Smart Pill-Organizer (Team 14)

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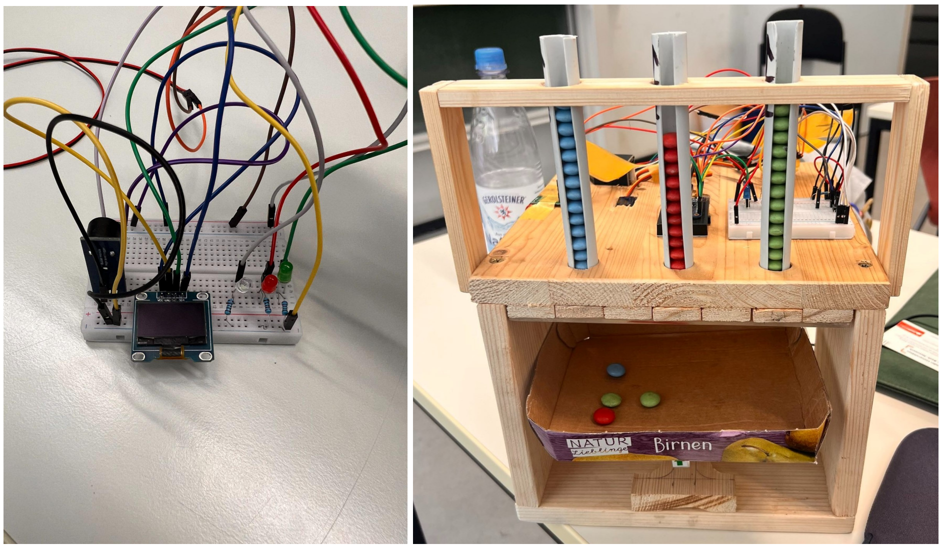

Figure 1: Our SPO in its full glory!

ABSTRACT

In the case of long-term treatments in healthcare, adherence is important since non-adherence may lead to a negative impact on patients' health. Non-adherence can result from many factors, such as fear, cost, lack of medication management, forgetfulness, or stress. Traditional approaches, such as manual pill-boxes and paper-based reminders, often prove unsuccessful in addressing the matter of medication management.

We developed a Smart Pill Organizer (SPO) that consists of a smart wristband and a smart pill dispenser to support patients in handling medicine with the goal of improving adherence. The smart wristband has an audible and light notification integrated to inform users to take medication on time. Besides, it has a display showing concrete information. The smart pill dispenser has individual LEDs integrated into each slot, acting as a visual correctness check, while an appropriate mechanic with servo motors ensures the correct dosage. Furthermore, it has a fingerprint sensor to achieve security and avoid unauthorized third-party access.

By effectively making use of low-cost hardware, we refer to already existing studies, facing issues of non-adherence, and utilize those to improve our system and empower patients to adhere to their prescribed medication schedule. The user-based design and personalized features shall reduce medication errors, minimize healthcare costs, promote better treatment outcomes, and preserve a patient's safety.

Our prototype was tested with four participants. Two questionnaires were applied to evaluate our system. One focused on its everyday use, and the other on the comparison with a classical pill-box. Results showed SPO was not only acceptable and convenient to use but also its reminder system can improve medication adherence. Besides, its advanced functionalities and easy-to-learn instructions were positively evaluated as more developed and practical factors compared to classical pill-boxes.

1 INTRODUCTION

According to the Health Policy Institute's 2021 statistics, about 66% of adults in the U.S. take prescription drugs. Among them, each person takes an average of four drugs per day [6]. In 2023 the number of adults in the U.S. taking at least one prescription medication per day has shifted to 70% stated by Civicscience.

In the case of long-term treatments, adherence is important, because non-adherence may lead to a negative impact on patients' health. There are many reasons for non-adherence, including difficulty taking medicines as prescribed or not taking them on time. Therefore, making it easy and simple for patients to participate in treatment is a priority. The most common solution to this problem is using a classical pill organizer shown in Figure 2 incorporating

Figure 2: A classical pill organizer [7]

medicines into daily routines. The pill organizer contains seven boxes for each weekday, and each box is segmented into four slots for four daily schedule lines, namely morning, noon, evening, and night. However, it has many drawbacks. For example, it does not have any reminder function for users to remember to take a certain medicine on time. Furthermore, it is bulky, needing to be refilled weekly by a pharmacist, and still leaves much room for user error. In addition, Asa Alftberg [1] pointed out that the classical pill organizer gives people a feeling of aging and old age.

The medical device we propose should alleviate many of these shortcomings by being more space-efficient, requiring fewer refills, and leaving less space for user error. It consists of 2 connected devices, a wristband, a dispenser, and a companion application. In the companion application, a medical professional or an independent user can enter the medication, dosage, and times it needs to be taken and assign each a different color. It will then output a simple pseudonymized file, which only contains dosages mapped to colors. This file can then be uploaded to the bracelet via a serial connection.

The wristband itself will then buzz and its light signal will turn on when it is time to take medication. Once the user is next to the pill dispenser they can authorize themselves using a fingerprint reader. After authorization, the pill dispenser will communicate with the wristband to determine what dosage to dispense from which chamber. The dispenser will then dispense a dosage (typically pills) onto a scale, which will double-check the dosage for correctness by weighing it. During this, the wristband itself will also display the dosage on its screen and have an LED indicating the color of the chamber from which the dispenser should have dispensed medication. This serves two purposes. For one, it allows the user to double-check again that the dosage and medicine are correct, but more importantly, it can serve as a backup mechanism if the dispenser does not work correctly or at all. In order for this to work, the user would also need their medication available to them outside of the dispenser in whatever packaged form the respective medication comes from. The packaging then needs to have a color indicator (i.e. sticker, permanent marker) placed on it. In case of an error, the user can then use the color of the LED and the dosage displayed by the wristband to take the correct medicine and dosage on their own.

Both of these processes can then be repeated for each medicine required one after another.

2 RELATED WORK

In 2014 Mira et al. [5] tested a Spanish pill organizer app called ALICE for elderly patients taking multiple medications. The goal was to find out whether this app can improve both adherence and safe medication use.

ALICE is designed to help elderly Spanish-speaking patients manage multiple medications more effectively and improve their medication adherence. It can be used in Android and iOS systems. Each user can personalize it with his individual prescriptions and medical advice, as well as store images of each medicine, including its packaging and medicine itself shown in Figure 3. Furthermore, it has an alert function reminding users to take their medications at the correct time, and the app also alerts users in case there are potential interactions between different medicines. In addition, it allows users to communicate with their healthcare providers in case of having questions.

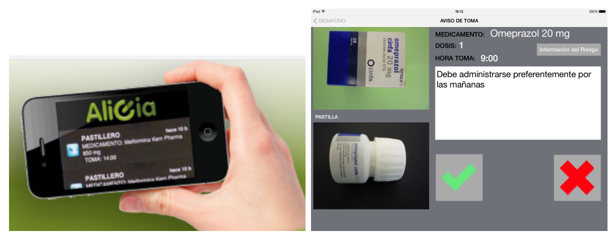

Figure 3: ALICE app [5]

The study was in term of three months and ALICE was used daily. The author found out that ALICE helped elderly patients to remember whether they had taken their medicines, and patients felt more independent in managing their medications. Although this app has more complex functions compared to our system, the study showed that elderly patients who had never used modern techniques, such as smartphones, computers, and the Internet, were capable of using the app. This shows that our simple device should also be user-friendly and elderly users should not have problems using it. Besides, ALICE does not check whether a patient actually took the appropriate medication with the correct dosage after the alert was confirmed. Our device solves this problem, because our wristband is linked to the pill dispenser, and our light signal from the wristband can only be turned off after users have activated the dispenser with their fingerprint, ensuring users have taken their medications. Besides, our dispenser has an appropriate mechanism to ensure releasing the correct dosages. Furthermore, users can also check whether it is the correct medicine by verifying it with the LED color indicator.

Another smart technology is to assist patients to refill a pill organizer, developed by Martin Ingeson, Madeleine Blusi, and Juan Carlos Nieves in 2018 [4] and completed in 2019 [2]. It is a smart augmented reality mHealth application. They implemented a Medication Coach Intelligent Agent (MCIA) embodied in an AR-headset that can manage different input information from the headset to support medication self-management. Inputs can be the voice, vision, and gestures of users, and outputs can be visual and audible.

Figure 4: AR-headset [2]

Figure 4 illustrates how the MCIA is used to help people in this situation. A user is wearing an AR-headset. When he looks at a medicine carton, the MCIA acts on the input information and shows the user instructions on how many of each medicine to put in each slot of the pill organizer. MCIA also can help users to distinguish whether a medicine was prescribed to them by looking at a medicine. In case a medicine was not prescribed, MCIA will give information that this is the wrong medicine.

The technology was tested with 15 participants, aged from 17 to 76. 7 participants were older than 65 years. The results of the study showed that although the AR-headset was comfortable and feasible for most patients to use, people older than 65 felt less comfortable and were more hesitant to use it.

Our device does not allow that kind of interaction but the need for it is not there as for our device the refill of multiple containers with a mix of different medications is not necessary for the user, at most once for each intake but the user is guided with the colored containers.

Fărcaş et al from the Applied Electronics Department at the Technical University of Cluj-Napoca in Romania [3] proposed an electronic pills dispenser that includes a reminder for the intake.

A photograph of the experimental setup is shown in Figure 5. The basic component is a container that is connected to a motor to dispense the pills, a micro-controller activates it at a given time. The time can be set using buttons, a display shows information. The micro-controller triggers an audio signal when the user should take their pills. As an addition it was proposed that an SMS-message can be sent to a cellphone if the user forgets about the medication after some time, this was not implemented in the device proposal of the paper.

Our device has many similarities such as the auditory output or the reminder function where there are some critical differences. Our device instead of a chamber per day and time has chambers per type of medication. This way our device is more flexible than the device proposed by Fărcaş et al. as it does not require the chambers to be changed when only the schedule needs to be adapted, also it is more flexible in size as it allows for an easy extension of the time period managed. Furthermore, our device has a different kind of messaging as we use a wristband with visual indication which does not need the user to own a cellphone. The combination of auditory and visual notification is useful for people with impaired hearing or vision.

Figure 5: The experimental setup [3]

In summary, first, our device is designed in a user-friendly way that makes it easy to use even for elderly users. Then, it has a buzzer alert and a light signal to notify users on time with concrete information displayed on the wristband screen, and an appropriate mechanism integrated to dispense correct dosages. Besides, each slot of the dispenser has its LED with an individual color corresponding to the information on the wristband screen acts as a visual check. In addition, to check whether the patient has actually taken the proper medication, the light signal is designed in a way that it can be turned off only after the user has activated the dispenser. Furthermore, our device does not need a bulky AR-headset to check the correct medications since our dispenser works according to an individual prescription.

3 USE CASES

To better understand how SPO can be used, we present three different use cases in this section.

Use Case 1: Elderly Medication Management

Personas:

- Dr. James Mueller is a 32 years old medical professional who is trained in using the device.
- Patric is an elderly patient at the age of 81 with a chronic health condition who needs to take multiple medications throughout the day.

How does Dr. Mueller set up the device for Patric and how does he use it?

Flow:

(1) Dr. Mueller fills each compartment of the pill dispenser with a different medication.
(2) He sets Patric's personal medication schedule in the companion application as prescribed, i.e. entering the information about medication, dosage, and times it needs to be taken, and assigns each kind of medication a different color.
(3) The data gets transferred to the device.
(4) Adam registers with his fingerprint.
(5) He puts on the wristband.
(6) The wristband is buzzing and lightening as it is time to take a certain medication.
(7) Patric recognizes the warning, turns off the buzzer, and authenticates on the pill dispenser with his fingerprint.
(8) The pill dispenser communicates with the wristband and releases the appropriate medication according to the setting.

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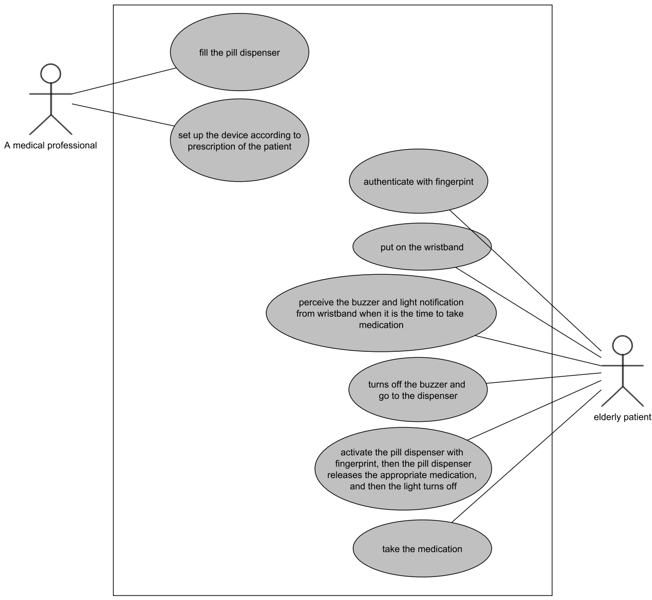


Figure 6: Use Case 1: Elderly medication management

(9) The wristband turns off the light.
(10) Patric reads the information from the wristband display and checks whether the output medication is correct.
(11) He takes the medication.

Use Case 2: Refill Pill Dispenser

Persona:

- Jon Schmidt is 27 years old, he is a young independent patient who is able to refill the pill dispenser himself.

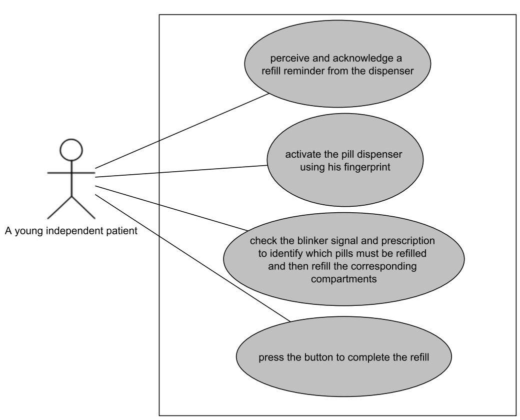


Figure 7: Use Case 2: Refill pill dispenser

How can Jon Schmidt refill his device once he gets notified?
Flow:

(1) Jon perceives and acknowledges a refill reminder from the dispenser system indicating that the pill supply is running low.
(2) He activates the pill dispenser using his fingerprint.
(3) He checks the blinker of the dispenser and the prescription to identify which pills must be refilled and then refills the corresponding compartments.
(4) He presses the button to complete the refill.

Use Case 3: A Patient With Procrastination

Personas:

- Peter Paul (45) is a patient who is always hesitant to take his medication on time. As his medication plan changes every now and then he does not have a routine.

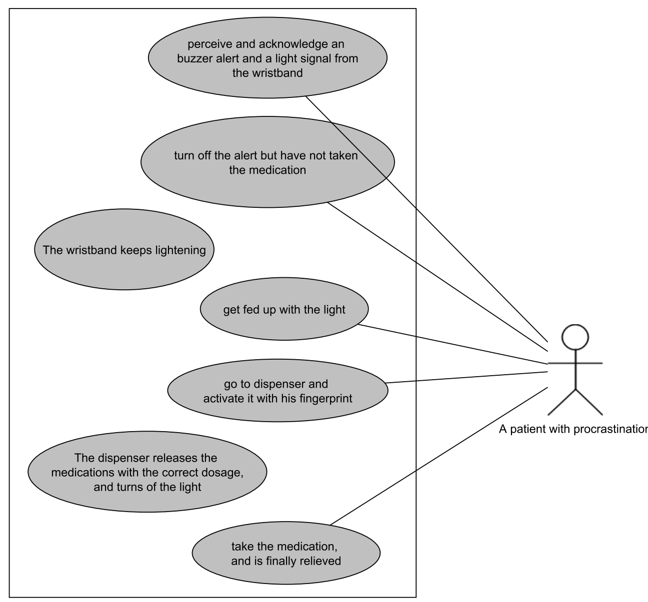


Figure 8: Use Case 3: A patient with procrastination

How does Peter Paul with procrastination get pushed to take his medications on time?
Flow:

(1) Peter perceives and acknowledges the buzzer alert and the light signal from the wristband, indicating it is time to take medication.
(2) He turns off the alert but has not taken the medication.
(3) The wristband keeps the LED lightening.
(4) After a few minutes he is fed up with the light.
(5) He finally goes to the dispenser and activates it with his fingerprint.
(6) The dispenser then releases the medications with the correct dosages, and turns off the light.
(7) He takes the medication from the dispenser and is finally relieved.

4 IMPLEMENTATION

4.1 Companion App

The companion application allows users to enter dosages and map these to colors, a dispenser compartment, and a schedule. These entries are then converted into a simple byte format, which can then be transmitted to the band over USB via Serial protocol. The primary challenge here, which will be recurring over the course of other parts, is the variable size of the dosage entries. Some may repeat on a daily schedule, others on a weekly or bi-weekly one. We now had to decide whether we trade space for simplicity by giving each entry a fixed amount of space for its schedule or we minimize the amount of space used by using variable length structures like vectors, which are more complicated to (de)serialize in an embedded context. We opted for the latter, given that the resources of the controllers are very constrained.

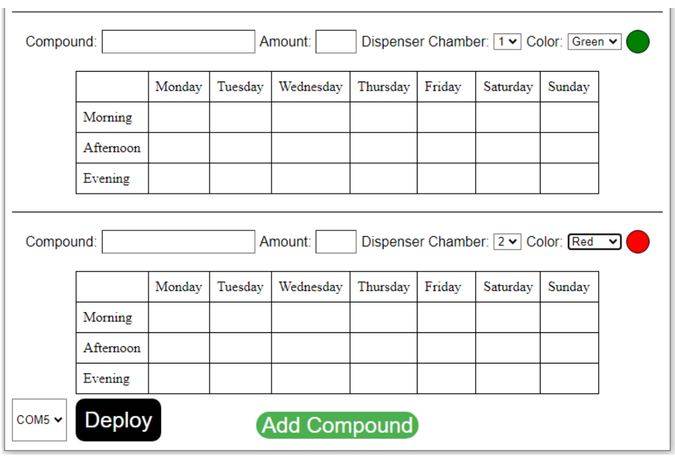


Figure 9: Companion app, cropped for size

Since the data sent by the companion app to the device should persist through power cycles, we also had to find a way to store it on the device persistently. Luckily, the standard Arduino EEPROM library is compatible with our controllers, which emulate EEPROM by designating a block of flash storage for it. Since we opted for variable length data structures as described above, writing the data is unfortunately not as simple as it could be, but reusing the logic for byte-serialization from the Serialization proved to work well enough to write the data byte by byte. Since the EEPROM uses a memory buffer and only commits to storage when asked, writing the data byte by byte does not have a significant performance overhead.

4.2 Secure Peer-2-Peer Communication

As the protection of sensitive personal data also is a central goal of our application, the communication between the wristband and dispenser proved to not be as straight forward as expected. Connecting to a WiFi router, and therefore the internet at large, was out of the question due to the security implications. However, our controllers support the ESP-NOW library, which allows for encrypted peer to peer connection using WiFi without connecting to a router. We worked around the need for byte serialization here, as a packets

```
void write(Shedule shedule) {
    this->clear();
    std::vector<u8> buffer = {};
    for (auto entry : shedule) {
        std::vector<u8> data = entry.to_bytes();
        buffer.insert(buffer.end(), data.begin(), data.end());
    }
    int counter = 0;
    for (auto byte : buffer) {
        EEPROM.write(counter++, byte);
    }
    EEPROM.commit();
}
Shedule read() {
    size_t counter = 0;
    Shedule shedule = {};
    while (EEPROM.read(counter) != 0) {
        shedule.emplace_back(Entry(EEPROM, &counter));
    }
    return shedule;
}
```

(a) Persistent storage read and write

```
std::vector<u8> to_bytes() {
    u8 total = 4 + times.size();
    std::vector<u8> res = {};
    res.push_back(total);
    res.push_back(this->color);
    res.push_back(this->dispenser_id);
    res.push_back(this->unit);
    res.push_back(this->unit_value);
    for (auto time : times) {
        res.push_back(time.val);
    }
    return res;
};

Entry(EEPROMClass buffer, size_t *next) {
    size_t counter = *next;
    size_t total = buffer[counter++];
    this->color = (Color)buffer[counter++];
    this->dispenser_id = buffer[counter++];
    this->unit = (Unit)buffer[counter++];
    this->unit_value = buffer[counter++];
    this->times = {};
    for (size_t i = 0; i < total - 4; i++) {
        this->times.push_back(Day(buffer[counter++]));
    }
    *next = counter;
}
```

(b) (de)serialization

in ESP-NOW are fixed to 250 bytes in size, regardless of the size of the content, which allowed us to use fixed size structures without overhead. On top of this, we implemented a stateful protocol that allows the Wristband to know in which state the dispenser currently is, if any errors happened and communicate these to the user when necessary. This also allows the wristband to execute a fallback strategy if the dispenser is in a non-recoverable error state.

4.3 Security Trade-offs

As noted above, connecting to the internet at large is a no-go for our project. The most significant implication for this is how to synchronize the internal clock of the wristband to local time. This is typically done using the internet, however, more rudimentary ways to do this exist. One example would be outfitting the wristband with a radio receiver used by radio clocks. Should this not be feasible due to environmental conditions (radio shielding in hospitals due

```
Wireless(u8 *receiver_mac,
         void (*recv_handler)(uint8_t *, uint8_t *, uint8_t),
         void (*sent_handler)(u8 *, u8))
    : mac(receiver_mac) {
    WiFi.mode(WIFI_STA);
    if (esp_now_init() != 0) {
        Serial.println("Error initializing ESP-NOW");
    }
    esp_now_set_self_role(ESP_NOW_ROLE_COMBO);
    esp_now_add_peer(receiver_mac, ESP_NOW_ROLE_COMBO, 1, password, 4);
    esp_now_register_recv_cb(recv_handler);
    esp_now_register_send_cb(sent_handler);
}
```

(a) Shared ESP-NOW setup

```
void send(DispenserMessage msg) {
    memcpy(&this->messageOut, (u8 *)&msg, sizeof(this->messageOut));
    esp_now_send(this->mac, (u8 *)&this->messageOut,
                 sizeof(this->messageOut));
}
```

```
void message_received(uint8_t *incommingMacAddress, uint8_t *incomingData,
                      uint8_t len) {
    memcpy(&this->messageIn, incomingData, sizeof(this->messageIn));
    this->callback(this->messageIn);
}
```

(b) Send data from wristband, receive on dispenser

to interference for example), it would still suffice to synchronize time with the companion app together with the medication data, as the clock typically needs not be accurate to the second, only the rough time of day. This of course also requires the band to be equipped with a large enough battery to last in the mean time.

Of course, we do not have access to a radio receiver, and therefore decided to only use a rudimentary timer that is not synchronized for demonstration purposes.

4.4 Scale Limitations

As the scale provided to us is unfortunately nowhere near accurate enough to measure the output of our dispenser, we could not fully implement this part of our project to specification. So instead, we implemented the weight measuring separately from the rest of the project, with much heavier weights. Based on this, we put all the implementation into place so that IF we had a scale which was accurate enough, it would only require putting it in and setting a flag in the code. Also we ran out of GPIO-pins as some pins are reserved for specific functionalities.

4.5 Dispenser Fallback Mechanism

Of course, no piece of hardware or software is perfect. As such, it is very likely that our dispenser would fail at some point due to software or mechanical reasons. While it is of course important to minimize the chance of this happening, it is even more important to plan for when it inevitably will happen. In this situation the most important question is how the user can still take the correct medication on time, as this might potentially be a question of life and death.

To work around this scenario, the wristband will always display the dosage and color of a medication when it is due. The user should then have access to emergency rations of their medication. On the packaging of this the rations should be a colored marker that corresponds to the colors the wristband displays, so that in such an emergency, the user can easily identify the correct medication and take the correct dosage.

Of course, this assumes that the wristband works correctly. If this is not the case, there is unfortunately not much our device can do about this, so it is always important that the user also has a backup plan should our device fail. However, this applies not only to our device but any medical device and any form of long term medication and is therefore out of the scope of our project.

4.6 Accessibility

Of course we would like anyone, regardless of any physical or mental impairments to be able to use our device, especially so since many people that would rely on our device would also have some form of impairment. The primary issue we had to address here were people with visual impairment, with blindness as an example, and auditory impairment, with deafness as an example.

As the only auditory signal our device relies on is the signal to take medication, which already also incorporates blinking lights, a deaf person would most likely be able to use our device without modification, but ideally for such a person the auditory buzzer would be replaced by a haptic one.

Blindess on the other hand would be a bigger issue, as many parts of our design rely on the users ability to read and to recognize colors. To mitigate this, we though of using a haptic buzzer instead of colored LEDs. So when the medication needs to be taken, the auditory buzzer would notify the user to take their medication, and the haptic buzzer would use morse code or other easily distinguishable patterns to tell the user which medication is due, and how much. The dispenser could then also use auditory signals instead of LEDs to signal that the correct dosage was dispensed and it is ready to be taken. For the fallback mechanism, instead of putting colored stickers on the medication containers, one could put Braille stickers on them to serve the same purpose.

Finally, in the case of color blindness, instead of using individual color LEDs, it would be easy to use the 3 LEDs on the devices for patterns. So for instance ON/OFF/OFF would be "Red", ON/OFF/ON would be "green" and so on. The same patterns can then be put on the fallback containers.

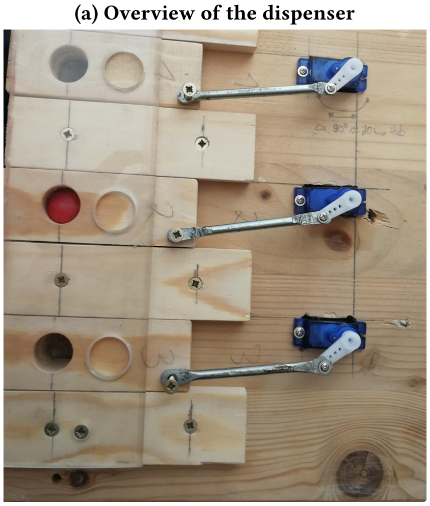
Of course, all of this could also be combined into the same set of devices so they could all be used by anyone. Due to constraints on our hardware, specifically the limited amount of ports on our controllers, we did not have the leeway to implement these accessibility features, but as demonstrated we already planned it out and put abstractions in place so that implementing them would be straight forward.

4.7 Design

When designing the dispenser, the problem we faced was how to ensure that it would release exactly one pill at a time.

We have found a solution, using a push construction. We stack the pills on top of each other, as shown in Figure 12 (a). In this way, each pill can fall from itself. Then, we use a sliding motor to push a pill from one hole into another hole. However, we have only servo motors, but what we need are sliding motors. Fortunately, we have found a solution to turn servo motors into sliding motors.

(a) Overview of the dispenser



(b) Technical details

Figure 12: Technical details of the dispenser

As depicted in Figure 12 (b), we have fixed each servo motor with a stable metal lever. In this way, when the servo motor turns forwards or backwards, it pushes the metal level also forwards or backwards. Each hole we made has exactly the size of one pill, i.e. in our case the size of one Smarty. Besides, we have limited each servo motor in a way of allowing it only to rotate with a specific angle forwards and backwards, so that it pushes each pill exactly into the output hole.

By repeating the experiment several times, the results show that we have succeeded in this construction. Since this construction is so successful, the scaling system is actually not necessary. However, it is good to have it in case any servo motor is defect.

Other than that, there is a small flaw in our prototype. Since we are using Smarties, which are made of sugar and chocolate, as medications, they will melt in the heat and then stick together. This may affect the performance of dispensing pills.

4.8 Technical Considerations

There is a technical consideration due to the scaling sensor we got, which is not suitable for our project, since we are using Smarties as pills, each Smarty has only 1 gram, and the scaling sensor rounds the number nondeterministic, leading to inaccuracy. This problem can be solved in the future using a more accurate scaling sensor.

4.9 Hardware

The following list contains the hardware we are using for the project:

- **ESP8266 Wemos D1 Mini:** Our main piece of hardware, which directs and controls all the processes necessary to remind users and dispense the required items.
- **Button with wire, Tasters or Touch Buttons:** The buttons are used by the user as an indicator for the smart pill dispenser to confirm, that they have successfully received their pills.
- **Servo motors:** The motor functions as part of the dispensing mechanism, pushing the pills out by rotating. We are using several motors in case of differentiating between different drugs.
- **LEDs:** LEDs are used to show, which medication is supposed to be taken depending on the flashing of the respective LED (each LED has a different color). It therefore acts as a visual reminder.
- **Buzzer:** The buzzer acts as an additional auditory reminder, besides the mentioned LEDs. It starts to go off as soon as the appropriate time has been reached.
- **OLED (SSD1306 128x64):** The screen, displaying the corresponding weekday and the dosage, that needs to be taken.
- **Wires, Resistors, Breadboard:** All these components are used to connect the wristband and the pill dispenser to the micro-controller as well as the buzzer, the LEDs, the motors, the buttons, and the scale module.
- **Fingerprint Reader (AS608):** Used as a security mechanism by the user. To prevent strangers from getting access to the pills, the user has to verify their identity, using their fingerprint. This process is to be executed before the pills are dispensed.
- **Scale Module (HX711) with load cell:** As a second dosage check to check if the correct amount of the respective medication has been dispensed by weighing the output on the scale.

5 PSEUDO-EVALUATION AND RESULTS

To pseudo-evaluate our device, we decided to look at two goals, that we want to achieve and thus thought of the following two appropriate questions to verify if the product matches the users' needs:

(1) Can the participants imagine using your project in everyday life?
(2) Does the product perform better than that of a competitor?

5.1 Study Design

In order to evaluate the above two aspects, we created two questionnaires, namely Questionnaire A and Questionnaire B. The collected data is going to be represented by four participants, that decided to partake and help improve our system. To protect the participants' privacy, their names are not going to be mentioned, except for their gender. Other than that, we also made sure to include participants that do not take any medication and also those, who do not own a pill dispenser. As it is shown in the Appendices, for the first goal, we designed 10 questions concerning everyday medication. For the second goal, we included 8 questions, trying to incorporate as many advantages and disadvantages over normal pill-boxes as possible by looking at different areas of their usage.

5.2 Results

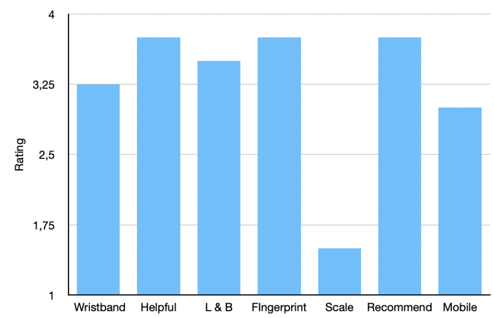
Everyday use of the product

Figure 13 depicts the result of Questionnaire A. Firstly, the result shows that most participants found our device helpful and would recommend it to others. Besides, they were comfortable using a fingerprint sensor to access their medications, implying high confidence in the system's reliability due to authorized use. Then, regarding our notification system of using a wristband with LED lights and a buzzer, participants reported a high likelihood as it provides convenient reminders for medication intake. Both were also chosen to be the most beneficial feature of the product. Furthermore, the use of our smart wristband also received a relatively high rating. Individuals expressed a liking for the simple integration onto the human body and thus their everyday life, indicating the positive portability and versatility of the wristband. However, the mobility of the device got a rating only above average due to the large dispenser. Participants also expressed concern about the accuracy of the scale. Besides, among factors that pose a challenge, 25% of participants each mentioned comfort, fingerprint reliability, and cost.

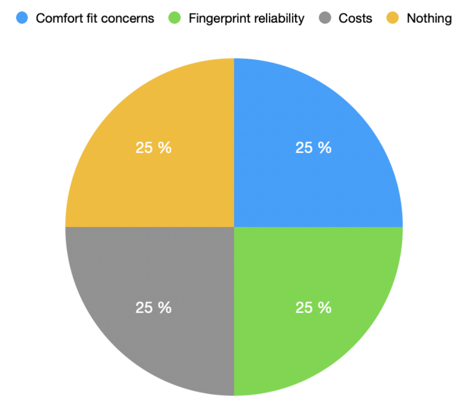
In conclusion, the evaluation highlights the product's strengths in improving medication adherence, convenience, and safe usage. Participants especially praised the potential benefits of the reminder system. Areas for improvement include cost-effectiveness and addressing individual preferences for simplicity and familiarity.

Comparison to a Normal Pill-Box

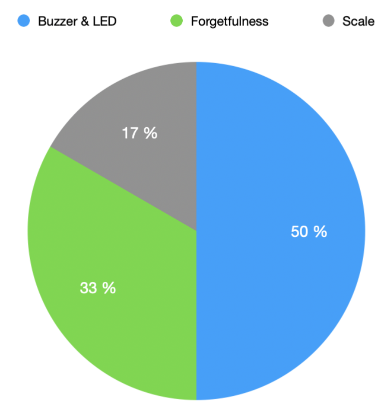
Figure 14 depicts the result of Questionnaire B. Firstly, the participants reported several advantages of the smart pill organizer over a normal pill-box. They expressed a higher likelihood of choosing it due to its advanced features and functionalities. The convenience of use of it was also rated higher than those of a normal pill-box. Then, regarding recommendations, participants were more inclined to recommend our product compared to a normal pill-box. However, participants also reported the advantages of a normal pill-box over the smart pill organizer. They acknowledged that a normal pill-box may offer a sense of familiarity and simplicity, indicating the preservation of a more traditional approach being preferred and thus the technical setup and learning factor being points of disturbance, making the pill-box look more suitable for certain scenarios.



(a) Ratings for Questionnaire A



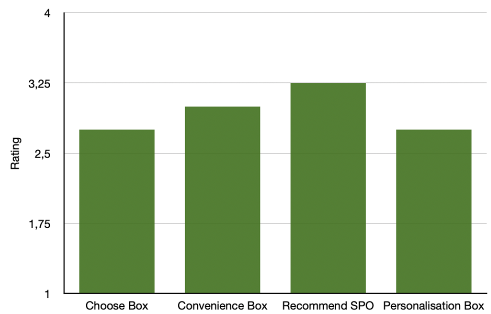
(b) Challenges in using our device



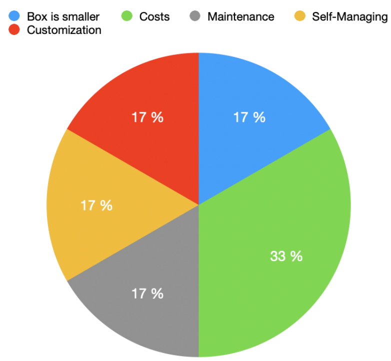
(c) The most beneficial features

Figure 13: Result of the Questionnaire A

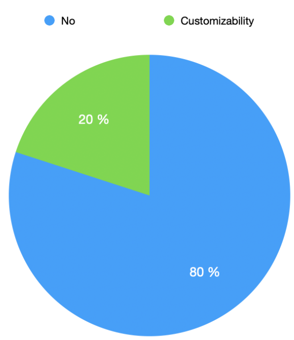
In conclusion, the familiarity and simplicity of a normal pill-box were acknowledged as potential advantages in specific contexts, but overall, the many advanced functionalities and easy-to-learn instructions of our product proved themselves to be far more developed and practical.



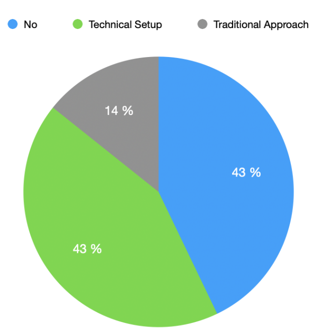
(a) Ratings for Questionnaire B



(b) Factors making someone choose pill-box



(c) Advantages that pill-box offers but SPO does not



(d) Is pill-box more familiar and why?

Figure 14: Result of the Questionnaire B

6 CONCLUSION

Experiencing the ever so often changing world, we humans are exposed to challenges to face almost all the time, potentially leading to stress or forgetfulness, following physical and mental overload. This makes concepts, that help us counter those problems even more important.

We tried to provide such one in the medical field, helping those, who are affected by health problems, maintain a fixed intake schedule of their medication using multi-modal notifications, as well as a fingerprint sensor to avoid third-party access.

By testing how users would incorporate the SPO and all its functionalities into their everyday life and how they would compare our device with an already existing, rather traditional one (i.e. normal pill box) with respect to different interactive fields, this study established that the SPO proved itself to be more favourable than classical approaches. Accompanied by strong preferences targeting the notification features thus effectively achieving the said purpose, participants also favoured the aspect of mobility in the form of the wristband. Though addressing the lack of familiarity, all in all, people were prepared to stray from the usage of traditional pill-boxes and agree on managing their medication via the SPO.

Future research into such medical-technological field should therefore focus on providing a stronger sense of familiarity, making smart pill dispensers, just as ours for instance, the default by bringing up more aspects to improve individuality. Whilst this study and project rather focused on functionality and utilization, it would be therefore also interesting to investigate, how new technologies can be best integrated into all kinds of social groups to counter mentioned challenges.

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APPENDICES

Questionnaire A: Everyday use of the product

Interactive Systems - Questionnaire

"Smart Pill-Organizer"(SPO)

Introduction

First of all:

Thank you for partaking in and agreeing to this questionnaire!

As the title already suggests, our project is supposed to assist people, that are required to take medications. The so called **"SPO"** consists of a **smart wristband**, that functions as a reminder for users when to take which medication in form of a LED light and a buzzer, that , in turn, displays a certain color, corresponding to the respective pill; and a **smart pill dispenser**. Via a **fingerprint-sensor,** the patient will be able to access the required drug, which will, after correct identification, be weighed on a scale, attached to the dispenser to assure the right dosage, that is supposed to be consumed.

Since we would like to **improve our view on the user's needs**, we have created a questionnaire, that we would like you, the "user", to fill out.

Questionnaire A

	4 - very likely/a lot	3 - more likely/a bit	2 - barely	1 - not at all
How likely are you to use the smart wristband?	☐	☐	☐	☐
Would you find it helpful to have a smart pill dispenser?	☐	☐	☐	☐
Do you believe that the LED lights and buzzer would remind you to take your medications at the specified times?	☐	☐	☐	☐
How comfortable would you be using a fingerprint sensor to access your medications?	☐	☐	☐	☐
Are you concerned about the accuracy of the scale?	☐	☐	☐	☐
How likely are you to recommend this project to others who require assistance with medication management?	☐	☐	☐	☐
How likely would you take the SPO with you, when leaving home?	☐	☐	☐	☐

Questionnaire A - Everyday use of the product

General Information

Name	
Age	
Gender	
Required Medication (Yes/No)	
If answered Yes: Pill Dispenser (Yes/No)	
If answered Yes: Schedule for Medication (Yes/No)	
If answered Yes: State the schedule (Optional)	

For the following questions, we would like you to write max. 2 sentences - preferably use bullet points	
Do you perceive any potential challenges or limitations in using the SPO?	
What features of the wristband and pill dispenser do you think would be most beneficial?	
Can you share a specific scenario or situation where you believe the smart wristband and pill dispenser would be particularly useful to you in your daily routine?	

Questionnaire B: Comparison to a normal pill-box

Interactive Systems - Questionnaire

"Smart Pill-Organizer"(SPO)

Introduction

First of all:

Thank you for partaking in and agreeing to this questionnaire!

As the title already suggests, our project is supposed to assist people, that are required to take medications. The so called **"SPO"** consists of a **smart wristband**, that functions as a reminder for users when to take which medication in form of a LED light and a buzzer, that , in turn, displays a certain color, corresponding to the respective pill; and a **smart pill dispenser**. Via a **fingerprint-sensor,** the patient will be able to access the required drug, which will, after correct identification, be weighed on a scale, attached to the dispenser to assure the right dosage, that is supposed to be consumed.

Since we would like to **improve our view on the user's needs**, we have created a questionnaire, that we would like you, the "user", to fill out.

Questionnaire B - Comparison to competitor

General Information

Name	
Age	
Gender	
Required Medication (Yes/No)	
If answered Yes: Pill Dispenser (Yes/No)	
If answered Yes: Schedule for Medication (Yes/No)	
If answered Yes: State the schedule (Optional)	

Questionnaire B

	4 - very likely/a lot	3 - more likely/a bit	2 - barely	1 - not at all
How likely are you to choose a normal pill-box over the SPO?	☐	☐	☐	☐
Rate the convenience and ease of use of a normal pill-box compared to the SPO	☐	☐	☐	☐
How likely are you to recommend the SPO compared to a normal pill-box?	☐	☐	☐	☐
Rate the level of customisation and personalisation offered by a normal pill-box compared to the SPO	☐	☐	☐	☐

For the following questions, we would like you to write max. 2 sentences - preferably use bullet points	
What factors do you think would make someone choose a normal pill-box instead of the SPO?	
Are there any specific advantages or conveniences that a normal pill-box offers that the SPO may not?	
Do you believe that a normal pill-box is more familiar and easier to use compared to the SPO?	
In what scenarios or situations do you think a normal pill-box would be more suitable or practical than the SPO?	