Final Project: Pill Adherence System

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Date: Tu, 05/02/2017

1. Problem Statement

People get sick at some moment of their life. Inevitably, most of us always have to take medicine to cure their illness. Medication adherence is a self-regulatory process that requires an active process of the self monitoring and adjustments to perform medication taking consistently overtime. However, it is a headache for us to take pills timely and correctly. According to the survey, about half of the people in the United States fail to take their medication on time, which has resulted in the 290-billion[1] additional medical expense annually. This problem is particularly acute among older groups. Consequently, how to make sure that patient, especially the older patient take the right-dose medication on time has become an crucial issue in the world-wide medical field.

Many groups are being impacted by this problem. First and most principal, patients themselves will influenced by their medication-taking status, which is directly related to their health. Second, patients family would be also affected. Quick and high-efficiency treatment resulting from timely and correctly medication could not only benefit patients, but also provide their family with a better life by stop the worrying about patients' health status and saving the treatment expense. Third, health insurance companies. Those companies concern this problem because the fact that patients' insurance fee would reduced a lot if their medication is dose-correct without delay. Besides, more groups is also being affected by this problem, such as hospitals and government.

Older patients forget to take pills or medication late for many reasons, such as bad memory, busy with other things, no medication habit or no reminding. For instance, lunch time, an old lady may busy with cooking in the kitchen when her pill reminder is ringing. She has no choice but stay in the kitchen at that moment, so she decide to ignore the remind. However, when the lunch is done, she has already forgotten to take her pills.

This problem has several serious consequences. For those elder patients, if they fail to adhere medication plan and take pills on time, their disease could not be cured more quickly or relieved at the greatest degree. For patients' family, their living condition depend a lot on the patients' health status. And, their health status rely on their medication. For those insurance companies, their income and profit count on those patients' medication. To be specific, if those elder patients adhere their medication plan and could be cured as soon as possible, expenditure of those insurance companies could be decrease a lot and profit could be increased.

Elder patients' medication adherence is of great significance because that millions of families, social security system and medical resources are closely related with this problem. If it could be solved or even relieved, the whole society could benefit greatly.

2. Related Work

People have come up with numerous solutions and ideas to solve this problem. While some of those solutions have been made into products and sold to the consumers, others are under research and development.

2.1Existing Products

There are several existing solutions which have make some difference in solving this problem. They could be divided into types: mobile app, pill dispenser and pill robot.

2.1.1 Pill Reminder App

To help people remind their medication, some tech company develop mobile application. One of those famous apps is Medisafe Pill Reminder[2], which is developed by Medisage Inc. By using app, users could get their pill reminding of each dose, see the progress report and send it to the doctor or nurse.

Fig1: MediSafe mobile app

2.1.2 Smart Pill Bottle or Dispenser

Instead of the mobile app, some products are trying to offer the reminding through pill bottle or box[3]. GlowCap[4] is one of those productions. It could remind patients by ringing and glowing when the it's time for taking medicine. Patients could hardly miss one dose because it will keep ringing and glowing until its cap is opened.

Fig2: GlowCap

Besides, there are also some advanced products which have more functions than GlowCap, for example, the HERO[5]. Compared to the GlowCap, it has more features. HERO is locked and password protected, so it is safe from the children. Also, it supports multiple users instead of only one user. Besides, it could warns the users to refill when the stock is running low, which guarantees that never run out of pills again.

Fig3: HERO Dispenser

2.1.3 Pill Robot

One more step is being taken in the medication area: Pillo[6]. This is a personal home health robot whose main function is to remind people to take pills. It could remind via screen, voice and mobile apps. Another feature is, Pillo could notify patients' caretaker in case of an emergency happens.

Fig4: Pillo Robot

2.1.4 Comparison

Products	Function	Simplicity	Life	Price
Mobile App	single	difficult	life-long	$0-$40
Bottle & Dispenser	single	medium	10-20 year	$10-$50
HERO Dispenser	multiple	medium	5-10 years	$599
Pill Robot	multiple	easy	5-10 years	$500-$700

Table1: Comparison of 4 existing products

2.2 New Approaches Under Study

2.2.1 Real-Time Feedback

Instead of those existing products above, a new method provides a different thought to help people remember their pills taking: real-time feedback[8]. Systems that sense and reflect back behavioral information can provide feedback for this self-regulatory process. By doing so, this system enabled individuals to take their medications more frequently, promptly, and correctly.

2.2.2 Mature Children Feedback

In addition to the feedback strategy using device, some researcher have tried to use family's help. According to a thesis published in the 2013 conference on Computer supported cooperative work, mature children who live apart could help as an additional reminder on their parents'

medication adherence[9][10].

3.Proposed Solution

Even though such above products could make a difference to help elder patients improve their medication adherence, they do have some limitations. For example, the mobile apps are not user-friendly to those old patients. People who are not familiar with smart devices may find some troubles to use it. For the pill bottle, it is just a alarm, which means if patients fail to take pill on time it would do nothing to help. Thus, something need to be done to make some improvement. Based on all those existing products and ideas, we propose a new solution.

Our solution is to build a multiple platform of medication reminding system by integrating all beneficial and advantageous approaches. It is a more smart and efficient product which contains updated hardware and software. Hardware part includes the pill container, main host computer, smart watch, wristbands and other ends. Software contains the best remind-end choice algorithms and learning algorithms of user's daily living activity.

3.1 Hardware

3.1.1 Main Dispenser

The main dispenser is the core part of the whole system, which play the role of brain and warehouse. Patients just need to use the main dispenser when they are at home. We decide to use the Pillo as the main dispenser because it has been well-developed. All other ends are connected with the main dispenser to exchange signals with it. It contains the pills and when time for the medication, it would detect the best remind end and send the alarm signal. This mechanism is shown in Figure 5.

Fig5: Connection of Hardware

3.1.2 Auxiliary Dispenser

Considering the fact that patients are not always stay at home. For example, an old professor may get invitations from other universities and go there to give a lecture. In this context, the main dispenser is inconvenient to carry around, that's why we designed the mini dispenser. It contains the medication time and less pills than the main dispenser. Probably we may choose the PillDrill or GlowCap as the auxiliary dispenser.

Fig6: Auxiliary Dispenser (PillDrill)

3.1.3 Smart Watch or Wrist Band End

A smart watch or wrist band should always be weared by the old patients. It could not only collect the real-time data such as temperature, heart rate data and the body movement, but also communicated with the main dispenser. All those data gathered by smart watch or wrist band will be sent to the main dispenser and used as the input for further computation. Plus, they are all under the control of main dispenser.

Fig7: Smart Watch & Wristband

3.1.4 Other Ends

Besides the smart watch and wrist band, more devices at home could be used as the remind end, such as television and speaker. For example, Amazon echo could be connected into the system and play as a role of reminder. After receiving the notice from main dispenser, it could speak in human voice to remind patients to take what pills at what time.

Fig8: Amazon Echo

3.2 Software

3.2.1 Mobile App

To help old patients remember their medication, we still need the mobile app. However, this app is not designed for patients themselves, not for their children and caretakers. By using this mobile app, children could help to set up the alarm even though they live far away from their parents. Besides, this app could read the medication status from the main dispenser and provide it to the children. That is to say, children could monitor parents medication progress through mobile app. Once their parent missed one dose, they will receive a notice in the app.

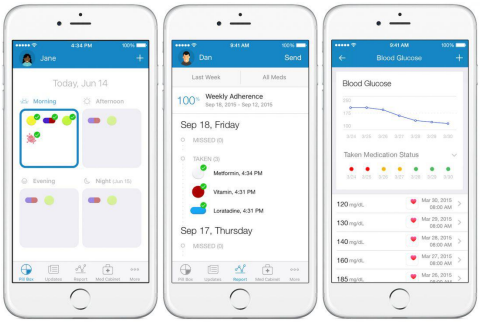

Fig9: Mobile App

3.2.2 Activity Recognition Algorithm

We will use the raw sensor data received from all the ends equipment including max, min, sum, mean, deviations, zero crossings, spectral energy, and signal energy. By using all those data, a decision tree model could be employed to learn a mapping from a sequence of raw sensor readings to an activity label. After enough labeled data has been collected, the model can accurately detect the type of physical activity which will be used as a part of contextual information to train the adaptive prompting model

3.2.3 Adaptive Prompting Algorithm

By using the activity label provided by Activity Recognition model and several other features such as time, day of week, and location, we could create a feature vector which are mapped to a binary label. All those binary labels show the occurrence of a medication-taking event. This mapping will be fed to a binary machine learning algorithm to learn the user-specific rules that can determine the likelihood of adherence given a feature vector of contextual information. Upon detection of an appropriate time, the main dispenser will notify the remind end to deliver a reminder if it is within the window of an scheduled medication.

4.Evaluation

To see whether out medication reminder system works well, we need to recruit more than 24 old volunteers and design a 6-month experiment to evaluate. Those volunteers should meet the

following limitations: 1)they have to take multiple medication (pills) daily , 2) they should live alone without partners. 3) they should have children or caretakers in connections, 4) they must older than 60 years. However, there is no restrictions on the sex ratio, both old men and old women are accepted.

All those participants are divided into two groups. Each individual was assigned randomly to either the existing-solution group or our-solution group. Both groups had their medication taking monitored with the pillbox. A researcher visited on average once or twice a month to check on the sensors, replace batteries, and administer questionnaires throughout the study.

We mainly consider those metrics of this experiments: adherence, promptness and time variance. adherence characterizes how often pills are taken. Promptness characterizes whether the pills are taken before the user-specified time-of-day threshold for late pills. Daily variance measures how the time of day that medications were taken varied from one day to another. Lower variance is better.

Metrics	Existing-Products	Our-Solution
Adherence		
Promptness		
Variance		

Table2: Metrics Comparison

If the results shows that our product could help older patients to remember their medication by improving the adherence rate, reducing the daily variance and decreasing promptness, we could have the conclusion that this is successful solutions. Otherwise, this proposal need more upgrades.

Reference

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