THE CANADA SCIENCE FAIR JOURNAL

ARTICLE

Engineering

Pill Smart

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Edited by: Pranav Khanolkar
Layout By: Jonathan Leung

Awards:
Bronze Medal, Canada Black Scientist Network Science Fair 2023
Silver Medal, Canada-Wide Science Fair

Dementia is a neurodegenerative disease increasing in prevalence, and currently affecting tens of millions globally. This number is expected to triple by 2050 (Greenblat, 2017). Dementia also referred to as cognitive impairment or decline and commonly causes memory loss, disorientation and confusion which can make it a challenge to carry out simple tasks such as adhering to medication as prescribed (Bhandari, 2023). While there are medications to alleviate these symptoms, it can be difficult for patients to remember to take the medication.

INTRODUCTION:

Jill has Alzheimer's disease, she was prescribed medication to take every day by her doctor, but she hardly remembers to take her pills, leading to even worse effects. There are millions of Jills out there, and they could all use a helpful device to remind them to take their medication.

There are several devices aimed to assist dementia patients with adhering to medication, yet they can still cause the risk of non-adherence to medication or incorrect doses being taken. While some lack user-friendly designs, others are not designed with any safety guards. Many of the products on the market have complex and unsafe designs for patients to use and can be a challenge for loved ones to assist with often busy schedules (Levy, 2023).

In solution to this, the Pill Smart is an automatic pill dispenser designed with several adaptive safety features which aim to increase adherence to medication and remove stress from a caregiver.

Purpose:

The purpose of this project is to create a device with adaptive features specifically designed for seniors with mild and moderate dementia to increase adherence rates. This project is designed with safety guards, ease of use, a reminder system, and a caregiver intervention app targeted to eliminate the common issues seniors with dementia have with adhering to medication.

MATERIALS AND METHODS:

The main components of Pill Smart include the servo motors, funnel chutes, speaker, an LCD screen, LED light indicators and a clock module.

The pill dispenser prototype is structured from plexiglass, which is joined using hinges and screws. This prototype includes a pair of hinges that connect the upper section to the main body of the enclosure, allowing for easy access when refilling medications. On the bottom, plexiglass makes a tray to hold the medication. Due to storing away items being a symptom of dementia, pieces of plexiglass are attached to the sides to screw on the wall, this way, the Pill Smart can't be easily manipulated with.

A programmed LCD screen was attached to the front of the box to display the date and time to avoid poor recollection of time for a user, along with 7 LED lights to indicate which day of the week it is. The speaker and its sound module would play a voice recording as an alarm feature to remind a user to take their medication.

Inside, the box contains seven separate funnel chutes for each day of the week. These chutes were made through a 3D printer and constructed to have a wide opening for refills, and a small circumference for a chute to make it hard to take the medication, eliminating the factor of taking the wrong medication and adding a safety guard. Attached to the bottom of each chute is a servo motor with a horn. A round disk is attached to each motor to make a covering at the end of the chute to hold medication. Using the clock module, the motor assigned to the specific day will rotate along with the disc according to the scheduled time, dispensing the medication and rotating back to its original spot for the next refill.

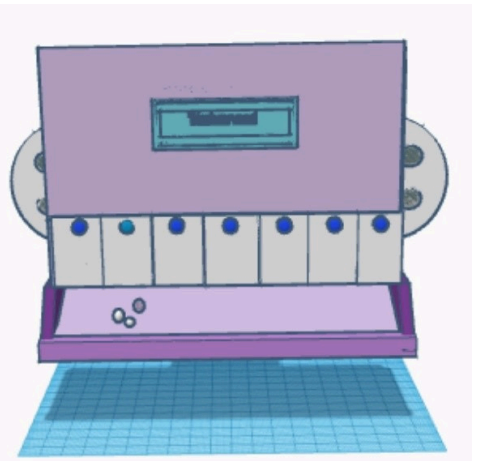

Figure 1: Pill Smart 3D Prototype.

Next, an app interface was made to interact with Pill Smart. This way, when medication is either taken or not, it will be recorded through the app and a notification will be sent. This app interface would allow a caregiver to control the Pill Smart and track if, and when medication has been taken.

After the modules and other parts were coded, they were attached to the ESP8266. The ESP8266 serves as the device's "brain" by making the following decisions about how to use all of the data collected from the modules.

Attached to the ESP8266 are a clock module, LCD screen, and 7 LEDs indicating the date and time. When the ESP8266 requests the time, the clock provides that information, which it then displays on the LCD screen and the day's LED indicator. Also attached to the ESP8266 is the motor control board which holds 7 servo motors. The ESP8266 will alert the motor control board that the servo motor, which corresponds to a specific day, has to be rotated at the time when the medication is supposed to be dispensed. The motor control board will revolve the horn of one of the seven servo motors, opening the bottom of the funnel chute, dispensing medication, and rotating back to its original position, closing it back, in response to the ESP8266's "request".

Finally, attached to the ESP8266 are the sound module and speaker, and an infrared sensor (IR sensor). Once the medication is dispensed, the IR sensor will inform the ESP8266 that there are objects on the tray. Three tasks are completed by the ESP8266 using this new knowledge. First, it gives the sound module the command to play the message that has been pre-programmed for this particular day and is played through the speaker. Then, it connects to the internet and sends a notification to the app that the medicine has been dispensed, which is logged along with other notifications. Lastly, it records the time that the medicine was dispensed.

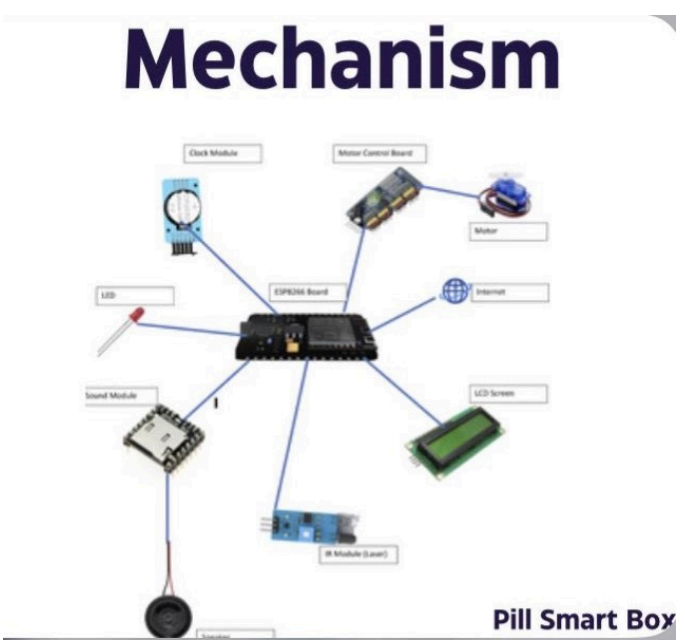

Figure 2: Pill Smart Mechanism.

RESULTS:

This final prototype was designed after considering the various deficiencies of the 3 previous prototypes. This prototype addresses and provides a solution for three common reasons dementia patients have issues adhering to medication (Treichler, 2022). The most common being poor memory, the Pill Smart addresses this concern by allowing weekly refills and automatically dispensing medication only for the current day. Additionally, due to poor recollection of dates and times, the Pill Smart uses a 24-hour clock, ensuring medication is dispensed solely for the present day without requiring the user to do anything for this function. To prevent instances of medication not being taken, the Pill Smart incorporates an IR sensor. If the tray is sensed as empty, a notification is sent to the app for confirmation; conversely, if medication is present, an alert is sent as well.

Demonstrating the impact of assistive technology on adherence rates in seniors with cognitive impairment, the Pill Smart stands out with its adaptive, easy-to-use, and safety features. Moreover, it offers a cost-effective solution compared to some less adaptive pill boxes on the market. At present, the prototype costs $70 to build, although this could be decreased to $40 or even less, when material such as plexiglass is replaced with an alternative in contrast to other pillboxes priced at $80 and higher. This device would be especially useful for seniors dealing with moderate and mild dementia due to its simplicity. Frequently, caregivers assist seniors with dementia in these stages, enabling the app to be employed by caregivers, and enabling users of the Pill Smart to leverage its numerous features.

DISCUSSION:

The initial design of the Pill Smart box was a push-to-open mechanism including seven separate compartments that would automatically lock or unlock based on the day. This device would also include a speaker, seven daily light indicators, and wall hooks. These flaws were that there was no clock display, and the device required a user to know the date as each compartment would have to be manually opened.

This design would have a hollow box with dividers for 7 days, each day the box would be pushed over the hole on the bottom of the box to release the medication. The device would include wall hooks, a speaker, light indicators, and an LCD screen. The flaws of this design were that it required a button to be pushed, which can be considered too complex for the target demographic. The movement of the compartments could also cause medication to be damaged due to it being dragged across the box.

This design was a wheel mechanism. The box included a speaker, weight sensor, light indicators, an LCD screen, and a button. Each slot of the wheel would store medication for each day and rotate according to the day. There would be one hole at the bottom of the wheel to release medication and one on the side to refill the wheel. The issues with this design were that the wheel mechanism would make it difficult to refill the medication as the wheel would have to rotate a certain degree to access each compartment. Additionally, if the medication were not taken on a day, the medication would still have to dispense for

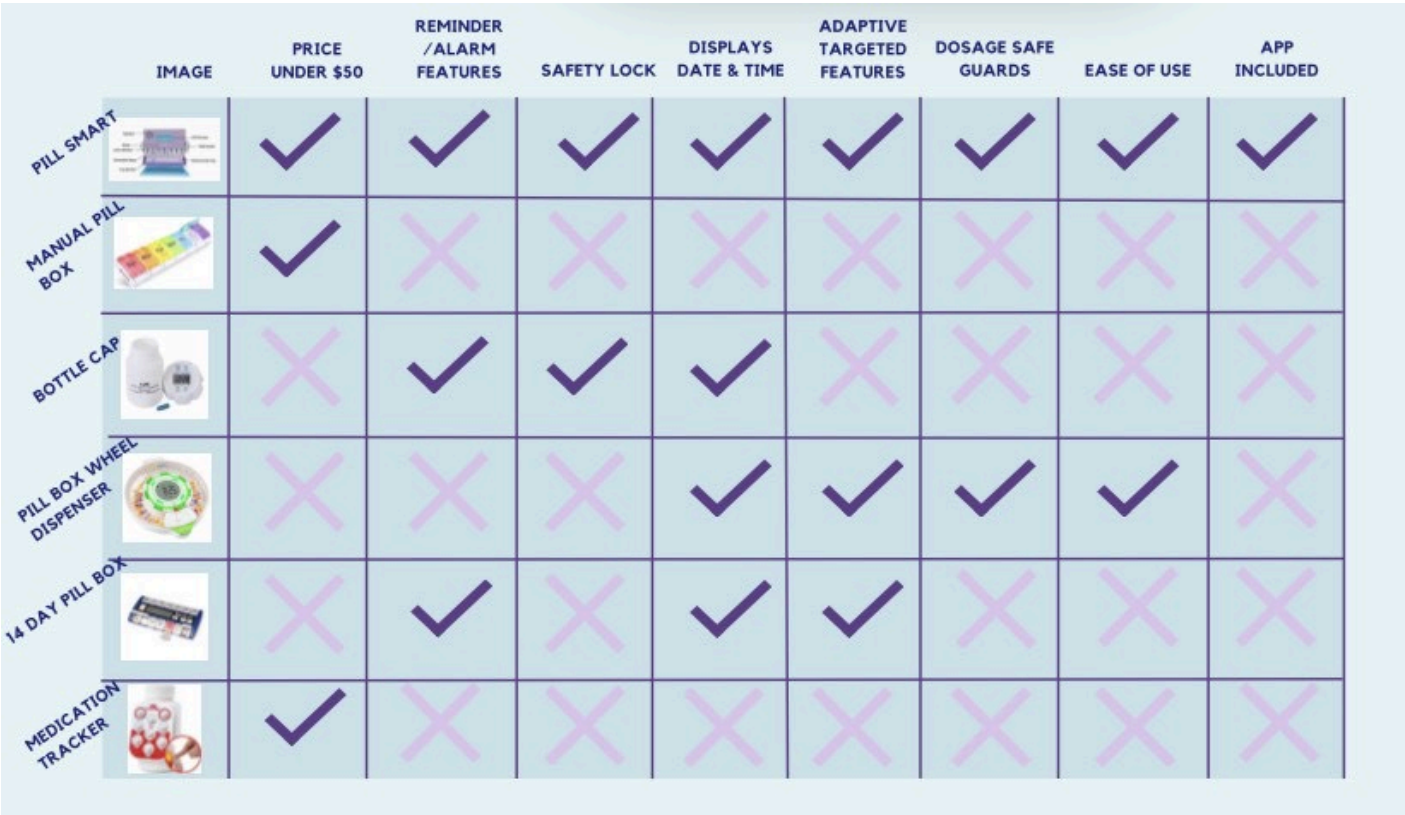

Figure 3: This graph in figure 3 compares the Pill Smart to various other pill taking devices on the market based on 7 topics. In this comparison, the Pill Smart is the only device which had all 7 features, in contrast to the others having 4 of the features at most, and none having an app intervention.

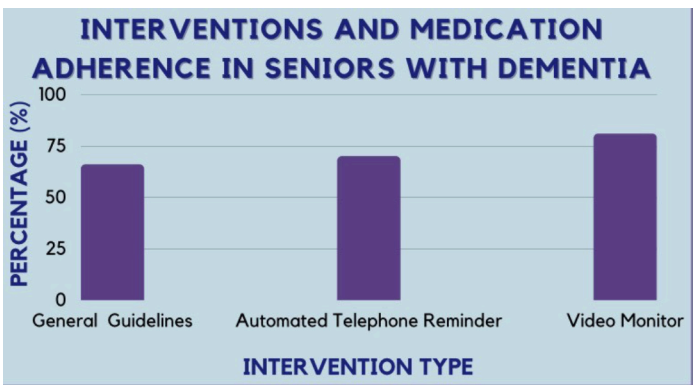

Figure 4: A study by the National Institutes of Health compared different interventions when assisting a senior with Dementia to take medication and concluded a significant increase in medication adherence with technology assistance. This study showed that the adherence rate of 14 seniors was 66% with general guidelines (pharmacy instructions) compared to a 70% and 81% adherence rate when an automated telephone system and video monitor were used (Greenblat, 2017). This study further proves the significance of technology in adherence rates in seniors and how Pill Smart could be a solution to this.

the missed day, even if it is the next day.

Through these many design changes, The Pill Smart was made considering 7 key factors including adaptive features, ease of use, alarm features, dosage safety guards, safety lock, date and time, and an app intervention.

Advancements for Pill Smart in the future include the ability to dispense medications multiple times a day if a patient has staggered medication times. Additionally, an app feature to track when the medication needs to be refilled, this way if the Pill Smart is not refilled, the app will know and be able to continuously alert through the app.

CONCLUSION:

In conclusion, the project aims to introduce a device that significantly enhances the lives of individuals living with dementia, along with their dedicated caregivers. The primary objective of this endeavor is to offer practical support in mitigating the challenges that arise in the wake of the life-altering condition. The initial attempts encountered design errors, such as the mechanism of the box, which served as invaluable lessons, contributing to the evolution of a more efficient and effective design. While the Pill Smart itself cannot serve as a direct treatment for seniors with dementia, its pivotal role lies in elevating medication adherence rates, thereby optimizing the administration of crucial symptomatic treatment.

Although the Pill Smart can not directly treat seniors with dementia, it can increase the rate of them taking the medication which treats their symptoms and can be another tool in the toolbox of assistive devices for seniors with dementia.

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ABOUT THE AUTHOR JOY AKINKUNMI

Joy Akinkunmi is a 15-year old grade 10 high school student in Halifax, NS, Canada. Joy is very interested in how the fields of medicine and engineering can be used to develop new technology to tackle health care issues. An aspiring medical doctor, Joy hopes to pursue medicine in her post-secondary education and be able to contribute to studies in the health field. Outside of science, Joy enjoys volunteering at a local long term care facility as well as reading and playing basketball.