Interactive Medication Dispenser

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Abstract
In this paper, we describe a portable medication dispenser that manages complex medication regimens and provides timely ambient alerts based on the patient's schedule, thus easing the process of managing one's medications.

Keywords
Design Prototype, Medication, Health, Monitor

ACM Classification Keywords
Health, Medical information systems

Introduction
From our personal experiences and encounters, we've recognized a true need for a simple yet effective system to ease the unpleasant daily routine of taking prescription medications. Managing one's medication is a complex and time-consuming task for people suffering from chronic illnesses or other medical conditions that necessitate they take multiple medications several times a day. According to a report in the *New England Journal of Medicine*, 33-69% of all medication-related hospital admissions are due to poor medication adherence, resulting in medical costs of approximately $1 billion annually [5]. The more medication a person is supposed to take, the more difficult it becomes to faithfully follow a medication

schedule. Also, as the frequency of dosages each day increases, adherence suffers significantly [2].

There is confusion involved in keeping track of which medications to take, when to take them, or how many pills to take. Failure to manage these tasks effectively can compromise the effectiveness of certain medications, result in negative health effects, or even prove fatal.

Related Work

There are several products in the market that aim to simplify and improve this process. Simple pill boxes serve as containers for medication, but the people using them have to go through the rigor of placing combinations of medication methodically into slots. Also, reminders for time-sensitive medications are lacking in such products. While there are reminder systems such as specially-designed wrist watches (see Figure 1), they are not physically coupled with the medication, can be easily dismissed, and do not address many of the needs of their users. Automatic dispensers exist, but are often bulky appliances in which medication is compartmentalized and dispensed on a schedule. Pill boxes with built-in alarms exist, but tend to contain small writing, are confusing, and require pills to be mixed together (see Figure 2). Systems like these and other smart medicine cabinet-type products are often expensive and the setup required may necessitate dependence on a caretaker for some people.

Figure 1 Medication reminder watch [1]

Figure 2 Monitored automatic pill Dispenser [3] and Automated pill box [4]

We propose to build a simple device that addresses the disadvantages that current solutions suffer from. The system we propose is a portable device that is easy to setup, maintains complex regimens, provides timely alerts, is easy to carry around, and is extremely easy to use.

System Design

We envision a portable medication container that is linked to a daily schedule set by the user, a family

member, loved one, caretaker, or physician. Our initial design consists of a simple, familiar plastic pill box that is modified to include ambient visual and physical alerts. The pill box consists of several compartments, in which different types of pills can be stored. Each compartment holds a specific type of medication. This design differs from common current pill boxes, most of which are designed so that each compartment holds a set of different medications depending on the time of day or day of the week the selected dosage is meant to be taken. Our system avoids the confusion of mixing different pills together, in that each type of medication is stored in a single compartment, separated from the other types of medication.

Scheduling and Portability

A schedule for which pills to take at which times and on which days is set on a computer via a simple and clear graphical user interface. Once the schedule is set, it is uploaded to pill box itself (or, optionally, a wireless communication system between the computerized or online schedule and the pill box could be designed). The user can then take the pill box with wherever he or she goes.

User Interaction

When time comes for a medication dosage to be taken, the pill box begins to display ambient and physical alerts. The longer time that passes since a medication dosage is meant to be taken, the more intense the alerts become, helping to ensure that the user's attention is drawn.

Once the user recognizes the alerts, he or she opens the pill box and the alerts shut off. Only when the user opens the box, do the alerts stop. This is to ensure that an important dosage is not missed. LED lights are placed under each of the pill compartments. When the user opens the box, the compartments corresponding to the specific pills to be taken at that time light up. In this way, the user is notified, in a clear and unambiguous way, which pills to take. This illuminated compartment design was influenced by the indicating system of WineM, an interactive wine rack and selection system developed by ThingM [6]. The user removes each of the pills indicated by the illuminated compartments and ingests them. The pill box recognizes when a pill is removed and accordingly shuts off the light for that compartment. Ideally, the system would also recognize if an incorrect pill is removed and would alert the user that he or she is taking the wrong pill.

After the user has taken the correct pills, he or she shuts the lid of the pill box and waits for the next alert on the schedule. If the user opens the pill box before the next time scheduled alerts, none of the pill compartments will illuminate.

Monitoring Functionality

Our system design also includes a monitoring function, which is often an important factor in medication adherence [5]. Each time the user successfully takes a dosage of medication, the system sends an e-mail, SMS text message, or voice mail to any number of recipients. Recipients can be set through the initial scheduling interface. The messages include information about the specific medications the user took and the time and date the user took them. The system can also be set to send a message if a user has missed a certain dosage.

This alert system is useful in several different ways. First, it can allow the user, caretakers, family members, and/or physicians to keep a record of the user's medication taking behaviors. Daily, weekly, or monthly digests can also be generated, which would allow interested parties to view trends and patterns of behavior. Physicians can use this information to tailor future medication prescriptions. Users or caretakers can use this information to modify behavior based on how well they are able to follow the current schedule. Also, especially useful for elderly patients or those who have memory problems, the system can alert relevant parties when an important medication has been missed or when the user has taken an incorrect medication.

Initial Prototype

Our prototype consists of a plastic pill box that contains seven compartments where pills can be stored. The pill box has a translucent orange lid that is latched at the front of the box and pops upward when opened. We drilled holes in the bottom of the pill box and positioned an LED light in each pill compartment. We placed pieces of plastic diagonally above the LED lights, sloping from the front of the box to the back. The plastic pieces divide the compartments so that the LEDs rest underneath and the user's pills can be placed on top. The plastic dividers are coated in translucent paper, which effectively diffuses the light coming from the LEDs below. This allows the LED lights to illuminate their respective compartments (see Figure 3).

Figure 3. LEDs illuminate respective medication compartments.

For our prototype, we did not have sensors sensitive enough to measure when a pill is actually removed from one of the compartments. So, for demonstration purposes, we fitted our pill box with a push button switch that is activated when the box is opened and closed (see Figure 4).

Figure 4 Push button switch activates when opened or closed.

We attached a small vibration motor to the back of the pill box (see Figure 5). All of the LEDs, the push button switch, and the vibration motor are connected by wire to an Arduino NC board. For our initial prototype, we had not yet designed the scheduling interface, but instead directly set a looping demonstration schedule through the Arduino software which randomly illuminates 1-3 pill compartments at each interval.

Figure 5. Vibration motor attached in back of pill box.

Interaction Loop

When the system reaches a specified time on the schedule, the alert system begins. Our alert system consists of the LEDs built into the pill box compartments and the vibration motor attached to the box. The alert begins with the middle compartment blinking. Vibration of the box corresponds with the lighting display. After a set interval of time has passed without the user opening the box, the middle three compartments begin to blink on and off, along with the vibration motor, at a quicker pace. After another time interval has passed, the middle 5 compartments illuminate and blink, with the vibration motor, at an even quicker pace. Finally, all 7 compartments illuminate and blink at an even faster pace while vibrating. If the user has not opened the pill box by the end of this time interval, all 7 compartments continue to blink and the pill box vibrates continuously until the box is opened.

Once the user is alerted that it is time to take a pill, he or she opens the box. This triggers the switch, which turns off the alerting display and illuminates 1-3 of the compartments. The compartments stay illuminated until the user closes the box. The Arduino software prints which pill compartments were illuminated to the computer's serial port and the Processing application reads the information. Processing then sends an e-mail to the address(es) specified in the program with the pill information. Once the user closes the box, the system waits another random interval before starting the loop over again.

Initial Evaluations and Future Work

During initial user demonstrations, it seems we were able to effectively communicate the need for such a system. The initial prototypes were received well by the audience it was exhibited to. People who interacted with the prototype perceived it as something that would be instantly useful to someone they knew. Some even commented that they'd be interested in purchasing such a system and that we should plan to get the product out on the market!

Based on initial user discussions and our own reflections, we identified several limitations that need to be addressed:

- Limitations in sensor technology that we had access to prevented us from including a mechanism that could ensure that the user took the appropriate pills while also ensuring none of the other pills were mistakenly taken. Such a mechanism is important to prevent adverse drug effects or over-dosage and needs to be explored.

- The system should be able to detect removal of pills when none is scheduled and should alert the user that he/she is not supposed to take a pill at that point.

- Another scenario may arise when a patient needs to take more than one pill of a certain type at the same time. The system needs to be improved to handle such a requirement. A possible solution could include varying the LED display to reflect how many pills of a certain type to take or audio notifications.

- Research and user testing and is necessary to design an effective scheduling interface. We need to examine ways to make scheduling simple yet robust. Perhaps involving the pill box itself in the scheduling interaction is an option. We could also explore the usage of RFID tags on pill bottles.

- The prototype is not set-up to function wirelessly. The numerous wires, USB cable, Arduino, and breadboard restricts portability.

In addition, there are other issues that need to be considered:

- Reliability is an important issue in such a device, as slightest of malfunctions could be harmful to the user. Robust implementation and extensive testing are necessary tasks in identifying the best ways to address error-handling.

- Another related factor to consider is the power supply. The system needs to constantly monitor its own health to ensure health for its user. Power conservation and persuasive notification need to go together. Rechargeable batteries or standard alkaline batteries may be used to power the device, but mechanisms to monitor the health of the batteries need to be in place.

- Alternate notification mechanisms are also necessary to make sure that if any of the LEDs fail, there is an alternative notification that informs the user of this mistake.

- Another issue we considered when designing the prototype was some sort of notification system that provided the user with relevant information about the pills being taken. For example, if one pill is supposed to be taken with food or the user is not supposed to eat for an hour after taking a pill, could our system provide this information? Possible options for this might be a visual display built into the top of the box or perhaps an audio system.

- User testing also needs to be done to determine what types of alerts are most effective. We decided upon ambient visual alerts because these should be easily understood by the user. We also employed the vibration to provide another form of feedback in case the visual alerts are not noticeable (if the box is kept in a bag or out of site, or the user's vision is impaired, for example). Adding an (optional) audio alert system is a possibility.

- Finally, we designed our prototype based on the form of a pill box because it should be familiar and easily recognizable as such. We could also explore the possibility of designing a system that is integrated into a more common everyday object

that people carry with them. A water bottle might be one possible choice, seeing as the user will need water when taking the pills. This could help in making the task of taking medications more discreet and unobtrusive.

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Citations

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