Safer Virtual Pillbox: Assuring Medication Adherence to Elderly Patients

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ABSTRACT
In this paper, we describe a new mobile application for assisting to elderly patients and their caregivers (familiars, physicians, pharmacist) in the medication management at their homes. This mobile application will help patients to maintain medication adherence in a reliable and correctly intake of their drugs. The main target users of this application are polymedicated, polypathology and over 65 years old patients. The application was designed using User Centered Design (UCD) methods, taking always into account the characteristics of these target users, so usability and accessibility principles were applied in the design of interfaces. The design has been tested with a pre-test group of selected patients and we have confirmed that patients using this mobile application have increased their medication adherence and have reduced the frequency of adverse drug events.

Categories and Subject Descriptors
H.3.4 [**Systems and Software**]: User profiles and alert services. J.3 [**Life and medical Sciences**]: Health – *Medical information systems.* H.5.2 [**User Interfaces**]: User-centered design - *User interface management systems (UIMS)*

General Terms
Management, Measurement, Design, Reliability, Experimentation, Human Factors

Keywords
Medication errors, Patient Care, Safety Treatments, Mobile Apps, mHealth.

1. INTRODUCTION
Elderly patients over 65 years old are increasing in worldwide and they are composing an important group of attention for all governments as they represent the group of population with increasing expenses regarding to hospitalization, consultations and pharmaceutical expenses. Several studies have demonstrated that old patients who have to manage a polypharmacy at home (in the sense of patients who have to take five or more drugs, during a period of six or more months) are exposed to frequent errors in their intakes of drugs and the number of hospital readmissions of these patients is increasing [3,6].

The rate of errors in the intakes of drugs by elderly patients is directly related with increasing of age, decreasing of mental score and the number of drugs prescribed. A good knowledge of drugs and proper labeling of drug containers aids patient to compliance with medication. The main errors in polypharmacy management by elderly patients are naming errors (only 10% of patients were able to name all their drugs correctly), dosage errors (over 36% of all patients gave the dosage of their medications with complete accuracy) and frequency errors (around 70% of patients made mistakes in responding to their drug frequency) [1].

In a recent study of polymedicated patients over 65 years old [7], Garrido-Garrido E.M. et al. concluded that use of drugs in chronic elderly patients is of considerable magnitude, affecting one out of every three. They found that polypharmacy in elderly is a common and serious problem that needs to be reviewed and evaluated continuously. The prevalence of polypharmacy in patients over 65 years old was 33%. These patients were using an average of 9 drugs and had an average of 5-6 diseases. The prevalence of polypharmacy was greater among women, but differences decreased in people more than 85 years old.

Medication errors are common when elderly patients are transferred between primary and secondary care. On an average, there were two medication errors each time a patient was transferred between primary and secondary care. Improvement in documentation and transferring data about elderly patients' medications could reduce these errors [14]. Other authors consider that routine questions that physician asks the patient to identify other drugs of other physician must be reviewed to avoid this medication errors [15]. In a study of Metlay, JP et al. [13] for the Pennsylvania Pharmacy Assistance Contract for the Elderly Program, 32% of the sample reported that they had not received any specific instructions about their medications, 35% reported that they received instructions from their primary care provider, 46% indicated they received them from a pharmacist and 54% of participants indicated that they used a pillbox for organizing their medications.

The use of ICT for the medication adherence of elderly patients could offer an improvement in the safety of intakes of drugs, indicating the correct dosage and providing an adequate identification of the medication. In a recent report about the use of ICT by elderly people in Andalucia, Spain [2], 85% of

households in Spain where at least one person between 65 and 74 years old lives have a mobile phone. The use of mobile phones by older people is often underestimate but the reality is that older persons are using mobiles phones and they feel more useful, social and enjoyable in their lives [5]. There is no evidence that older people reject technology more than people of other ages; elderly accept and adopt technology when the latter meets their needs and expectations.

There are many medical applications for mobile phones, tablets and laptops, mainly for smartphones in all their platforms (Android, iPhone, Windows Phone or Blackberry), designed for virtual caregivers or pillboxes [8,9,10,11,12]. But mostly of these apps are designed for general population and they have been designed without considering the needs of the elderly people. Some of them are complicated to use, both when programming the alerts for intakes of medication and when user have to respond to notifications (small controls, small fonts, contrast, etc). Normally, these apps are mere reminders of intakes of drugs and do not register activity of the patient. And in many cases there are no communication between patient and caregiver or between patient and physician.

The Chronic Care Model [4] promotes a number of interventions for a comprehensive and integrating approach to care chronic polypathological patients that emphasizes on the innovation in the interaction between patients and professionals and the design of tools to facilitate self-care.

The paper is organized in the following manner. In section 2 we present the design of our virtual pillbox, the procedure followed in the design and the modules that compound the application. In section 3 are presented the user interfaces and the implementation of the application. Results of the use of the application are shown in section 4 and conclusions and future work are discussed in section 5.

2. THE DESIGN OF VIRTUAL PILLBOX

In this section we describe the design of the mobile application. We wanted to define a new tool, which could be used from the first pharmaceutical visit, through dispensing in the pharmacy and followed by the caregiver of the patient at home or the own patient.

The main features of the designed tool are described next. The tool has to register all actions of the patient regarding to accepting or rejecting one take of a drug at a specific time. The tool will offer a complete list of all the medications for all professionals who are responsible for continuing the assistance. It must be recorded the changes that have been made with respect to the patient's previous medication. The application should improve patient safety regarding to intakes and/or interactions between different drugs. The application must also include all medications considered appropriate for the elderly. The schedule of intakes must be easily programmed by the patient and/or the caregiver taking into account his/her lifestyle and minimizing the number of takes (whenever possible). The application will assess the adherence to medication of the patient.

Taking in account all these considerations, as shown on Figure 1, we have designed a mobile application to obtain fewer medication errors by patients, a safer prescription, give more autonomy to patients, a greater compliance and lower costs by avoiding unnecessary treatment (including hospitalization) and treatment of the consequences of adverse events due to medication errors of most frequently used drugs for the most common diseases.

Figure 1. Main goals of the mobile application designed

2.1 Design process

The first step in the process of design of the application was capturing information from professionals to define the conditions to be satisfied by the tool, specifically identifying causes of common errors and safe practices in the medication management of polymedicated and polypathological elderly patients (or their caregivers), gathering useful information for the design of the tool.

We conducted a focus group between health professionals with experience of at least three years of basic health areas with predominantly older patients. One moderator and one observer, both researchers of the Miguel Hernandez University, conducted the focus group on February 2012. Seven health professionals compounded the group: three family physicians (two men and one woman) and four pharmacists (one man and three women). We defined a brief questionnaire with only three questions for determining the main aspects of the design of the tool: a) we want to know the main problems that patients have between consultation and next consultation regarding with the medication: the more often and the most common mistakes. b) what are the more severe risks with usual medication that a helpful tool, as a virtual pillbox, should help reduce. And c) what type of information would be useful for patients.

The results of this focus group were that the main problem of patients is forgetting the medication. The patients don't know when to take the drug, especially with generic medications. Side effects cause treatment discontinuation by patients. If the patient have cognitive problems, lack of adherence to treatment is very likely. There is a lack of information about the disease itself and the drugs. Caregivers or family environment are essential in order to the patient be compliant. It would be advisable that the patient knows what goals to achieve. Another aspect to consider in the design of a virtual pillbox is the drug interactions that can have the medication. Finally the application should have any procedure for remembering to the patient to take one drug that patient forgets or that the patient does not attend when the application showed the alert message. Moreover the virtual pillbox should be a system of communication between the patient and the professionals (not only physicians but also pharmacist).

2.2 Application modules

As a result of this preliminary focus group we selected two users to involve them in the design of the application, one patient and

one caregiver helped us in the design process. The application should be composed by five modules:

a) Medication Management
b) Alarm Manager
c) Register
d) Communications
e) Setup

The Medication Management module is the more complex module, as here the user has to introduce all the information about the medication prescribed by physicians (drug name, active ingredient, dosage, frequency), as you can see in Figure 2. The application was designed to collect all the medications that take the patients, prescribed by a physician of the Public Health System, a physician of the Private Health System or even a homoeopathist and also drugs from a herbalist that patient could be taken. The application can also schedule treatments, not involved with drugs, prescribed by any doctor or physiotherapist to the patient for better health care (like "drink a glass of water now" or "it's time to walk for one hour").

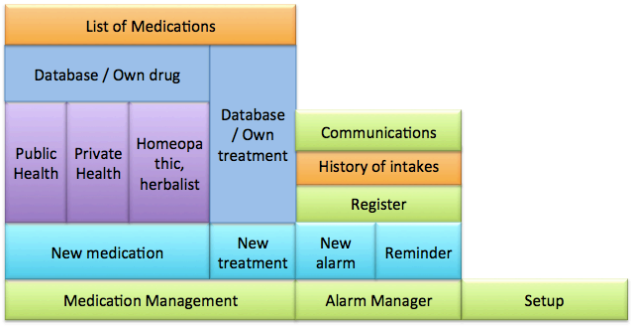

Figure 2. Modules of the designed tool

All medications and treatments could be recovered from a database of the most common drugs and treatments for the patients selected for evaluating the application. If one drug or treatment cannot be found in the database of the application, the user can always introduce a new drug or a new treatment in the database of the application. This new drug can be shared with the rest of users of the application using a distributed database hosted in a central web server.

The main feature for defining a new drug in the database is one photograph of the pill and one photograph of the box of the drug. It's very important for facilitating the use of the virtual pillbox that the patient can identify in a secure and easy way the drug to be taken when the alarm sounds. Due to the great variety of sizes, shapes and colors of pills, one picture of the pill/drug is the more easy way to help patient in drug identification.

After all medications have been entered in the application, normally by the caregiver, the patient will have a complete list of all the drugs (and treatments) that s/he has to take each day. This complies with one of principles of design we defined in the focus group.

The Alarm Manager module is the responsible for dealing with alarms of each intake of one drug and their reminders. When one alarm sounds (or simply appears in the screen of the mobile application) the patient can attend it or not. If the patient accepts the alarm, the application will register the time when patient has taken the drug. But if the patient does not attend the alarm, the application will remind him/her the intake up to five times more. If the user still does not attend the alarm then the application will record the intake as unattended and will send an email or an SMS the caregiver.

The Register module will offer a list of all intakes of drugs of the patient during the medication. This module will allow verify the medication adherence as we can recover all the actions that the patient has performed during his/her medication. This list of intakes of drugs can be sending daily to the caregiver at a specific time. In this list the caregiver or the physician can analyze if one drug is repeatedly untaken, which could be due to side effects of this drug and the patient stops the intakes of this drug.

The Communications module handles the sending of messages to the other agents of the system (caregiver, physician or pharmacist). The alerts can be sent immediately or scheduled. When the patient does not attend one intake at scheduled time after six reminders, the application will send an email or an SMS to the caregiver immediately. The application can also be programmed to send daily the history of intakes to the caregiver or to a central database where all histories of registered patients can be collected by the same hospital or primary care center.

Finally the Setup module permits to personalize the application regarding to level of sound of the alerts, e-mail address and/or mobile phone number of the agents (caregiver(s), physician(s), pharmacist(s)), delay time between reminders of one intake, e-mail of the agents (or the central system) where the application will send daily the history of the patient and, off course, the user management of the application as well as the password for accessing to this module.

3. IMPLEMENTATION AND INTERFACES

The first decision we have to deal with was the mobile device we were going to implement the designed tool. Due to characteristics of final users of this application we consider in a first stage developing for a mobile phone with a screen size of 3" or more. After some prototypes of the initial interfaces of the application, we decided to implement the application for one tablet of at least 7". We needed a device with camera and with 3G connectivity. We needed also a device with WiFi connectivity. Bluetooth connectivity was considered initially, but we decided to connect devices nearby with WiFi for a more reliable and fast data transfers. One application for Android tablets was developed as first prototype. We selected a BQ Verne 7" tablet, a Spanish and cheap tablet, that meets all requirements. The main feature of this tablet that led us its election was an internal socket for SIM card instead of a USB port for an external 3G modem. It was important to have the more compact device and easy to use by elderly people. The only inconvenient of this tablet was the battery life, as the user had to charge it every night. If the patient forgot one night to charge the tablet, probably the next morning intakes were not alerted and the patient forgot to record them. Otherwise this tablet has met expectations.

In Figure 3 is shown the user interface of a reminder presented to the patient for the intake of 1.0 pills of the drug "Adiro 100 mg" at 2:00 pm. The user can see one photograph of the drug container and one photograph of the pills where s/he can easily identify it by size, shape and color of the pill. The button "+" will show more information about the drug, but only main recommendation for the

intake of the drug is shown in this main screen. We considered that only essential information should be offered to the final patient and we leave additional information (as complications, risks and cautions) to the caregiver in a secondary screen that will appear after pressing the button '+'.

Figure 3. User interface of a reminder of one intake

This screen is presented to the patient while the device sounds the selected alarm. The user can decide to postpone the intake for several minutes by pressing the yellow button, to accept and register the actual intake or to cancel and do not take this drug at this time. In this latter case, the application will send a message to the caregiver (an e-mail or an SMS) warning of this event. If after six reminders the patient does not take the drug, the application will also send a message to the caregiver.

In Figure 4 you can see a screen of the list of all medications and prescriptions of the patient. When the patient accepts one intake, the application will mark it in green and the patient cannot re-mark that take as accepted. Likewise if one intake has been not attended, the application will mark it in red to help the patient identifying forgotten intakes. When user accedes to the application will see what drugs have not been taken (colored in red) and decide to mark it as taken at that moment. Then the Register module will record this case and later the caregiver can analyze these delays in the intakes of drugs.

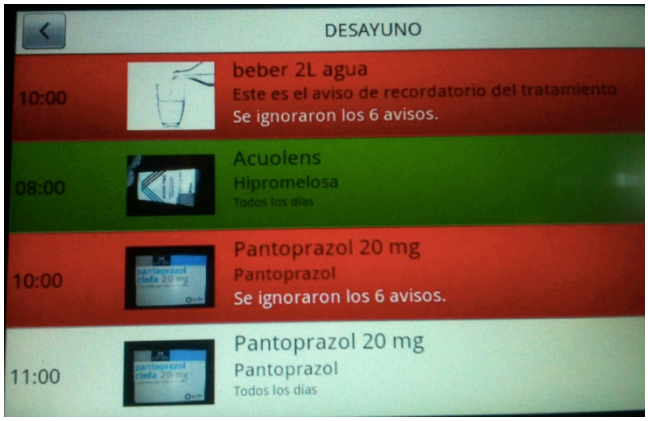

Figure 4. List of all medications of a patient

This list of intakes of drugs can be send daily to the caregiver at a specific time as a CSV file including drug name, active ingredient, dosage, alarm time and intake time.

4. RESULTS

The application has been tested by a preliminary group of 24 patients selected as volunteers from five different health care centres of the province of Alicante, Spain. Patients were selected meeting the criteria: polypathologic, polymedicated, over 65 years old, with a Barthel index over 60, who lives at home with any familiar and who is responsible for the administration of his/her medication. We collected their written consent to participate in the study. All subjects received oral and written information about the major risks to patient safety and common mistakes of patients in the self-administration of medication. We lent a BQ Verne 7" tablet to each patient and we previously formed him or her on the use of this tablet.

The experiment was conducted between 24 subjects, 14 men and 10 women, with an average age of 72.16 years old. All the subjects were using the tablet an average of 2.67 months. All subjects had a mobile phone but only 5 of them had a smartphone (20.8%) whereas the rest of users had an old mobile phone, without touchscreen. Majority of users did not own or use a computer at home (16 users didn't have and only 8 user had computer).

After the experiment all subjects responded a survey to assess the degree of satisfaction with the selected tablet, with the design of the application and especially with medication adherence.

Table 1. Satisfaction with selected tablet

	Yes	No	Sometimes
Easy of use of the tablet	22	1	1
Screen size appropriateness	21	1	2
Touchscreen responsiveness	18	1	5
Battery life	20	1	3
Tablet reliability	8	15	1

Generally all users found the tablet easy of use (91.7%), with an adequate screen size (87.5%) and touchscreen responsive (75%), as we can see on Table 1. The reliability of the tablet was only good for a 33.3% of users, as we have to mention that from 16 users who had problems with the tablet, we only have to replace one tablet and all other problems (no sound for 5 users, suddenly hangs for 3 users or poor battery life for 3 users) were solved.

Table 2. Satisfaction with design of application

	Yes	No	Sometimes
Are alerts designed adequately?	24	0	0
Buttons size adequate?	19	1	4
Font size adequate?	24	0	0
Box photo helps intakes properly	23	0	1
Pill photo helps intakes properly	24	0	0

All users considered adequate the design of alerts and the size of fonts employed in the application, but only around 20% of users experimented some problems with the size of buttons (see Table

2). On the other hand the idea of a photo of the box and a photo of the pill was helpful for taking the drugs for all users.

Table 3. Usefulness with compliance of the medication

	Many times	Some-times	Never
Forgotten or skipped any takes?	0	10	14
Did you cancel any take?	0	2	22
Did you wrong with any take?	0	1	23
Do you think you have taken more doses than intended?	0	0	24
Do you have confused and took medication does not match?	0	0	24
Have you run out of medication at home?	0	2	22

As can be seen from Table 3, the application helped to patients with the compliance of their medications, regarding to they never took more dosage than recommended by physician (100% of users), they never felt confused and took medication does not match (100% of users) or they never run out of medication at their homes (91.7% of users). Only one patient was wrong to take any medication (i.e. 95.8% of users take correctly their medication) and only two users canceled any take of their medication (i.e. 91.7% of users took all their medications in time). The application helped to 14 users (near 60%) to never forget or skip some takes of their medication. At this point seems that our application needs more reinforcement or changes the strategy of design in order to help to those 10 users that sometimes forgot or skipped some of their takes (near 40% of users). It is worth mentioning that, generally the compliance of medication was high and these omissions are difficult to solve even with any mobile application, due to the characteristics of the patients and, in some cases, to the complexity of their medications.

Table 4. Overall satisfaction with experiment

	Yes	No	Sometimes
Did you take your medication better?	16	1	7
Will you recommend this tool?	23	0	1

Finally, the mobile application has helped patients to take their medications better, as we can see in Table 4 that 16 users had taken better their medications (66.7% of patients), but if we consider that 7 patients reported that sometimes also had taken their medications better, the final rate will be of 95.8%. Only one user responded that the application did not help him/her to take better his/her medication. In this table we can also see that 95.8% of users will recommend this application to their friends and familiars if they would need it.

The final question of the survey was the overall satisfaction with the experiment and the use of the application in that tablet and we got an average of 8.63 (over 10 points) with a stdev of 1.37, so we can say that the design and the selection of the tablet were successful.

5. CONCLUSIONS

In this paper we have presented a new mobile application for polymedicated, polypathological and over 65 years old patients to assist them in assuring with the compliance of their medications. The main difference of this application is a new approach to involve patients with their caregivers but also with their family doctors and pharmacits, maintaining all of them connected by e-mails or by SMS to achieve a safer and correct management of the medications of patients at home.

We have designed a mobile application for Android platform oriented to tablets with screen of 7" or more for an easier interaction of our users (normally with sight difficulties), always with usability and accessibility principles in mind: selecting adequate font size, good contrast in all interfaces, making messages readable and understandable to interacting easily with users, granting the users to control the application and their freedom in their decisions, minimizing the user's memory load for attending the alerts and using the application in general, and all of these with an aesthetic and minimalist design and off course, helping users to recovering from errors of the application.

In the preliminary test of the application we conducted with a selected group of 24 patients we have found that most of users think that the application is easy of use, the size of the screen was adequate and the touchscreen was responsive, but this tablet has not been as reliable as we expected for users. All users were satisfied with the design of alerts, font size and photo of the pill and photo of the box, so we have demonstrated that it's a good idea to show the patients a real image of the pill and the container for an easy identify of the medication they have to take at specific time. Generally the application helped to patients with the compliance of their medications, avoiding to take the incorrect drug in each intake or taking higher doses than recommended. Finally the application got an average of 8.63 points over a 10 points scale in the overall satisfaction with the experiment by users.

We are working on the migration of this application to other platforms like iPad or iPhone where we will experiment with other functionalities, other screen size and other kinds of communications with users. At the moment we have not fully developed the stock management module where pharmacists could play a major role in this application, offering or even taking home the drugs to the patient before they run out.

We plan to extend the experiment to other regions, to collect more data from more users and also from other mobile platforms to compare the usability and the medication adherence we can get with this application.

6. ACKNOWLEDGMENTS

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