useful concept to change patients' behaviors in medication.

Therefore, the researchers researched and developed a prototype system called DCMed in response to the need of medication reminder system for stroke patients. The concept of Information, Motivation and Behavioral skills (IMB Model) is adopted to develop the system in order to change patients' behaviors and enhance efficiency of medication compliance [14, 15]. IMB Model is developed based on the concept of Social and Health Psychology in order to explain the behaviors leading to HIV transmission, and promote the medication compliance among AIDS patients. IMB Model consists of 3 main components [16]. The first component is information. It is argued that the patients must receive correct information such as disease information, treatment procedure, and side effects of medications in order to change their behaviors. However, the information alone is not enough. The second component is motivation. Motivation is what motivates patients to do particular activities influenced by both personal and social motivations. The last component is behavioral skills. It is believed that before doing any activities, the patients must have skills relevant to those activities. Moreover, the patients must know if they have enough ability to perform including the persistence to overcome their problems. All of these components must work together in order to influence the patients to act and change behaviors [16].

With the important features collected from the literature, this study aims to present the needs and architectural structure of the medical reminder system. Also, DCMed is introduced to stroke patients at Siriraj Stroke Center, Siriraj Hospital, and the conclusion is drawn for further development.

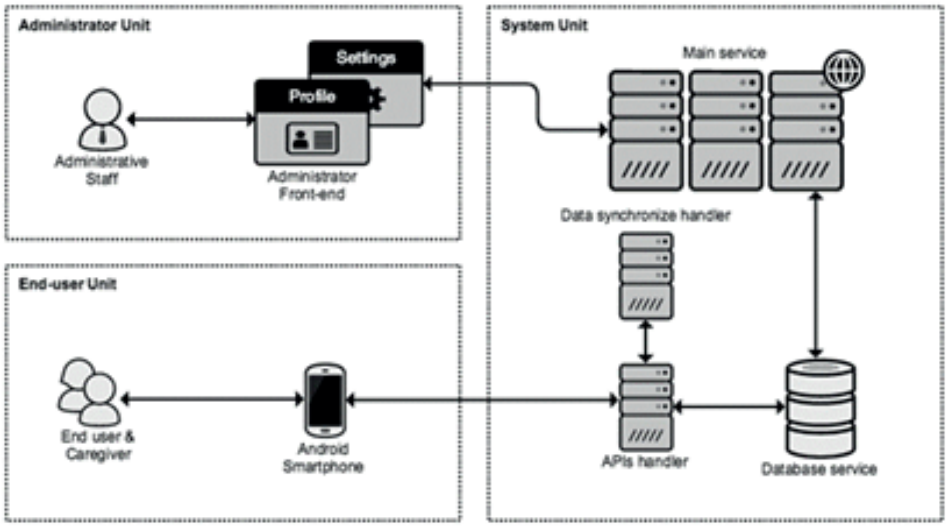

Figure 1: The architectural structure of the prototype of DCMed system.

2. Methods

The researchers studied and reviewed the previous research related to the development of medication reminder system similar to the concept of this study, and measurement of the system performance, which are the validity of the system and user satisfaction, adopting IMB Model introduced by Fisher & Fisher [9] in order to change behaviors. The researchers collected and defined appropriate features in the prototype system based on 5 relevant research works denoted as A [11], B [17], C [12], D [13], and E [18], respectively. Moreover, the researchers added more necessary features which are not introduced by the prior research. After that, all features were categorized into Information, Motivation, Behavioral skills in IMB Model. When classifying all discovered features into 3 dimensions in IMB Model as shown in Table 1, it can be seen that the prior research works have different features, and some of research works do no cover all 3 dimensions in IMB Model. Hence, in order to create a successful system based on IMB Model, the researchers combined all features in A, B, C, D, and E, and then denoted as F in Table 1. However, due to the limitation of time, some features were neglected, especially voice features and other people, leaving a room for future development.

After defining the desired features, the researchers designed the architectural structure and components of the prototype system of DCMed. The researchers developed the prototype of DCMed system, and classified the development into three main modules which are End-user Unit, Administrator Unit, and System Unit showing as architectural structure in Figure 1.

Table 1: The comparison of features in medication reminder system between previous research and the system adopting IMB Model.

Features	A	B	C	D	E	F
Information						
Medication list			✓	✓	✓	✓
Packaging and tablet pictures			✓	✓	✓	✓
Prescription list						✓
Reporting side effects of taking medications			✓		✓	✓
Patient history		✓	✓	✓	✓	✓
Appointment reminder						✓
Button for listening to the information				✓		
Motivation						
Weekly reporting to encourage medication compliance						✓
Reporting the statistics of medication use			✓	✓	✓	✓
Using the voice of the doctor who treats to remind		✓				
Behavioral skills						
Medication reminder	✓	✓	✓	✓	✓	✓
Delaying time and repeating reminder	✓		✓	✓	✓	✓
Schedule self-timer	✓		✓	✓	✓	✓
Reminding with daily activities	✓					✓
Others						
Reminding other people			✓		✓	
Reminding when medicine is almost run out	✓					
Using voice on fixed line to remind		✓				

End-use Unit is for the patients to receive medication reminder, information of medications in detail, appointment with a doctor, and daily, weekly, or monthly medication. Moreover, this module receives and sends medication information to System Unit for storing data in the database. Administrator Unit is for the officers and nurses, who use DCMed system to record necessary information for patients requiring the use of DCMed such as basic symptom, medicine, schedule of medications, daily medication, appointment with a doctor, and other essential information about the various settings of DCMed system, to store the information in the databases as a source of information for End-user Unit. Lastly, System Unit acts as information management. It consists of

application server, web server, and database. The main service provides web application data to Administrator Unit, and passes them to the databases. For APIs handler, it provides mobile data exchange service with End-user Unit, and sends to the database. Another important module is Data synchronize handler which compares and manages data between End-user Unit and System Unit to have similar information updates. For example, when End-user Unit works offline, and is online again, this module will update the information in End-user Unit and System Unit to be the most recent.

In End-user Unit (Mobile application), the background job runs to check the online status every 1 minutes. When the mobile connects to the internet, the mobile application will call Data Synchronize module through APIs to start synchronizing data between End-user Unit and Databases. The database is designed to store ID in UUID format in order to simplify the synchronization process in End-user Unit and Databases by using the same ID. In each table, the version and timestamp data are stored when created from End-user Unit and Databases (createdat, updatedat, version). For the database in mobile application (End-user Unit), there is a 'synced' flag helping inform if data are synced or not. As a result, when new data are added but the internet is not connected, Data Synchronize module are able to know that what data are not updated, and then update the data in both End-user Unit and Databases.

The components of the DCMed software are divided into three components. The first component is web application dealing mainly with administrators and nurses. Web application uses web browser to display data from the web server through Hyper-Text Transfer Protocol (HTTP). Secondly, APIs serves as the primary or central service for the operation of APIs in the form of REST Web Service, and download the data from the database directly, which is easy for working between mobile application and database. The most important component is mobile application. This component serves as information provider and reminder though Android smartphones. Moreover, this component can be only installed in Android operating system version 4.0 or above. The architecture of software components is presented in Figure 2.

In order to understand the operation in the system, Use Case diagram of the system was developed presenting the interactions between Use Case and actors as shown in Figure 3. The End user/Caregiver and the administrative staff interact with the system as follows:

A. The patient (End user/Caregiver) takes medication and records medication information through mobile application, and then sends the information to the central system.

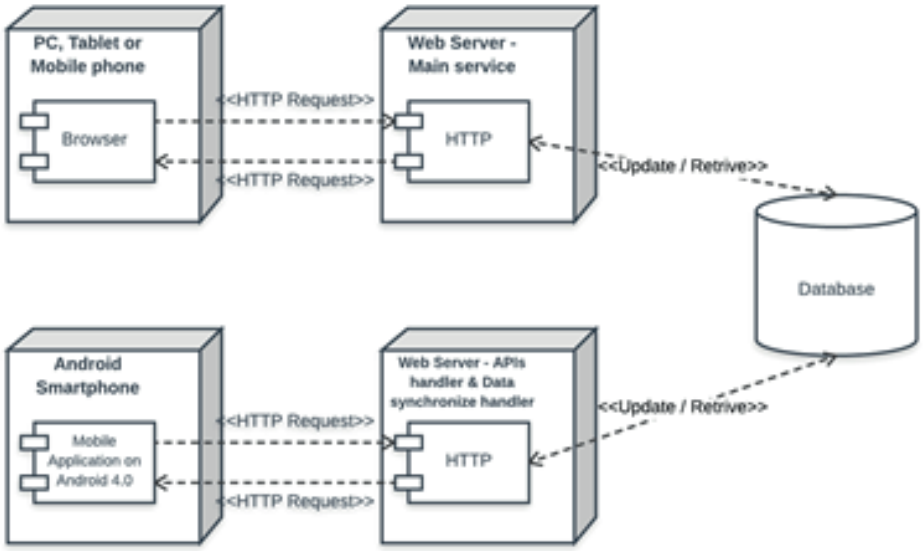

Figure 2: Software component architecture of DCMed prototype.

B. The patient (End user/Caregiver) receives medication reminder through mobile application which medication information and schedule are from the central system.

C. The patient (End user/Caregiver) can view the information such as packaging, medication information, report, appointment, and system information though mobile application, while administrative staff can view the information though web application.

D. Administrative staff can manage the information such as patient's information, medication information, prescription, appointment, and users through web application.

E. Administrative staff can management system information such as permission and customization through web application.

The User Interface can be operated on both web browser and mobile browser. For the web browser, users must verify the identity (Login) in order to use. For the mobile application, users must install DCMed application in their Android smartphones. Similar to web browser, users can log in with a user ID in order to use the application. Both browsers contain the main page with menus such as medication box, medication information, report, appointment, and setting. Inside the medication box, users will find the medication schedule including the reminder window notifying when the users have to take medications. The medication information section includes details of name,

Figure 3: Use Case diagram presenting the interactions between End user and Administrative staff.

size, picture, packaging, property, and side effects. Moreover, it presents report of medications taken daily and weekly, and appointment with a doctor at the hospital.

3. Results

In order to measure the result, there are three indicators used to measure in this study which are (1) performance and stability of Android application, (2) average level of satisfaction based IMB Model, and (3) medication compliance presented as follows.

3.1. Performance and stability

The Android application was developed in "Android Studio", the application for developers, and then tested by the use of tool called "TestObject" [19]. There are 3 different tests. Firstly, Install and Launch, the application was tested to see if it could be installed and launched properly. Secondly, Screenshots, TestObject took screenshots of different activities within the application to see how the application looks like on different devices, and detect any bugs. Lastly, Stress, TestObject conducted random clicks within

the application. The result of the stability and performance of the system is shown in Table 2.

Table 2: The stability and performance of the system tested by "Test Object" tool.

Item	Passed	Errors
Install & Launch	56	0
Screenshots	22	0
Stress Test	30	0

It can be seen from Table 2 that the system errors in Install & Launch, Screenshots, and Stress Test are not found. Hence, it can be concluded that the stability and performance of Android application developed in this study is in excellent level.

3.2. Satisfaction level based on IMB Model

In order to measure the average satisfaction level of Android application in DCMed system based on Information, Motivation and Behavioral skills, the researchers collected data from Internal Medicine Center, and Percutaneous Coronary Intervention Clinic at Siriraj Hospital by the use of questionnaire. The questionnaire was designed to consist of 18 items based on IMB Model, information (7 items), motivation (6 items), and behavioral skills (5 items). 56 stroke patients were selected as the samples and assigned to experimental group (28 patients) and control group (28 patients). The samples were asked to use the application and rate their satisfaction level from 1 (very dissatisfied) to 5 (very satisfied). From the analysis of the survey, it is found that the average score of satisfaction in the Information, Motivation, and Behavioral skills dimension is 4.46, 4.30, and 4.59, respectively. Overall, the average score of satisfaction is 4.47 as presented in Table 3.

Overall, it can be seen from Table 3 that average score in each dimension is higher than 4 (satisfied) showing that the samples were satisfied with the use of application. It is implied that this application can provide information and motivate the users to use this application. Also, the score in Behavioral skills is 4.59 which is the highest score among all dimensions referring to high level of usability. This can be seen from the item 'Application helps take medication on time' receiving the highest satisfaction score (5.00) as well. However, the result shows that the samples were moderately satisfied with the operating system (3.43.46). This might be because the application can be only installed in Android system, while nowadays, many users use another operating system like iOS.

Table 3: Descriptive statistics of the satisfaction level with Android application in DCMed system.

Items	Mean
Information	
Application provides information of how to do medication	4.71
Application provides information of medication reminder	4.64
Application provides information of medicine	4.57
Application provides information of treatment	4.29
Application provides information of appointment	4.39
Application provides Help function and user instruction	4.21
Application processes quickly	4.39
Average Information score	4.46
Motivation	
Interface appearance is attractive	4.68
Application provides ease of use	4.40
Application has all functions as desirable	4.21
Information in the application is reliable	4.79
Functions in application encourage the user to use	4.29
User is satisfied with application's operating system (Android)	3.46
Average Motivation score	4.30
Behavioral skills	
Application helps take medication on time	5.00
Application helps create positive attitude in medication	4.11
Application helps understand and gain knowledge of medication	4.71
Application helps create good discipline in medication	4.82
Application helps reduce problems and obstacles in medication	4.71
Average Behavioral skills score	4.59
Overall average	4.47

3.3. Medication compliance

In order to evaluate medication compliance, this study adopted Medication Adherence Report Scale (MARS) introduced and developed by Horne [20]. The questionnaire was designed to consist of 5 questions with scale of 5-25. This evaluation was conducted by

another study [21] permitted to use application by the researchers. 56 stroke patients were selected as samples and assigned to different groups. 28 patients in the experimental group were asked to use the application, while 28 patients in the control group were not. According to Chi-square test in Table 4, it is found that before using application, the compliance scores in both groups are not significantly different ($p > 0.05$). However, after using application, the compliance score of the samples in experimental group is significantly higher than the samples in the control group ($p < 0.05$). Moreover, the compliance score of the patients in experimental group increases by 42.86% [22].

Table 4: Comparison between the control group and experimental group using Chi-square statistic.

Compliance test	Experimental group (N=28)		Control group (N=28)		x^2	p-value
	Number (%)		Number (%)			
	Compliance	Non-Compliance	Compliance	Non-Compliance		
Before	4 (14.214.28)	24 (85.785.72)	10 (35.735.71)	18 (64.264.29)	3.43	.064
After	16 (57.157.14)	12 (42.842.86)	6 (21.421.42)	22 (78.578.58)	7.49	.006

4. Conclusion

In this study, the researchers designed and developed a prototype of DCMed system as a medical reminder application for stroke patients. After that, the researchers measured the performance and stability, average level of satisfaction based on IMB Model, and medication compliance. According to the result, it is found that the application has high level of performance and stability tested by TestObject. The samples were satisfied with the use of application according to the satisfaction score in each dimension of IMB Model which is higher than 4 (satisfied). Moreover, the result of compliance evaluation in stroke patients demonstrates that medication compliance increases after using the application.

In addition, this application was used in another study examining the medication compliance of patients with Acute Coronary Syndrome after hospitalization as well [23]. The study shows that after using the application, the average compliance score of the patients in experimental group increases from 22.50 to 24.89, and it is significantly different from the patients in control group ($p < 0.01$) [23]. This study demonstrates that this mobile application helps enhance medical compliance in not only stroke patients, but also patients with other types of disease. The findings are also in

accordance with the research of Safer Virtual Pillbox [12] and a pilot study which the system designed in the studies improved the efficiency of medication compliance [17].

However, this study also addresses the limitations leading to future improvement. Since the application is operated in Android system, the application might not be compatible with other operating systems, and reach users using another operating system like iOS. This issue is also reflected when the satisfaction of using operating system (Android) is the lowest. Hence, the future development should focus on designing and developing the application in another operating system as well. Moreover, due to the limitation of time, this study neglected some important features in Motivation dimension so that the satisfaction in this dimension is the lowest. Hence, the emphasis on the motivation features is needed such as using the doctor's voice to remind patients to take medications, or developing appointment feature similar to the Pilot Study [17].

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