Pill Box Proposal

A Rapid Prototyping Project

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ABSTRACT

Nearly half of the United States fails to take their medication on time. Medication Adherence is critical in terms of timing, dosage, frequency, and duration. In this paper we propose a new solution to medication adherence. The Pill Box incorporates a 7 day of the week pill box with weight scale, reminder LEDs, a button to open the lid of the pill box, a "pill lift" in each compartment, a sound alert for when it's time to take your pill or you've missed a pill, a human-centered mechanism that raises and signals when you've missed a pill, as well as an LCD display alert screen for when to take your pill or if you've missed pills. In addition to the physical pill box, our solution comes with an app so you can individualize when you take the pills. Our solution helps keep the patient on track with adherence to their medication and therefore improve health outcomes.

INTRODUCTION

The New England Journal of Medicine found that in the United States nearly 50% of medication is taken incorrectly in regards to timing, dosage, frequency, and duration. And of all the medicational based reasons that people in the United States are hospitalized, 33 to 69 percent of them are because of poor medication adherence.[1] As a result, this costs the U.S healthcare system anywhere between $100 billion to $300 billion annually[2]. Although there are many factors that influence medical non adherence, studies report that 40-60% of patients could not determine how their doctors wanted them to take their medication 10 - 80 minutes after the doctor had given them the instructions.[3] A separate study found that 60% of patients misinterpreted the instructions their doctor gave them.[4] Because many patients struggle with medical adherence, we wanted to develop a solution to this problem. Our device has many different mechanisms for reminding users to take their pill. Firstly, LED lights in front of each individual box that will be red or green based on if the pill has been taken that day. This can be calculated by knowing if the pill box has been opened and/or if the weight sensor has detected a change in pills. In order to improve ease of opening the pill box, it will have a single button that opens the lid of the whole pill box. We decided to implement this feature for users with dexterity issues who have trouble opening typical pill boxes. Secondly, we will have an LCD screen that will display if you missed a pill day or not and lastly, we are going to have a mechanism behind the box that rises up and displays an angry face when missed a pill. We chose to have this reminder in order to give human-centered emotional feedback to the user to encourage them to take their pill on time.

RELATED WORKS

In this section we present a thorough investigation of related material in the industry as well as academia. The first product is one that is currently on the market, it is known as The Hero Pill Dispenser, which sorts and dispenses a month's supply of 10 different medications and is connected to an app where you can set specific times for pills to be dispensed. It tells the user if they have missed pills and when they are

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[3] Svarstad B. Physician-patient communication and patient conformity with medical advice. In: Mechanic D, ed. The Growth of Bureaucratic Medicine. New York: John Wiley & Sons Inc; 1976.

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running low. There is a button on the back to initiate auto sort and dispensing of pills, which emits a sound and flashes a light. Some disadvantages of this device are it's bulkyness and its reliance on an app to program specific times. For example, many pill takers are usually older in age and may be less familiar with how to work smart phones, if they even have them. This could limit the target audience to younger, tech-savvy users [8].

The next product is the Medelert Automatic Pill Dispenser, which is a portable device that allows the user to set alarms for when to take pills. It's round in shape and has compartments for every day of the month. This device also comes equipped with a lock and key to protect the user's medication from unwanted visitors and to secure it. While this device is good at alerting users to take their medication, it does not alert users that they have actually not taken their pill out of the box. Because of the very small slots for pills, it might be difficult for people that suffer from dexterity issues to get the pills out[9].

Next, the Zewa Bluetooth box has four compartments that take blister packs or regular pills meant to be taken at different intervals throughout the day. The device can tell when a compartment has been opened and sends a bluetooth signal to your phone and an LED goes off. You can program alarms to sound when you've missed your pill and the box LED turns red. The LED also indicates which compartment should be opened next. This device also connects to a web or mobile app to help with scheduling. Some disadvantages of this product are that you have to refill the product every day and that the phone/app connection might be difficult for older generations to use effectively based on a technology skills gap [10].

Yet another device we found is described by Edwin H. Aiken in Patent U.S. Pat. No. 6,789,497 mainly focuses on the creation of a bottle top. It has a circular cover disk with a circular base plate, which is attached to the top of the pill bottle as well as an indicator between the cover disk and the base plate which allows to view the number of medications taken on a given day of the week. One of the pros of this invention is that since it is a simple attachment, it can be used on various other bottles which makes it more flexible. A con of this product is that it may be a nuisance for users to manually have to adhere the

attachment to their bottles themselves [1]. The next device that we found was invented by Richard G. Hamilton and David M. Liu in U.S. Pat. No. 49,397,05A. This device is a pill bottle container which has a detector that generates two electrical signals, one to detect the opening of the container and the second to detect the closing. The device also involves a timing mechanism which measures the time between the opening and the closing which helps it label an event as an actual drug dispensing event. An interesting aspect of this device is that it allows the information of dosing compliance to be accessed by the pharmacist and physicians of the patients. They discuss that another use of this data may be to alert the professionals/patients themselves, but it is unclear whether this was implemented or tried. Although this is a good idea, simply sending an alert to another device may not necessarily be as useful as actually displaying something on the bottle itself. If, for example, the patient cannot find the bottle, it may be useless to simply send an alert to another device or the patient's health care team [2].

The next device we found is a smart pill bottle that is already out in the market is produced by AdhereTech. The device is utilized to detect if the patient has taken a pill or not, and sends that information to a server to be analyzed and if a dose has been missed, it reminds the patient through their phone, as well as on the bottle lights and chimes. If a dose is missed, AdhereTech reminds the patient via automated phone call or text message - as well as on-bottle lights and chimes. One design limitation in this device is that it does not take into account that a user may be taking more than one kind of pill or different pills during the week and does not easily create a mental model for a user to take the pills they need every day of the week as is often modeled in the Mon-Fri pill containers[3]. Another related work we found was detailed in a paper describing a pillbox that tracks the medical adherence of users on a continuous basis. Their device (the MedTracker[4]), has a familiar 7 day drug store pill box interface, with the added benefit of automatic data collection to let users know if they have made medication errors. The system does not require user interaction, beyond taking the medication itself. The developer's target audience is the eldery that suffer from memory loss and early dementia. The

system collects data on the user through bluetooth connectivity. The device's shortcomings interfere with the vision of what we want for a device that improves medical adherence. The device so specifically targeted towards people of a certain age that it would not have the broad appeal that we are looking for. Also the jerry rigged design of the system looks jarring to us. Another more simple pillbox we found was the e-pill 4 slot pillbox[5]. The pillbox reminds users to take pills with a loud alarm and a physical vibration. The device also comes with a snooze function. The pillbox is easy to setup and the simple interface is perfect for storing in frequently used spaces like backpacks and purses. What the device has in portability doesn't make up for the lack of other features. The devices' alarm system would prove annoying to most users. We would prefer a more discreet way of letting the user know when they have to take medication, especially if they would be using the pillbox in public settings. The device can only notify the user on one day pill usage, not multiple days.It would prove tedious to utilize every day. Also the device has no way of making sure the pill was taken out of the compartment once the lid has been opened and closed. As we see it, the only difference between the device and a normal pillbox is the alarm system. There are no other systems in place to track pill usage. The last device we looked at was MedFolio[6], the wireless pillbox. MedFolio stores up to 7 days worth of pills, and each day is separated into 4 compartments for different times of day. The device comes with an alarm system that beeps when it's time to take the medication. The coolest thing about MedFolio is that it not only emails and texts the user reminders but it also stores cloud data so the user can see how they have been keeping up with their medication after a long period of time. This information would prove very useful to users or their caregivers. I think the only thing holding back the MedFolio is it's design. It is very clunky looking. Yes the device comes with a carrying case, but who is going to bring around a carrying case just for their pillbox along with their backpack/purse? It is not realistic. Many of the MedFolio's features inspire us

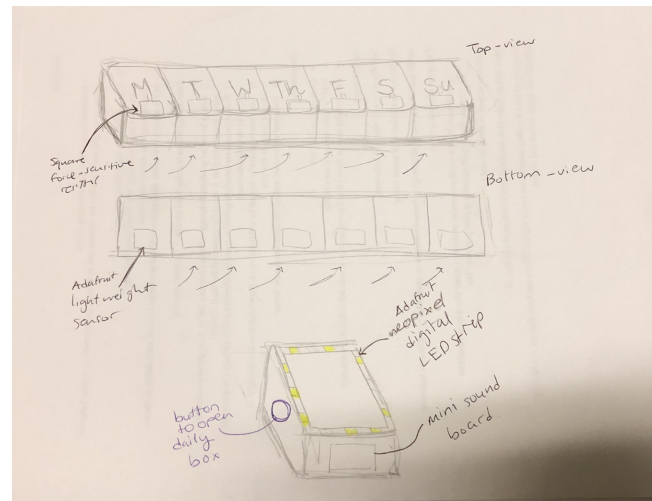but the overall design of the device needs improvement.

SYSTEM DESIGN

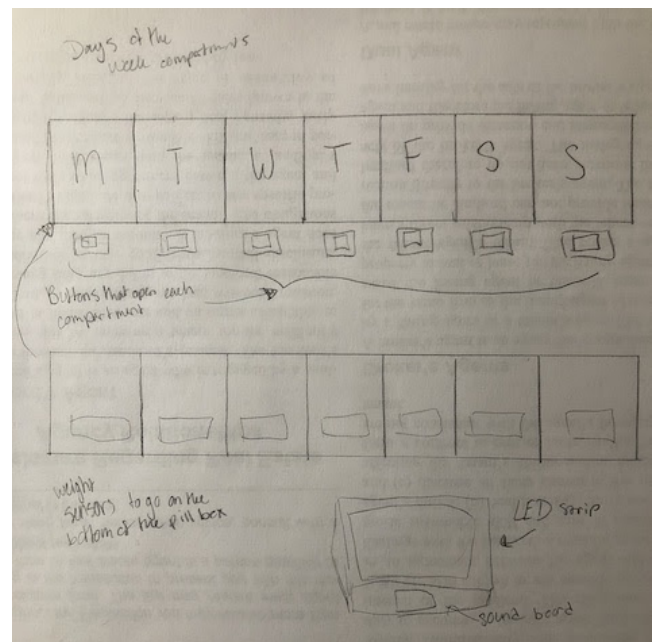Figure 1: **Initial Draft of the System Design**
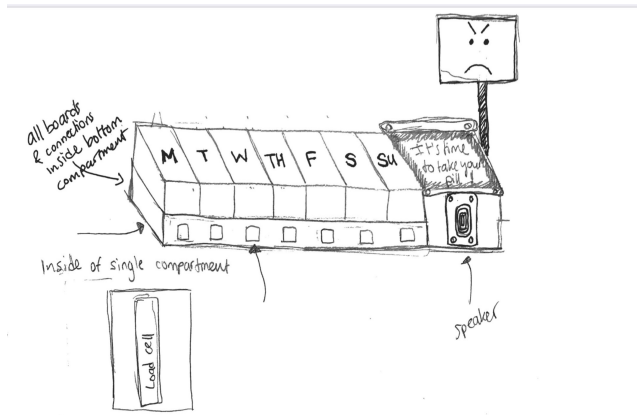

Figure 2: **Second Draft of the System Design**

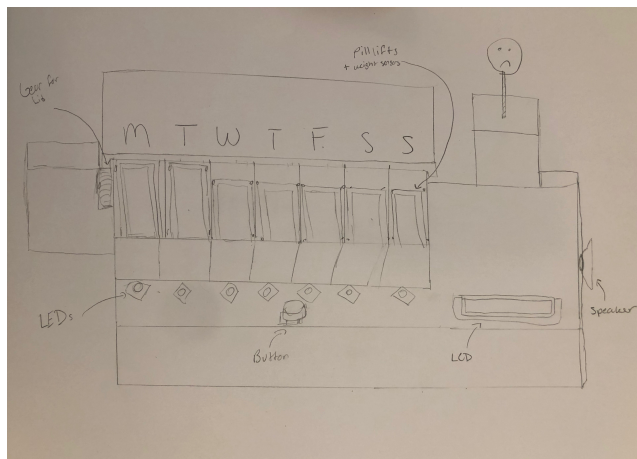Figure 3: **Third Draft of the System Design**

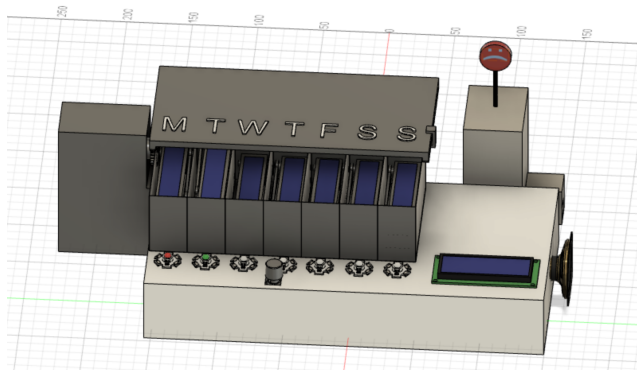
Figure 4: **Fourth Draft of the System Design**

Figure 5: **Final Implementation**

Design Description

Based on our past work research and literature review, we have decided to design a 7 day pill box because this is what many people already use and

will reduce the learning period for the product. In order to design for people who struggle with dexterity issues that have trouble opening bottles or click compartments, we will put a single button that opens the box lid and mechanisms that will raise the pills in each compartment depending on the day. These compartments will also be outfitted with a weight scale underneath that will turn the LED red or green and a sound alert if a pill is missed.

Our final system design includes the following components:

- A 7 day of the week pill box with weight scale
- Text alert option for when it's time to take your pill
- A linked app for time customization
- LED and sound alert when it's time to take your pill or you've missed a pill
- LCD Display message for when it's time to take your pill
- A mechanism that raises behind the pill box that has an angry or sad face

Our second draft includes buttons in front of each compartment that open the tops and the third draft contains the face mechanism. The 4th draft contains our final version which contains an updated "pill lift", which will raise the pills the user is supposed to take at designated times. Additionally, this draft has gear mechanisms to open the lid and the frowny face. The final implementation shows our 3D design and how the mechanical pieces actually work.
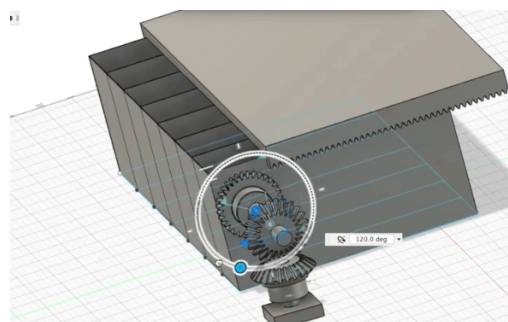
The specifics of the mechanical pieces are below:

Figure 6: **Lid Mechanics**

Figure 6 refers to how the lid for the pill box opens. There are 3 gears: 1) 20 Degree Pressure Angle

Plastic Gear - Round Bore, 32 Pitch, 32 Teeth, 2) Metal Miter Gear - Round Bore, 24 Pitch, 24 Teeth, and 3) 20 Degree Pressure Angle Gear Rack - 32 Pitch. All of these work together to convert the motion to linear. The lip of the led has teeth in it to make it move with the closest gear. The lid is physically attached to the box (see figure 5, right-hand side) to keep the lid in place. The vertical gear would be attached to a servo. In our actual design, we covered the gears with a box so the user doesn't mess around with it.
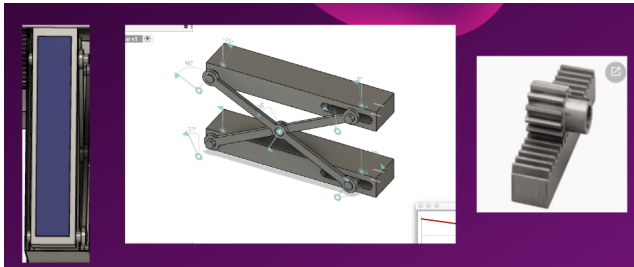

Figure 7: **Pill Lift Mechanism**

Figure 7 refers to the individual pill lift mechanisms. On the top of each "pill lift" in each compartment is a separate aluminum alloy electronic weighing sensor load cell weight scale (left picture), capable of measuring between 0g-100g. This part of the system measures how many pills are in each one of the compartments for each day. This portion of the system will dynamically report, after the opening of the compartment, whether the gram amount changed signaling that the user has taken out the pills they needed to take that day. In the middle picture, we have the mechanism that raises the pill up when it's time to. This will be connected to a rack and pinion (the right-most image) and a servo. The servo spins the pinion, which moves the rack that is connected to the bottom pin of the lift.
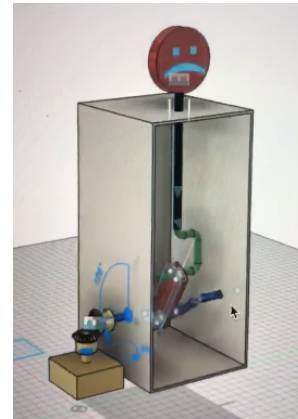

Figure 8: **Frowny Face Mechanism**

The frowny face mechanism in figure 8 is propelled using a similar gear system as the lid, but with one less because the second is attached to the rod that goes inside the box. This main rod connects to a link and a piston. When it revolves, it will create a vertical motion when it reaches the top, propelling the face up. The bottom gear is attached to the servo. In our final design (figure 5), we put a box over the gears so that the user wouldn't be able to change how this works.

The pill box system comprises 7 separate compartments made out of plexiglass.
The next component of our system is the opening of the compartment once the user presses the button. The button that we are using is the 12 mm Panel-Mount Push-Button Switch with Screw Terminals. Once the push button is pressed, the Push-Pull Solenoid Servo is activated to open the lid using gears as described above. After the lid opens, the "pill lifts" raise the appropriate compartment(s) depending on if a user needs to take a missed pill or they are on time. To close the pill box, the user presses the button again. The frowny face will raise as long as there is a red LED turned on to indicate a missed pill regardless of if the lid is opened or not. Gaging whether it is the correct day of the week will be discussed later.
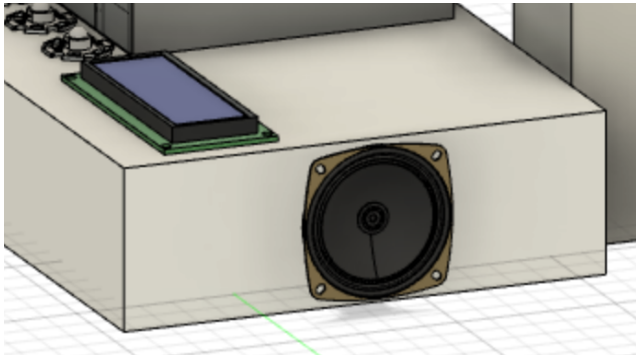
Figure 9: **LEDs and Button**

Figure 10: **Speaker and LCD Screen**

Another component of the pill dispensing system is the various modes of alert. We include an LED, sound, physical, and LCD screen alert components. When the user does not take their pills by a specific time in a day, they will receive a blaring alarm through the CQRobot 3 Watt 8 Ohm Speaker for Arduino. The LED lights will flash red, and an angry/sad screen will pop up at them until they press the button and take the pills. The Smraza 2004 LCD Display will display a message that prompts the user to take the pill as well until they do. The mechanical component for the raising and lowering of the angry/sad pop-up is also activated via a servo motor. The activation of all the components is possible through the integration of the different components on the Arduino IDE. Based on whether the user took/did not take the pills is possible through conditional statements that take into account the decreasing/stagnated weight gathered from the initial components discussed.

We also planned to have an app that users would be able to use to set text reminders, customize the times they're supposed to take pills, and how often.

DESIGN OPTIONS AND CONSIDERATIONS

Complexity
A design consideration we took into account was potentially making our system less complex as to make it more portable for our users. However, we decided that to implement all of our desired features, we would need to compromise on this aspect.

Pill Box Lid
We initially were considering making a seperate lid for each pill box compartment such that a user did not have the ability to reach into another day's compartment. However, we decided against creating seperate lids because each lid would need its own set of opening mechanism including gears and motors which would create a much bulkier and heavier design. Our work-around the need for separate lids for each compartment was in creating the pill lifts, such that the user knows which days' pills they need to take.

Button
Alongside the previously mentioned design consideration, we were also considering creating a button that would open each separate compartment lid. Since we decided against previously mentioned compartment style, we also then decided against the separate button style.

Reminder Features
Another aspect that we were taking into account when creating the Pill Box is the reminder aspect of our device. We were initially considering that it might be enough to just remind the user through a single means of communication that they need to take a pill, but we've decided on reinforcing this in a couple of different manners instead and specifically not just relying on a mobile reminder, since our device does cater to medical adherence for older individuals who may not be as well versed in technology. Because of this we also chose to remind the user through a mode of different senses both visual and auditory.

FUTURE WORK

One of the big things we wanted to implement in the future is an app that works with the pillbox. The app would let users customize their adherence schedule. It would also allow them to input pill weight and have

customizable alarms. It would serve as the bridge between our pillbox and each user's individual needs. With this, we would have to configure everything together in a way that allows for users to customize their pillbox at any time. So allowing users to customize their pillbox means changing when the pill alerts users when the pillbox opens up when it lifts the pill up etc. There are a lot of different mechanisms that go into this that we would have to account for. If we got to construct the box physically, we would also have to make decisions on how the size of each component within the box. Our pillbox has a lot of moving parts that might not lend itself well to a smaller design. It might not be feasible to have everything be tiny. We would also have to experiment with different materials, making tradeoffs between durability, weight, etc.

CONCLUSION

Our solution encompasses the answer to helping users take their medication on time every day while simultaneously helping people with dexterity issues. By having the lid and pill lifts motorized and open with the touch of a button, gone are the days of struggling to open annoying screw caps or snap lids every day. In addition to the motorization of crucial aspects of the pill box, we have many reminders such as LEDs that change color depending on when you're supposed to take your pill, an LCD screen, a speaker, and a human-centered frowny face that raises up when the user misses a pill. In order to customize pill frequencies per day, this pill box would have a linked app to go with it. While our solution is a little bulky and not very portable, it's ideal for those that are home when they need to take their pills. Future work will have to adjust for these trade offs.

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