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Novel Innovational Paper

Monitoring of Compliance on an Individual Treatment through Mobile Innovations

A Anastasiou[1]*, K Giokas[2] and D Koutsouris[3]

[1]Applied Informatics in m-Health (AiM) Research Team, National Technical University of Athens, Biomedical Engineering Laboratory, Athens, Greece

[2]Leader, Applied Informatics in m-Health (AiM) Research Team, National Technical University of Athens, Biomedical Engineering Laboratory, Athens, Greece

[3]National Technical University of Athens, Biomedical Engineering Laboratory, Athens, Greece

***Corresponding Author**: Athanasios Anastasiou, Applied Informatics in m-Health (AiM) Research Team, National Technical University of Athens, Biomedical Engineering Laboratory, Athens, Greece.

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Abstract

The present work examines the potential of smartphone usage for offering health services to elderly patients. The purpose of this work is the design, development, and implementation of a telemedicine application. This application aims to improve the monitoring mode and increase patient adherence to the instructions assigned by the medical staff. It consists of three parts: the doctor's application (Web Application), the patient's application (Android Application) and the Web Server of the platform, where the database is stored necessary for the smooth operation of the platform. Also the Web Server hosts the doctor's Web Application. The Web Application is based on web front-end technologies, providing the medical personnel with a variety of features and useful actions. These actions and capabilities are mainly relevant to the assignment of instructions to patients and the monitoring of their health progress. The Android Application has been implemented and validated for the Android-based mobile devices operating system and consists of a handy and user-friendly environment, equipped with the right tools so that the patient has the ability to update the system on the progress of his/her health by storing the appropriate measurements. Both applications also provide customization capabilities in regards to the patients' and doctors' profile.

Keywords: *Monitoring; Compliance; Smartphone; Web Application*

Introduction

More and more people own smartphones and are using them to access the Internet. Close to one third of cellphone owners have used their devices to access health information, a rate that nearly doubled in the last two years. In addition, about one in five has owned a health-related app, most commonly one concerning weight, diet and/or exercise. Given this information we need to really reflect on the obvious trends in the use of mobile health technology, moreover we need to leverage this knowledge and technology to reach out to more patients, and improve their lives. This will result in improving the future of the healthcare system through novel delivery channels. Improved medication regime adherence and compliance can result in better patient health outcomes while significantly cutting costs. On average, adherence levels are at 50% [1]. This means that patients get their prescriptions filled, follow dosing instructions, and renew and refill prescriptions as directed only half the time. According to recent statistics, poor adherence accounts for an estimated 33% to 69% of medication-related hospital admissions, which costs close to $100 billion each year as shown in figure 1. The annual direct and indirect costs of non-adherence in the U.S. are estimated to be as high as $290 billion. It has been estimated that 125,000 deaths per year in the U.S. can be attributed to poor medication adherence [2-4].

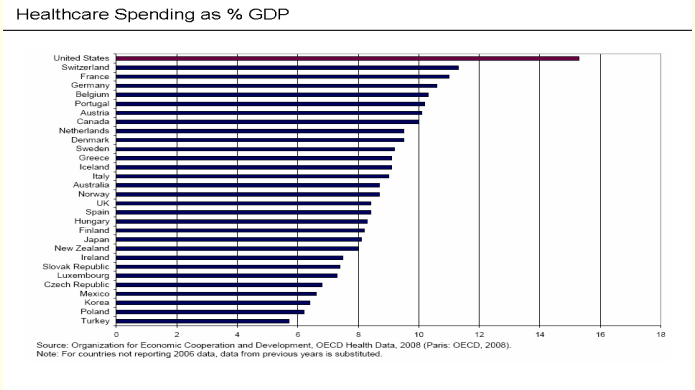

Figure 1: *Healthcare Spending as % GDP.*

Related Work

The research of 25 mobile applications which were studied [5] and whose technological characteristics and operations were recorded, led in the exportation of several conclusions and percentages, which refer to the way the applications function and the services they provide. Figure 2, shows the comparative results of the above mentioned research.

Application name	Creation of a web account/ online data entry	Cloud data storage	Database for automated medicines search	Supports multiple profiles	Medication reminder/Refill alert	Tracks missed and taken doses	Export/Print history of doses	Send medication reminders to other people connected with the patient	Graphs/ View percentage of compliance	Stores other medical data (ex. allergies, laboratory tests etc.)	Generates reminders with no internet connectivity	HIPAA-compliant data protection	For free	Multilingual	iOS	Android	Windows Phone	Blackberry
MyMedSchedule	✓	✓	✓		✓/✓					✓		✓	✓		✓	✓		
MyMeds	✓	✓	✓	✓	✓/✓	✓			✓	✓	✓	✓			✓	✓		
MedSimple	✓	✓	✓		✓/✓					✓	✓		✓		✓	✓		
Meds Agenda		✓	✓	✓	✓	✓	✓				✓				✓			
RxmindMe Prescription			✓		✓	✓	✓			✓	✓		✓		✓			
Dose Cast			✓	✓	✓/✓	✓					✓		✓		✓	✓		
TRxC(Beta)	✓	✓			✓	✓			✓	✓	✓		✓		✓	✓		
MediMemory	✓	✓		✓	✓/✓	✓					✓		✓		✓	✓		
PillManager	✓	✓			✓/✓	✓	✓			✓	✓		✓		✓	✓		
MediSafe		✓		✓	✓/✓	✓	✓	✓	✓		✓	✓	✓		✓	✓		
Med Helper Pill Reminder	✓			✓	✓/✓	✓				✓	✓		✓		✓	✓		
Winn-Dixie Rx	✓				✓/✓								✓		✓	✓		✓
My Pillbox				✓	✓/✓	✓	✓				✓		✓		✓	✓		
Rx Medicine Reminder				✓	✓					✓	✓		✓		✓	✓		
Visual Pill Reminders				✓	✓	✓		✓			✓		✓		✓	✓		
My Meds				✓	✓/✓	✓	✓		✓		✓						✓	
Medication Reminder					✓						✓		✓				✓	
Medicine Manager					✓						✓						✓	
Medica Reminders		✓			✓	✓					✓						✓	
Med Prompter Pro					✓/✓						✓		✓				✓	
On TimeRx					✓/✓	✓			✓		✓							✓
Medication Reminder-Health Assistant				✓	✓					✓	✓		✓					✓
Rx Reminder					✓	✓	✓				✓		✓					✓
TimelyMed					✓						✓							✓
Remind Me					✓						✓		✓					✓

Figure 2: *Research Study of Medical Apps.*

All the applications generate medication reminders at the time that the patient is required to take his/her medicine whereas 52% of the applications send refill alerts when the medication storage is nearing depletion. Despite the fact that the function of refill reminders

is very important and is directly connected to the correct medication taking, it isn't supported at a satisfactory grade by the Windows Phone and BlackBerry applications. Furthermore, 96% of the applications generate the medication reminders without internet connectivity. This feature is significant and demonstrates that the application is reliable as it reminds the patients to take their dose at the right time without mistakes that can be caused by connectivity problems or by the absence of an internet connection. Another feature of major importance in controlling the medication compliance level, is tracking the taken and missed doses. This function is a self-control tool for the patient so he/she can point out the exact day, time and reason of being non-compliant. The percentage of the apps which include this feature rises up to 60%. There is an imperative need for this percentage to increase in order for all these applications to not just be reminder apps but also useful tools for medication history tracking. The expansion of this functionality is the exportation or printing of the dosage history so that the user can share his therapy progress with his doctor or other people. In addition, the data exportation protects the history from getting lost by potential damage to the user's mobile phone. The percentage of apps which include such a feature is 28%. The graphs and the view of the compliance percentage are both very useful tools for rating the level of adherence. This important characteristic is supported only by 20% of the applications studied. Undoubtedly, the depiction of the medication compliance percentage, in any way it is achieved, contributes to self-control and acts as an incentive for the patient to take his medicine more systematically in case of low compliance. The incorporation of such a feature in more applications could further enhance the compliance level and support the applications' usability.

Only 8% of the applications send medication reminding messages to other people apart from the patient, such as family members or anyone else chosen by the patient. This feature is significant since in cases of chronic illnesses (such as diabetes) [6] the intervention of a third person could save the patient's life if he forgets to take his medicine. However, only 2 of the 25 applications studied, include this feature which shows that this crucial factor hasn't been evaluated properly.

Moreover, 36% of the apps enable storing of additional medical data such as allergies, laboratory tests measurements, heart pressure and glucose measurements and information about patients' medical history. The number of applications which support this functionality is small and should increase as it could help patients be more compliant through continuous monitoring of their state of health and the possibility of comparing the measurements with one another. The creation of multiple profiles for different users within the same application is a characteristic which helps family members to also be compliant. The percentage of the apps which include this feature is 44% and it should also be increased as the applications would refer to a wider age group and enhance the overall compliance level.

In addition, 32% of the applications allow the creation of a user account on the web site in order for the user to enter data online. This feature enables the patient to receive medication reminder alerts not only on his mobile phone but also on his computer. Cloud computing is connected with this function and it is supported by 36% of the applications. These percentages are low if we consider how useful the access from multiple devices is for the user and the enhancement of the level of adherence.

Another major concern about health applications is the cost for their installation. 72% of the applications studied are available for free which is an incentive for the users. These applications have a greater number of downloads than the applications which charge users as many people cannot afford to pay even a small amount of money in order to receive help in fighting their medicine forgetfulness. A fact which demonstrates the spread of an application on a global level, is its availability in multiple languages (apart from English). This plays a great role in the use of the applications by older people who probably don't speak any foreign language or in countries with high percentage of illiteracy. The availability of an application in multiple languages, increases the app's wider global reach. The percentage of apps which support such a feature, is 24%.

Only 12% of the apps protect the patients' data according to the HIPAA (Health Insurance Portability and Accountability Act of 1996) protocol, which shows that data security isn't the first priority for the majority of the applications. This is a serious problem and actions should be taken in order for data security not to be depended on each developer or Software Company but to be compliant to global security laws, standards and procedures.

When it comes to OS compatibility most applications studied (48%) are compatible with Android and iOS operating systems. Applications for Windows Phones account for only 20% and applications for BlackBerry for 24%. Our research has shown that, Android and iOS apps, include many more characteristics than Windows and BlackBerry OS apps. More precisely, the applications for iOS have got 98 characteristics/functions, the apps for Android have got 96 characteristics, whereas the apps for Windows Phones and BlackBerry have got 21 and 24 features respectively. These facts show that the most well-known and feature-rich applications run on Android and iOS as the compatible mobile phones as these OSes also have more complicated and technologically advanced software functions. As a consequence, the applications for Android and iOS are used by many more users.

System's Architecture

The doctor's application is a Web Application. A Web App is an application that is available to users over the Internet and the user only uses the browser to access it. Created by programming languages, which are supported by the browser (such as the combination of JavaScript, HTML and CSS) these applications are based on this for the representation of their content. The main reason for their popularity is the wide use of the browser by the public and the fact that web browsers can be found on any device with Internet access without any additional hardware. For the implementation of the Web Application we have used web programming languages such as HTML5, CSS3, JavaScript as well as the popular and widely used library of JavaScript, jQuery. Figure 3 shows the doctor's home page, thus the Web App of our work.

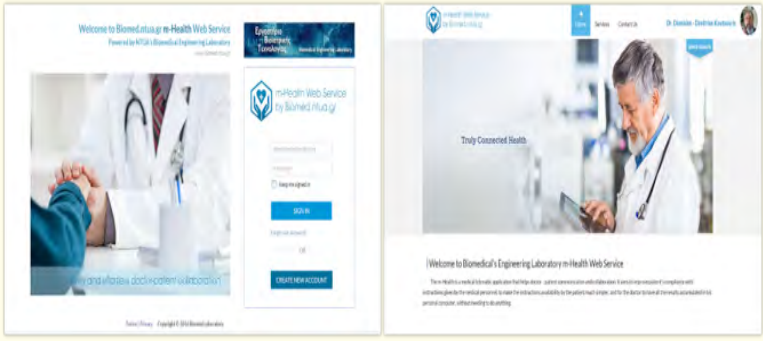

Figure 3: *Doctor's Home Page.*

The following figure 4, shows the patient's profile page that the doctor can have access to it.

Figure 4: *Patient's Profile Page.*

The tasks that may be assigned by the doctor are divided into three broad categories. The first category concerns the tasks walking or running (Walking/Running Tasks), the second category relates to the general tasks (General Tasks) and the third category is the Type Pill task (Pill Tasks) as shown in figure 5.

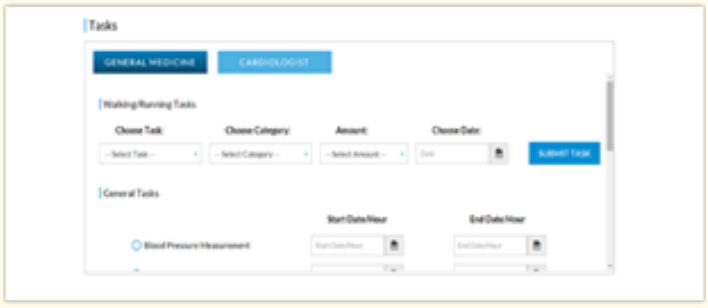

Figure 5: *Section award of task.*

After completing the assignment of tasks, the doctor has to send them to the relevant patient as shown in figure 6 below.

Figure 6: *Send the task general medicine to the patient.*

The patient's application, as previously stated, is intended for mobile devices with the Android operating system. The Following figures (Figure 7) show the operation of the Android App. The first is "Patient's Home Page", the second is the "Tab "Uncompleted", when the patient has unfinished tasks and the third is "The patient will complete task category pill".

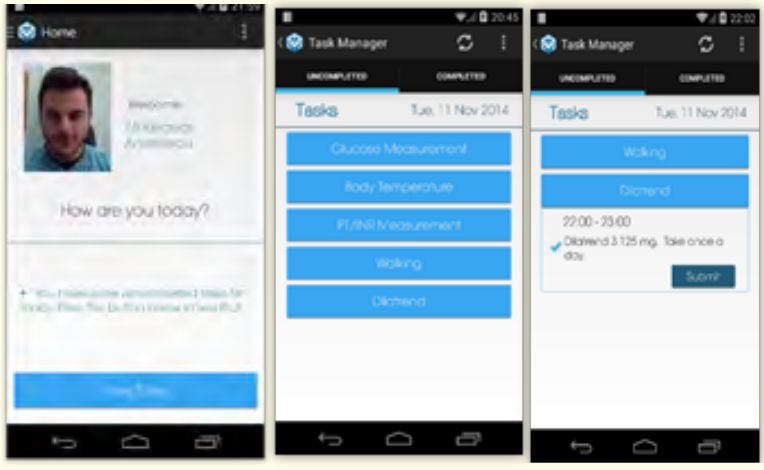

Figure 7: *Patient's Home Page.*

When the patient has to complete a walking or running task then by simple clicking on the button with the title of the task, a window is displayed just below this button, which contains all the relevant information such as, the information activity of walking and the Screen integration of task walking or running as shown in figure 8.

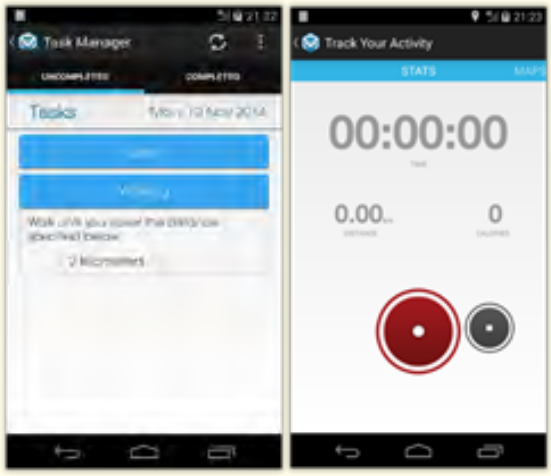

Figure 8: *Patient's Walking Activity.*

The following figure 9, shows the Path followed by the patient during the completion of the activity along with the distance covered and calories burnt.

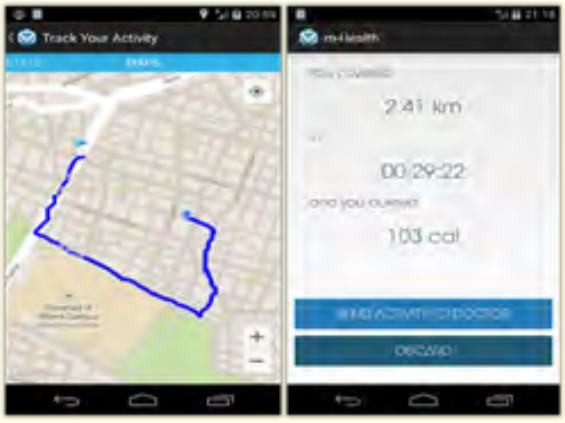

Figure 9: *Patient's Running Path.*

The unique feature of this work is the application of social behavior theories in such a way as to positively influence patients' compliance behaviors, including mobile-delivered contextual reminders based on association theory; mobile triggered questionnaires based on self-perception theory; mobile enabled social interactions based on social construction theory [1].

Interconnectivity of Adherence Apps

Currently, very few marketed adherence apps are interconnected with other information systems. Of the apps evaluated in this paper, five offer cloud storage of prescription data, of which only one has a companion website. However, none of the apps evaluated is fully integrated with patient record systems (e.g. community pharmacy prescription databases, electronic medical records, etc). Therefore, interoperability with existing prescription and medical records systems represents a vital frontier for future app development. For example, interfacing adherence apps with pharmacy prescription records could enable pharmacists to easily push patients' drug regimens to smartphone apps, allowing seamless transmission of reminders to patients. More importantly, pharmacists and patients could collaborate to customize reminders for regimens where adherence has proven to be challenging. This interoperability would shift the current

orientation of adherence apps to a more provider-focused technology and thereby provide pharmacists a potentially valuable tool to improve medication adherence.

In addition to connectivity to medical records systems, smartphone apps can be interfaced or synced to other devices with adherence capabilities. On the forefront of these technologies is the Proteus Digital Health Feedback System whereby solid oral dosage forms are combined with ingestible sensors that record basic physiologic parameters after ingestion and transmit the information to a dermal sensor or patch that can sync with smartphone devices. This unique system can record actual ingestion of individual doses and the precise timing of ingestion. Adherence apps working in tandem with such a system could send customized reminders only when doses are actually missed. Although such an integrated system has obvious applicability to the clinical trial research setting, its cost and the inconvenience of wearing a monitoring patch likely limits its usability within the boundaries of the normal clinical practice to therapies for which adherence is especially critical (e.g. management in tuberculosis and HIV infections). Several technologies for diabetes self- and automated monitoring have been developed and can be synced with smartphone devices [7]. These integrated systems may hold similar promise to monitor and improve adherence in diabetes. Electronic pill boxes that are equipped to monitor box openings, wirelessly transmit a signal to servers when a scheduled opening is missed, and then send SMS text messages reminders have been shown to improve adherence.

Conclusion

Despite decades of research, medication non-adherence still represents a fundamental health care challenge. Adherence apps are inexpensive, scalable, accessible to anyone with a smartphone, and do not require separate devices or packaging, which allows them to be easily implemented. Despite not having been evaluated in clinical trial settings, they could be considered a possible strategy that pharmacists could recommend to non-adherent patients and to incorporate into their practice.

In conclusion, all the characteristics and functions which are included in the applications are very interesting. Definitely, there is room for improvement and development in the design and the functionality as well as in the complexity of the application while giving additional emphasis on the medication adherence. For instance, the application could reward the patient when he is totally compliant by sending him a message or by giving him points/marks, in sort gamifying the user experience. This could have a positive effect on the patient's psychology and it could work as an incentive, even in a small scale, to keep taking his medicine properly. On the other hand, the application could send warning messages to patients who aren't compliant with their therapy in order to consult and warn them about the progress of their health state. The complexity of such functions may be increased, but patients' needs are also increased and the challenges, that the applications will face in the future, will be even greater.

If examined under a business perspective, such apps require minimum seed funding and can very rapidly evolve into a sustainable service since it bridges the gap between post-doctor-visit follow up and the patient, in its simplest form and an extremely accurate yet highly affordable and versatile tool for large volume data collection in a more complex configuration.

Last but not least, the system can incorporate many enhancements such as advanced analytics and statistics, cloud based services and can possibly be integrated with the national e-prescription service.

Bibliography

1. SW Campbell and TC Russo. "The social construction of mobile telephony". *Communication Monographs* 70.4 (2003): 317-334.

2. Constandache I., *et al*. "Enloc: Energy-efficient localization for mobile phones". In Proceedings of the 28th Conference on Computer Communications, Rio de Janeiro, Brazil (2009).

3. Cramer JA., *et al*. "Medication compliance and persistence: terminology and definitions". *Value Health* 11.1 (2008): 44-47.

4. Osterberg L and Blaschke T. "Adherence to medication". *New England Journal of Medicine* 353.5 (2005): 487-497.

5. https://play.google.com/store/apps/

6. Koutsouris D., *et al*. "The use of telephone monitoring for diabetic patients: theory and practical implications". *Smart Homecare Technology and Telehealth Journal* 2 (2014): 13-17.

7. Dayer Lindsey., *et al*. "Smartphone medication adherence apps: potential benefits to patients and providers". *Journal of the American Pharmacists Association* 53.2 (2013): 172-181.

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