Medispenser - Design Brief

1.0 Background and Problem

Failure to take medication as prescribed, or non-adherence, among elderly individuals (adults over 65 years old) varies from 26–59% (van Eijken, Tsang, Wensing, de Smet and Grol, 2003). As elderly individuals face several age-related barriers to taking their medication, they are at a significant risk for non-adherence which can worsen health conditions and lead to hospital readmissions. Thus, there is a great need for the design of affordable and intuitive interventions tailored to their age-related barriers. This product, Medispenser, aims to aid those who are prone to forgetting to take their prescribed medication and to reduce caregiver burden. This is achieved through the design of an automated medication dispenser with scheduled alerts and logging capabilities.

Through literature review, user and consumer surveys, and interviews with subject matter experts, the user and market needs for the proposed product were determined. It was identified that the target users are elderly individuals who live independently, but face difficulties in remembering to take their medication. As this user demographic faces age-related barriers to taking their medication, a list of requirements was created to fulfill these needs.

Firstly, it is essential that patients take their prescribed medication, in the right doses and at the right times. Increasing adherence to their prescribed medication plan reduces the risk of adverse effects and increases independence. The second need was product or system improvement. Advanced medication dispensing devices and services are currently on the market. However, they are expensive, particularly for those on a pension or tight budget and lack the functionality that Medispenser offers. Thus, there is a need for an effective and affordable device to aid in medication management and ultimately improve quality of life. The final need was to reduce caregiver burden. The medication dispensing devices currently available do not offer logging features. Thus, a personalized medication management system with logging capabilities would help caregivers, and potentially physicians, to analyze patterns and to take appropriate actions to mitigate factors that may contribute to non-adherence.

Based these analyses, the team chose to create a product to enable elders to take their medication independently, at scheduled times, and to inform caregivers and physicians through automated logging. This device will bridge the gap between cost and functionality through intuitive innovation and will offer a positive user experience to increase medication adherence.

2.0 Design Development - Methods/Approach/Solutions Considered

A core design aspect of Medispenser is the dispensing mechanism, as it directly affects how the rest of the product functions. Through interviews and needs analyses conducted during the initial stage of the project, it was determined that eliminating the need to prepare daily doses, a source of caregiver burden, would be integral to the design. To determine the best mechanism to fit product’s design objectives, two different designs of single pill dispensing mechanisms were chosen and fabricated: the Rotating Batch and the Vertical Feed.

2.1 Rotating Batch

The Rotating Batch is comprised of three main components: the top rotating plate, the bottom stagnant plate, and the motor. When activated, the motor turns the top plate, which rotates until a pill falls through the plate’s hole. The motor continues to rotate until the system detects a pill has fallen.

2.2 Vertical Feed

The Vertical Feed is comprised of two components: the vertical tube, and the dispensing mechanism. When activated, the motor with the circular plate, which is connected by the shaft, rotates and the dispensing block starts sliding between the vertical tube and hole, dispensing a pill.

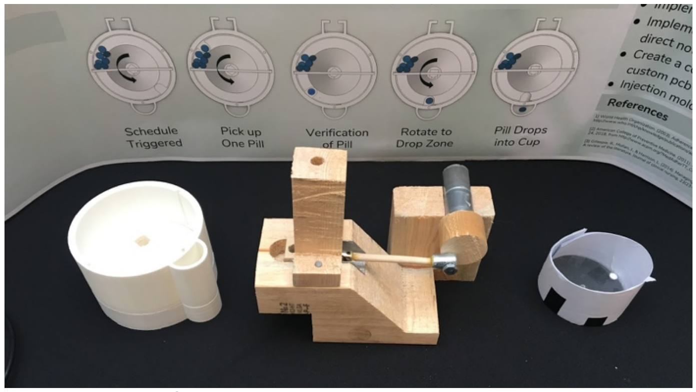


Figure 1: Prototypes. Left: Final Design. Middle: Vertical Feed. Right: Rotating Batch

2.3 Design Comparison

Both models are modular, which allows the device to hold and dispense a variety of pills, as well as the ability increase the capacity of the device. To determine which mechanism was best suited for the final design, the two models were tested for their reliability and capacity. Pills were placed in each model to count the number it would dispense in 10 cycles, with the desirable result being all 10 pills. The models were then compared to a standard manual pill box in regard to their respective pill capacities at a constant overall size. It was determined that the Rotating Batch out-performed the Vertical Feed in terms of reliability and capacity relative to size. The team therefore decided to select the Rotating Batch as the final dispensing mechanism.

3.0 Final Design - Description of Final Approach and Design

The rotating batch mechanism was refined into a final design which incorporates the electrical, control and web systems.

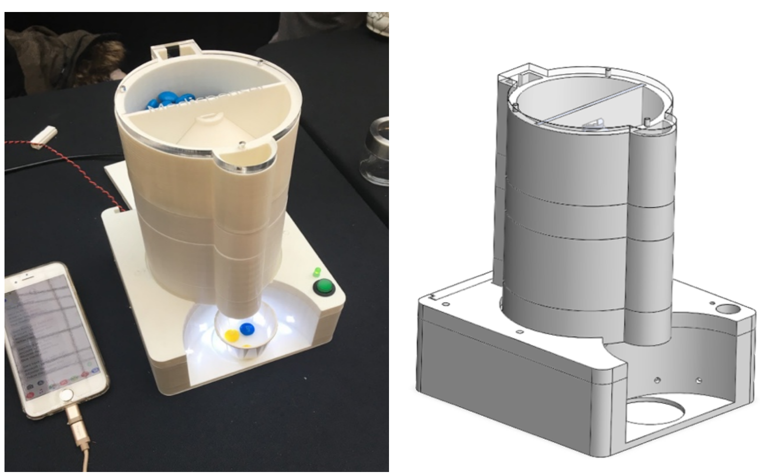


Figure 2: Final Assembly of the Medispenser

3.1 The Mechanical Design

The final mechanical design consists of nine unique components, with particular components duplicated depending on the number of modules integrated in the system (see Figure 3). The components can be break down into two groups: the Modules, and the Base.

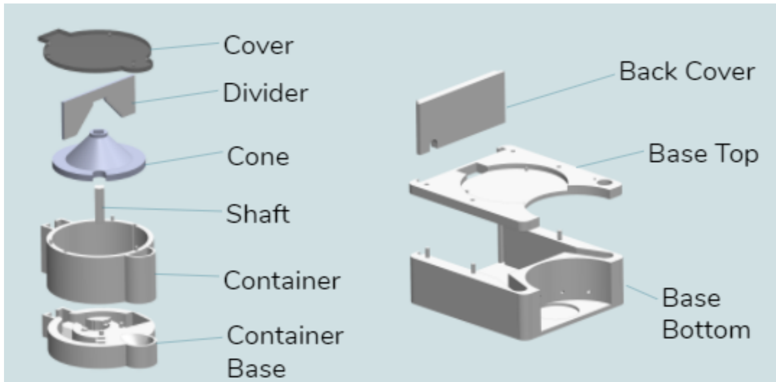


Figure 3: Component Names. Left: Modules. Right: Base

3.1.1 The Base

The modules consist of the container, container base, cone, shaft, divider, and cover. The container houses the pills. The container base houses the motor, IR sensors, and the motor board for each module. The slope of the cone ensures pills fall downwards to be picked up individually from the container. The shaft serves as a method of translating rotational motion from the motor to the cone. The divider tandems with the cone to separate individual pills from the container. The cover prevents dust particles and other contaminants from entering the uppermost module and to stop medication from falling out.

3.1.2 The Base

The base consists of the base top, base bottom, and back cover. The base top serves as the cover of the base bottom. It also features various holes for buttons, LEDs, and meshing. The base bottom houses the majority of the electric components. The back cover hides the electrical components from view, provides access to the volume in the base bottom, and provides slight structural rigidity.

3.2 The Electrical Design

The electrical components are controlled by an Arduino. Infrared (IR) sensors are used for pill dispensing verification and motor control. Stepper motors are used and powered by a 5 Volt, 2 Amp power supply, which goes through a voltage regulator and fuse before reaching the components. The motor will actuate based on the state of the infrared sensor when detecting whether a pill is present or not. The QRD1114 infrared sensor, 28BYJ-48 stepper motor and the ULN2003 motor driver have been implemented.

3.3 The Web Application Design

The web application is used to store and gather data regarding the user's medication requirements. This includes their name, the type of medication they take and their intake times. The user registers and logs into the website and inputs their data into generated forms. Their data is then stored in a database created using MySQL and Python. Python also contains a scheduling program which is being utilized to accurately schedule when the pills are to be taken. All of this is encapsulated in a Python framework called Django. The home page of the web application is shown in the figure below.

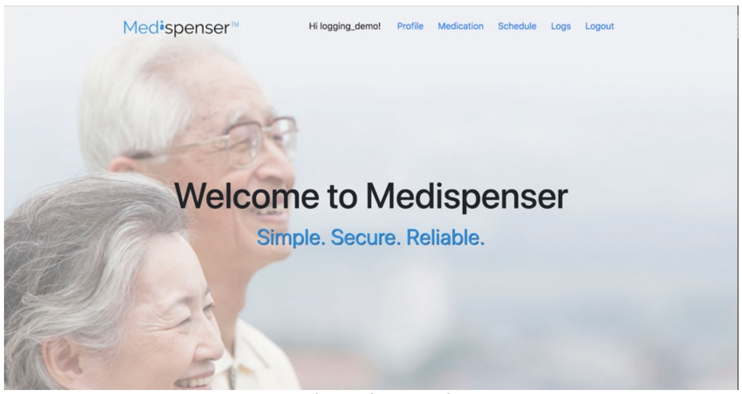


Figure 4: Web application home page

3.4 The Arduino API

In order to use the gathered data, the database must communicate effectively with the Arduino. Using Python, the API allows for the flow of information gathered from the user by the web application to be sent to the Arduino. The Arduino then activates the mechanical components of the device to dispense the correct pills at the specified times.

3.5 Logging

Medispenser keeps track of the user's medication adherence. The system has a button that allows the user to release the pills. When the button is pressed, the Arduino sends a signal back to Django and saves the information into the database. The information saved includes the time, user ID, module number and the pills taken. The user and their caretakers are able to access the logged information through the web application. The design assembly for the entire system is shown below:

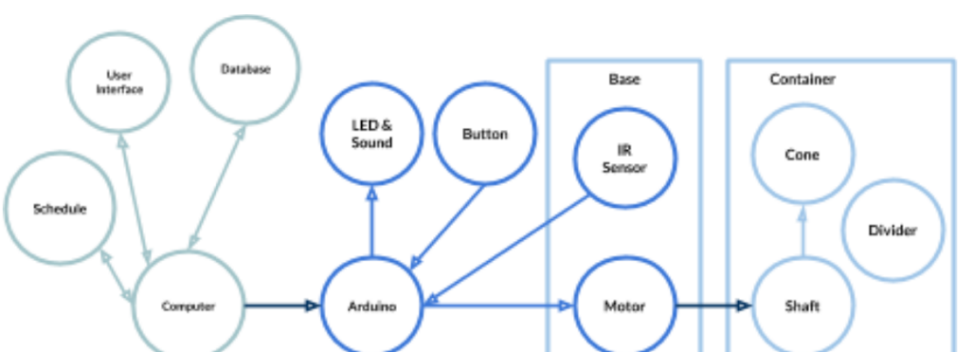


Figure 5: Design Assembly for software (teal), electrical (dark blue), mechanical (light blue)

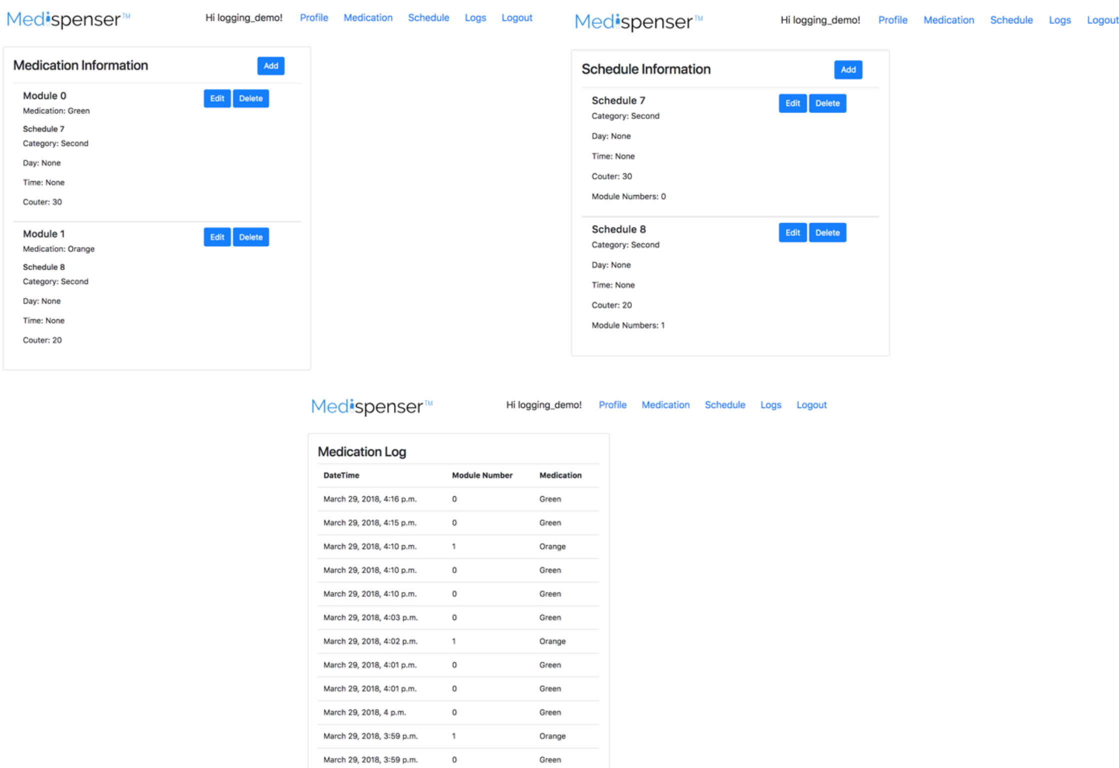


Figure 6: Left to Right: Medication and Module Information, Schedule Information, Logging information

4.0 Outcomes and User Feedback

Medispenser has three main functions: logging, reminding and pill dispensing. To ensure the final device of our project achieves the functions mentioned, it underwent a series of tests. Tests were conducted to ensure each function is reliable.

4.1 Logging

The goal of this test was to determine if the system would log the medication dispensing when the button is triggered. The test was conducted through a sample user account. The dispense button on the device was pressed when the LED indicator light was on, signaling the device was triggered and ready to dispense according to the schedule. The team then checked if the system successfully logged the action when the pill was released. Over 50 trials were conducted, with each trial testing either module 0 and 1.

4.2 Reminding

The goal of this test was to determine if the device's audio and visual alert system activates once the device is triggered. Similar to Logging Test, the Reminding Test was conducted through a sample user account. The team checked if the LED indicator light and sound reminder track activated successfully when the device was triggered. Over 50 trials were conducted, with each trial testing either module 0 and 1.

4.3 Dispensing

The goal of this test was to determine the accuracy and reliability of the device's dispensing mechanism. The test was conducted by dispensing a preset amount of pill(s) for each trial. The team checked if the device released the exact number of pills as scheduled. Over 50 trials were conducted, with each trial testing either module 0 and 1.

4.4 Analysis

Through the tests, it was found that the logging, reminding, and dispensing functions all have an 100% accuracy, given the conditions of the tests. This was due largely to the fact that the cone was perfected to fit the pill size used to conduct the experiments, and that each functionality was thoroughly tested separately prior to complete assembly. As shown from the results above, the device is capable of dispensing medication reliability, with an accurate data logging system and a functional reminding system, given that the cone is manufactured to the correct dimensions.

5.0 Significance

With the average life expectancy of elders increasing, the population of individuals over the ages of 65 in the United States is projected to nearly double from 48 million to 88 million by 2050 (He, Goodkind and Kowal, 2015). Thus, there is a great need for interventions tailored towards overcoming these age related barriers. An improved medication management system will increase the independence of elders, allowing them to maintain their lifestyle and not have to rely so heavily on others such as informal caregivers (e.g. family members) to aid them in taking their medication. Additionally, the ability to provide useful adherence metrics and notify a caregiver, in real-time, takes away the stress and burden experienced by the user and their family or friends.

The long-term benefits of Medispenser tie in heavily with its social impacts. The decrease in admissions to LTC facilities and hospitals will decrease the financial burden required of the families of the admitted patients. By using the device, the elder themselves will be less reliant on their caregivers, and thus not have to use their meager pensions or savings to paid for such aid.

6.0 Costs to Produce and Expected Pricing

The team was able to stay within the given budget of $500. The first $200 was used for testing prototypes and the next $286 was used to prepare for the demo. (See Appendix A for detailed project budget breakdown). The expected pricing of this product would be $200. The price point was set for the device is determined through the objective of the project: to offer and affordable device for majority of population. It was also determined through evaluating the manufacture cost of the device and the growth of the company.

7.0 Conclusion and Future Work

In conclusion, the team has successfully achieved a viable prototype which achieves the function to "aid elderly individuals who live independently, are prone to forgetting to take their medication, but are willing and able to take their medication". In addition, the specifications, including logging, reminding, and dispensing, have also been met and tested for accuracy.

For future work, the team aims to develop Medispenser to operate as a standalone product, without the use of a computer to load its scheduling. Also, integrating an LCD screen to the product and a smartphone app to input scheduling would improve the user interface. Lastly, the material being used and the environment which the product is manufactured must adhere to Food Safe Canada regulations. By promoting independence and greater quality of life, Medispenser will create positive change in the lives of elders living with cognitive and/or physical difficulties.

References

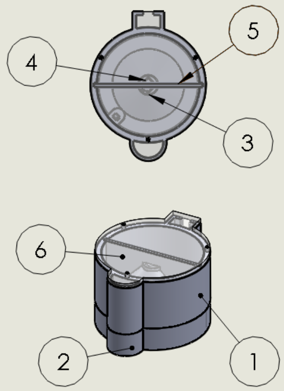
van Eijken, M., Tsang, S., Wensing, M., de Smet, PA. and Grol, RP. (2003). Interventions to Improve Medication Compliance in Older Patients Living in the Community. *Drugs & Aging, 20*(3), 229-240

He, W., Goodkind, D. and Kowal, P. (2015). *An Aging World: 2015*. Washington, DC: U.S. Government Publishing Office.

Appendix A

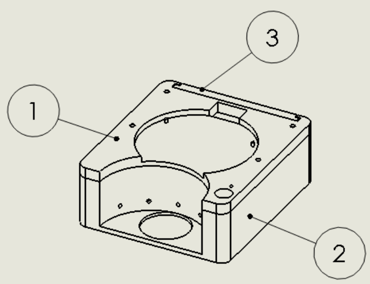
Project Budget for Design and Innovation Day Demo

No.	Item	Qty	Division	Cost (CAD$)
1	3D Printing Module (see Figure _)	5	Mechanical	0
2	3D Printing Main Base (see Figure _)	2	Mechanical	0
3	Stepper Motors with Drivers (28BYJ-48)	5	Electrical	30
4	Arduino Uno	1	Electrical	50
5	Arduino Mega	1	Electrical	60
6	IR Sensors (QRD1114)	10	Electrical	25
7	Power Supply 5V 3A	1	Electrical	15
8	Jack 2.1mm	1	Electrical	2
9	1M ohm Resistor	20	Electrical	5
10	Led	5	Electrical	2
11	Button	4	Electrical	12
12	Lcd Display	1	Electrical	20
13	Fuse	2	Electrical	5
14	Cable Management Tube	1	Electrical	10
15	Jumper Wires and Cables	3	Electrical	30
16	Pills	1	Demo	20
Total Cost				286



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Container	Pill holder	1
2	Base	Hold motor and IR sensor	1
3	Cone	Rotating plate to catch pill	1
4	Shaft	Connects motor to cone	1
5	Divider	Allows only one pill to pass through	1
6	Cover	Protects pills	1

Figure 7: Bill of Materials for module components for 3D printing



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Main Base Cover	Holds led and button	1
2	Main Base Body	Holds electronic components	1
3	Main Base Slider	Easy access to electronics	1

Figure 8: Bill of Materials for main base components for 3D printing