Potential Solution to the Problem of Medical Non-Adherence
The MediMemo Mobile Application
PBL Project 2019/2020, Summer

MediMemo Team:
T. Shahid (220993, 4TCS2), M. Skorupski (223949, 4TCS2), P. Wesoły (223953, 4TCS2),
Z. Łakomy (224077, 4S&T1)
Telecommunication and Computer Science
Lodz University of Technology, International Faculty of Engineering

June 17, 2020

Abstract

The goal of this project was to find a potential solution to the problem of medical non-adherence through the method of project based learning. We have created a team and developed its identity. We have first stated eight potential causes and then researched each of them. We have narrowed their number down to four. We have also conducted an online survey. We concluded that the most common causes of medical non-adherence that we could address are the ones related to mental state. Our target group would be the elderly. We have considered a few ideas. Our solution would be a mobile application connected with a box for storing medication. We performed a state of art analysis to establish their features. We verified our idea by conducting an interview. We wrote the prototype of the mobile application in Java, and we assembled the box using various electronic components and a plastic box. Our prototype received a positive review from a person from our target group.

1 Introduction

1.1 Background information

We were presented with a document describing several case studies of the phenomenon of medical non-adherence. The mentioned document also provided us with the source [1], to show that this problem is not limited to North America.

To work on this project, our group has formed into a team. We have established the structure of our team and chosen the leader and we have written a contract. Zofia Łakomy was to take the leadership for the duration of this project, Piotr Wesoły was to handle cooperation and making contact with people outside of the University. Muhammad Taha Shahid and Mateusz Skorupski were to tend to tasks appearing throughout the project, depending on who would be best suited to perform such the task. We established the identity of our team (Table 1). We wrote agendas and minutes for each meeting.

Table 1: Team identity details.

Type of identity element	Identity element
Name	MediMemo
Slogan	Motivation for medication
Mission statement	"To mitigate the issue that appears in all societies as medical care becomes available, the issue of medical nonadherence. Our objective is not only to alleviate this problem, but to do so in a humane and thoughtful way, with human health being the top priority."
Values	1. Compassion 2. Support 3. Integrity
Logo	

1.2 Problem finding

We started our analysis of the problem of medical non-adherence by identifying its potential sources. Each of us listed four potential sources, and, as each of us succeded with this task, we discussed and narrowed down the list to eight. The eight potential sources of medical non-adherence we listed were:

1) self-treatment,
2) lack of time,
3) lack of trust from the patient,
4) being unaware of the consequences of neglecting medical treatment,
5) discontinuing treatment prematurly,
6) using more or less medication than prescribed,
7) influence of other people,
8) not believing in the effectiveness of the treatment.

We have decided that each of us will research two of the listed problems, and the research will consist of analysing and writing a short summary of two research paper on each of the asssigned problems. If an appropriate research paper turned out to be impossible to find, reading a few articles on the internet and writing a short summary was sufficient.

We also conducted an electronic survey. We came up with the questions for specific groups of people we wanted to reach: general population, patients, nurses, medical doctors and students. Our survey consisted of the following questions:

1) General questions:

1.1) Have you ever ignored medical advice?

1.2) Have you ever chosen not to take prescribed medication?

1.2.1) If yes, why?

1.3) Do you believe that self treatment is more effective than one provided by a medical professional?

1.4) Have you ever stopped medical treatment before you were told it is safe to do so?

1.5) How often do you forget to take your medication over periods of time you are advised to take one?

1.6) How often do you forget to stick to the diet you've been recommended by a medic?

1.7) How often do you forget to guidelines regarding your daily life that you've been recommended by a medic?

1.8) What could stop you from taking prescribed medicine or following through with a medical treatment?

2) Specific questions:

2.1) Doctor:

2.1.1) Have you ever tried self-medication?

2.1.2) How often do your patients quit medical treatment without consulting you?

2.1.3) How often do your patients return after quitting the treatment?

2.1.4) How often are the consequences of stopping the treatment severe?

2.1.5) How often do you feel the patient would have difficulties with understanding the diagnosis and following your advice?

2.2) Nurse:

2.2.1) How often do your patients refuse to take medication?

2.2.2) Have you ever tried self-medication?

2.2.3) How often are your patients rude towards you?

2.3) Students:

2.3.1) Have you ever mixed medication with alcohol?

2.3.2) Can you always afford prescribed medication?

2.3.3) Have university matters ever conflicted with your medical treatment?

2.4) Patients:

2.3.1) Do you trust medical advice?

2.3.2) Have you ever tried self-medication?

2.3.3) Have your doctors been respectful towards you?

2.3.4) Do you feel like the doctors you visit care about your issues?

2.3.5) How often do you feel that your doctor has provided you with sufficient and comprehensible explanation?

As there was not sufficient amount of data available on self-regulating prescribed medication, we decided to look into the affordability of medication instead. The information about discontinuing medical treatment were taken from sources [2, 3, 4]. A patient's level of adherence drops when there is a lack of engagement or long lapses between communication with their healthcare providers. The information about the impact of the affordibility of medication on medical non-adherence were gathered from sources [5, 6, 7]. Many individuals with chronic illnesses have multiple medications prescribed that often are not covered by a third party, this can put a huge financial strain on them.

The influence of others was analysed using materials from [9, 10]. On forums, one can obtain a lot of information about side effects, not the effectiveness of the medicine. This can influence the patient's opinion and therefore their actions throughout the treatment. The lack of belief in the effectiveness of the treatment was researched using sources [11, 12]. Not believing in effectivness of treatment can be connected with fear of side effects. Nearly 55% of the elderly do not properly take their medications.

Self-treatment was researched using sources [13] and [14]. People who resort to self-treatment often have had an experience that shook their faith in medical professionals. They might have been prescribed a medicine that caused extremely unpleasant side effects or was ineffective. The lack of time factor was researched with the use of source [16]. The most frequent reason given for not taking medication properly is poor time management.

Lack of trust was researched using source [24]. Trust in the patient-doctor relationship is based around soft skills of the medical professional. The unawareness of the consequences of neglecting medical treatment was researched using the source [23]. Not adhering can stem from not being able to comprehend the instruction given by doctors. The instruction provided along with the purchased medicine can be ambiguous, too. When patients are supervised, they are more likely to follow through with the advice they received.

Out of each two causes, we picked out the one that seemed more significant. We mapped the assesed reasons on an Ishikawa diagram (Illustration 1).

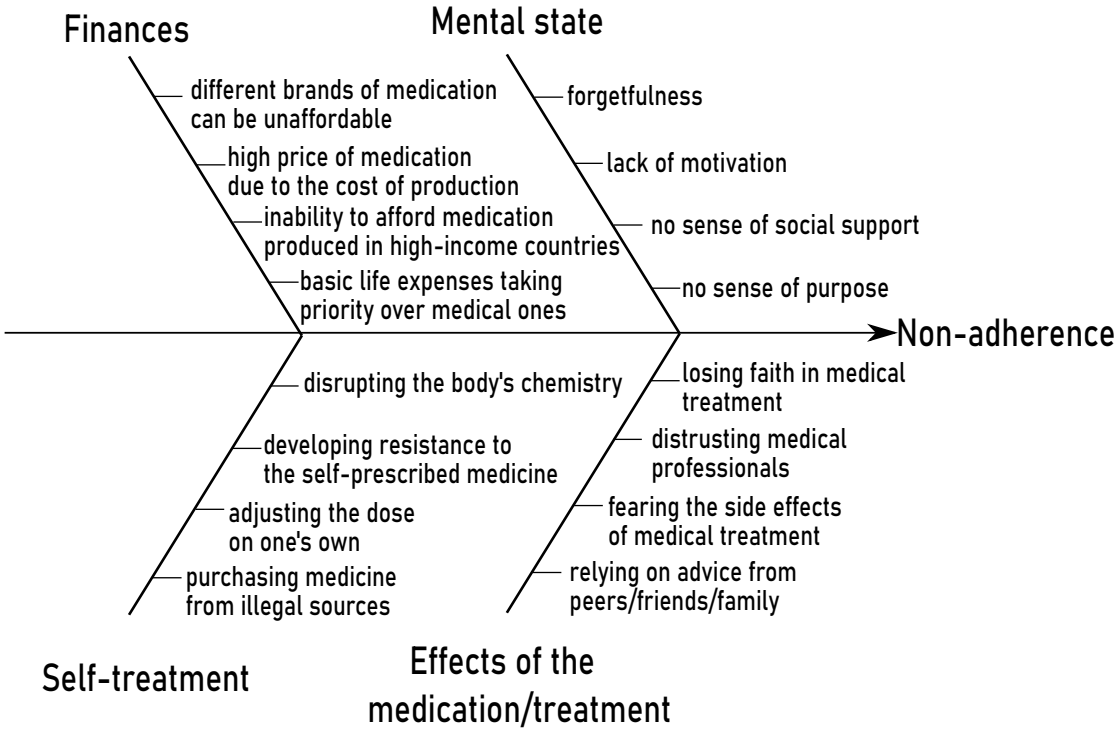

Figure 1: Potential sources of the problem of medical non-adherence depicted on an Ishikawa diagram.

Our survey was conducted in an electronic form (Table 2).

Table 2: The exact amount of samples in each category of our survey.

Language	General	Patients	Students	Medical Staff
English	34	26	23	7
Polish	81	74	71	7
Total amount of samples	115	100	94	14

Plots depicting answers relevant for our research are shown in Figure 2.

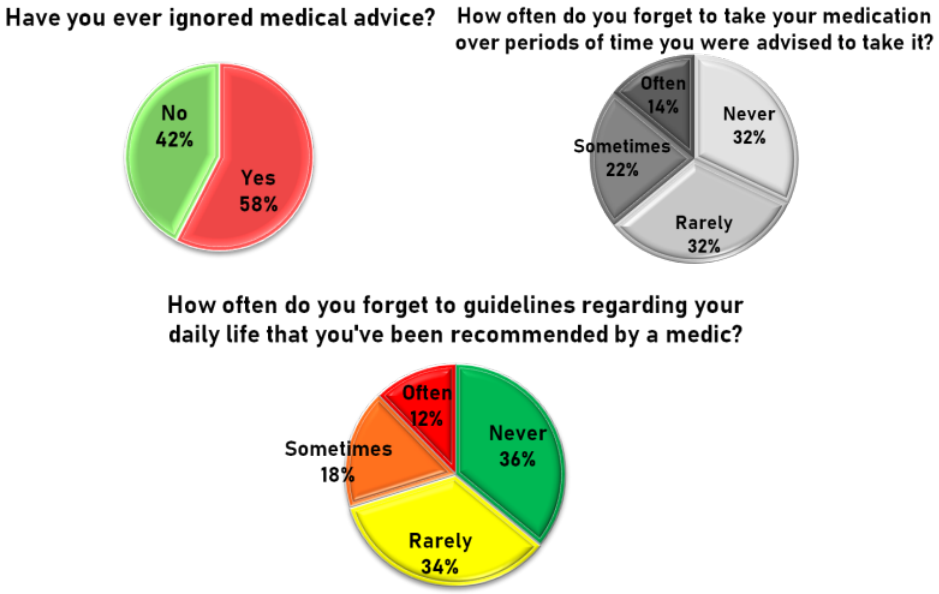

Figure 2: Plots depicting the answers relevant for our research.

After analysing the gathered data, we decided to address the mental state factor, as we cannot influence the medical staff, the governement or the pharmaceutical companies. We performed a stakeholder analysis (Figure 3), to highlight this fact.

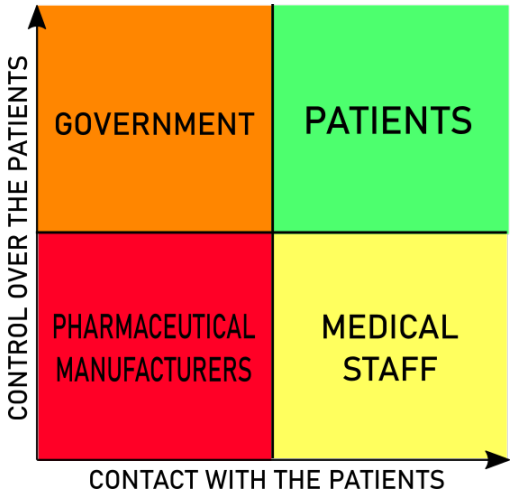

Figure 3: Our stakeholder analysis.

We decided that our target group would be people with chronic illness, mainly the elderly. To have a better idea of who we are designing our solution for, we constructed a persona (Figure 4).

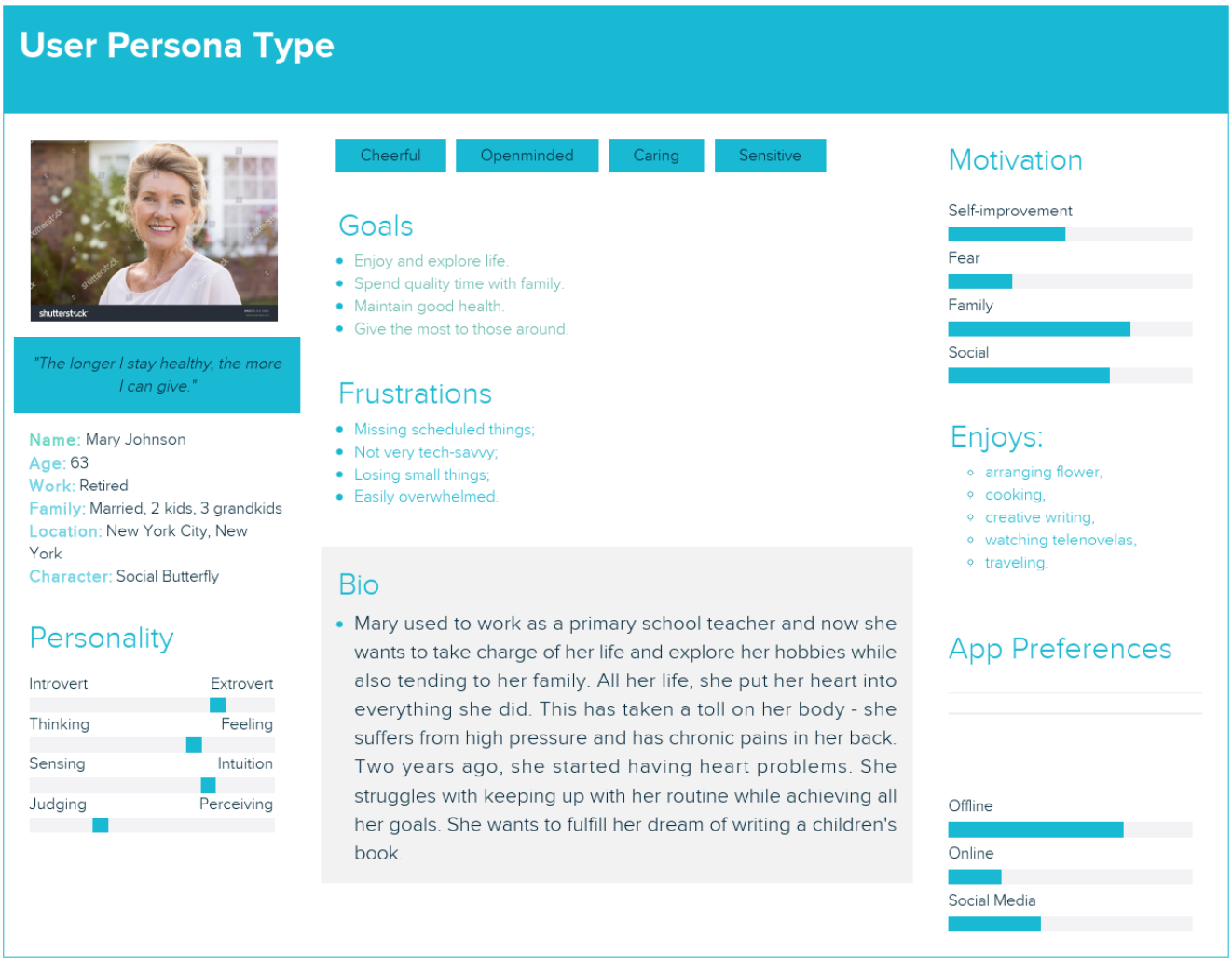

Figure 4: Our customer persona.

2 Idea finding

2.1 State of the art

To ensure the uniqueness of our solution, we researched products on the market that were similar to our final idea, a mobile application along with a box for medicine. We looked into the mobile applications that can assist the patient through the treatment. We analyzed the reviews given by the users and we chose three top-rated mobile applications to compare our product to. The information about what the available solutions lack would become the criteria for our solution to fulfill.

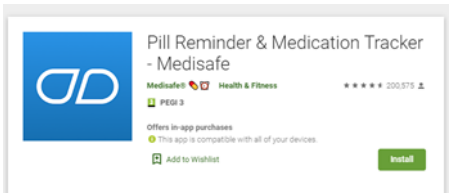

Figure 5: The Medisafe mobile application [18].

The application Medisafe (Figure 5) reminds about taking medication, getting a refill or it can keep track of medical appointments. It does have some faults, though. Firstly, it is not easy to navigate. People

find it difficult to schedule the alarms properly. It poses multiple questions when a scheduled event is missed. This can make people feel uncomfortable or annoyed.

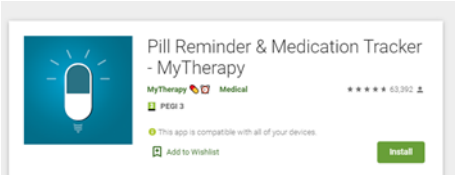

Figure 6: The mobile application MyTherapy [19].

The MyTherapy mobile application (Figure 6) reminds about taking medication and keeps records of the treatment. It can present collected data as a text document. The one thing it lacks is a calendar feature. It is difficult to see whether the medication was taken on a certain day or not. The schedule is hard to edit.

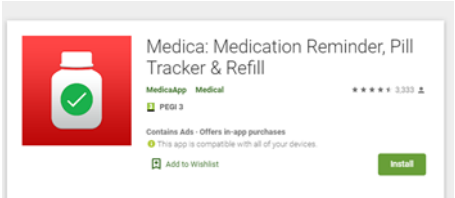

Figure 7: The Medica mobile application [17].

The Medica mobile application allows to schedule an unlimited number of medications and can create a medication report. It allows the user to attain some achievements when they take all of their medicine on time and it can be protected with a password. As for its pitfalls, it asks for too many permissions. If a permission is denied, it does not ask the user again, one has to go into the setting to use the application.

We also researched various medical containers that help the user adhere to the treatment. We chose three boxes for to analyse and compare our prototype to.

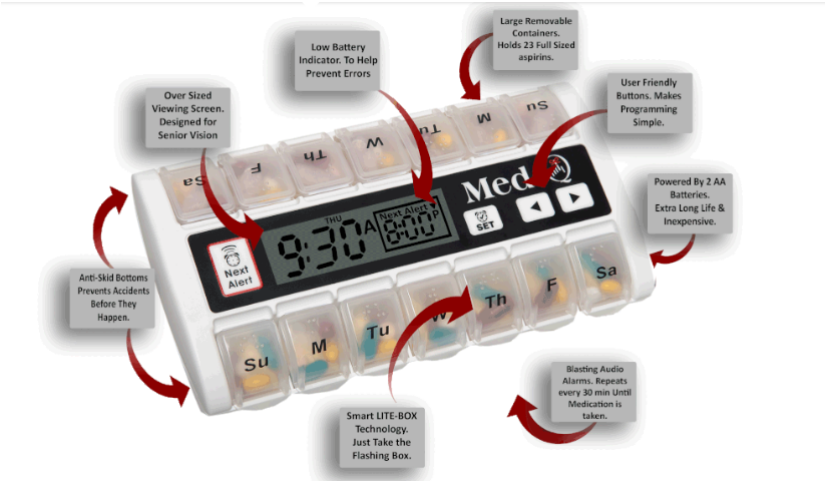

Figure 8: The Med-Q box [20].

The Med-Q-box (Figure 8) has compartments for different days of the week. It has a built in alarm clock and uses LEDs to indicate the correct compartment. A reminder can be set using the buttons on top of the box. Setting the reminders can be difficult, especially for different times, as the buttons are very small. Also, the compartments are not resizable.

Figure 9: The Med Smart-Plus box [21].

The Med Smart-Plus pill dispenser (Figure 9) can dispense the medicine at the programmed time. It reminds about the medication using a small light on top. It can send alerts about the medicine intake to the caretaker of the patient via text messages, an e-mail or a phone call. This device needs an active landline connection to work properly. It lacks a sound alarm. It can be programmed using the buttons and the display. It is also quite expensive, starting at $824.96.

Figure 10: The Med-e-lert box [22].

The Med-e-lert box (Figure 10) has a clock in the middle that can be programmed to remind that it is time to take the pill. Compartments are so small that it is so difficult to take out the medicine from them. One may spill all the pills trying to take one out.

Our solution does allow to program the box using the mobile application and our mobile application does have a calendart that displays the schedule of the user. It does not generate any report about the patient's progress and does not message anyone if the patients does not complete their routine. It is not protected with a password. While not all of these features could improve our application, as one of our goals was to make it simple and easy to use, it could be improved by implementing some similar features. Also, our box can be programmed only through the mobile application, there is no other option to do it.

2.2 Innovative ideas

Our first idea was to create a data base about various medicines. A lot of people do not read the information that are given on the leaflet that comes with their medication. The data base could give people easy access to important information about their medicine, but it would not solve the problem of forgetfulness. Also, it would be extremely difficult and time-taking to implement because of the amout of the information necessary.

Our second idea was to write a mobile application for doctors to connect with patients. The doctors to would supervise and communicate with their patients, in case of side effects, the patient could immediately contact the doctor. Unfortunately, it would cause the doctors a lot of work and, with a large number of patients, it would be difficult to implement.

Our last idea was a social media site for reminding each other about the medication and showing progress. The biggest advantage of this idea was that people with simillar problems could help each other. We came to the conclusion that the possibility to exchange data about medicines and their side effects without any input from a medical professional could lead to misinformation and, as a result, to medical non-adherence.

2.3 Main idea selection and justification

After rejecting the three initial ideas, we decided to think of a solution that would take advantage of modern technology, but also be easily accessible. Since our research lead to the conclusion that medical non-adherence is caused mainly by the lack of motivation and forgetfulness, our solution ought to address these issues. One of the ideas we came up with was a mobile application along with a box for medicine that would assist the patient throughout the treatment. They could be created in a way that meet the criteria that are crucial while working with our target audience – simplicity and availability, as the mobile application would not require an Internet connection to function once downloaded, and the box would need only Bluetooth connection.

We decided that a mobile application is a good idea, as in today's world most people use smartphones. An application could be handy, since most people carry their phones with them nearly all the time. As for the box for medicine, it would not be necessary to use the mobile application, but it is something that we could design with some of the things that available models lack.

We named our application "MediMemo". One of the key features of our application is a built-in schedule with a calendar. In this calendar, one can add events such as: "take medicine", where one states what is the name of the medicine, what kind of medicine it is and how frequently one has to take it, a medical appointment, where one can write the name of a doctor and the details about the appointment, or a different event. The added event will be displayed in the calendar so one can browse through them. The application will remind about them with notification. After the reminder goes off, the customer can state whether they took the medicine. This information is stored by the application. Customers can also choose to postpone an event if needed. Another feature of the application is a reward system. It will help the customers stay motivated. The customer can complete an achievement by attaining a specific goal. In the progress section, there is one general progress bar, displaying the overall progress, and some minor progress bars, that show the progress with individual activities.

The second part of our idea, the "MemoBox", is a box for storing smaller medications. Its compartments are resizable, the box is equipped with a power button and a buzzer. It also has a volume knob. It is not big, so it can be moved around easily. The top layer is removable, it can be easily taken out and cleaned. The box will be connected with the mobile application and, when it's time to take the medication, the box will make a sound alarm. To prevent people from taking the medicine from the incorrect compartment, we installed LEDs indicating the correct compartment. The box is powered by a 9 V battery, the battery can be easily replaced.

3 Solution implementation

3.1 Detailed solution description

Our solution is a combination of two ideas: the mobile application “MediMemo” and the medication box “MemoBox”. The application was writtren using Java Programming Language in Android Studio, since the majority of the world population uses android operating system [15] (Figure 11).

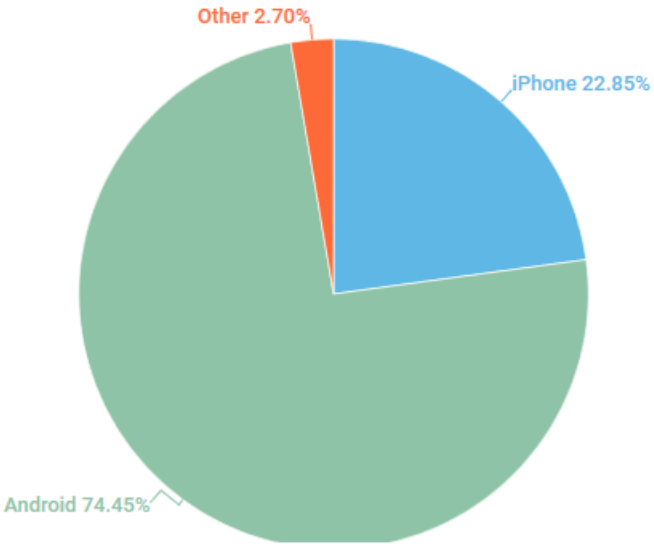

Figure 11: World operating system preferences [15].

We drew a diagram of the activites that we wanted to design (Figure 12).

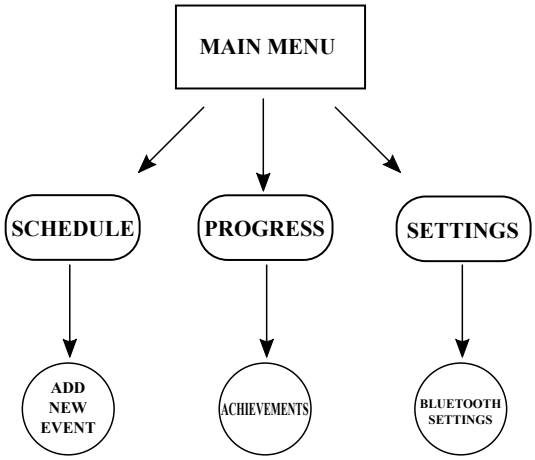

Figure 12: Diagram of the activities we intended for our mobile application to have.

The purpose of each activity:

Main Menu – the first activity shown after opening the application. The three buttons: “SCHEDULE”, “SETTINGS” and “PROGRESS” redirect to other activities. The buttons and the text are large, to facilitate navigation. Next to the buttons, there are large images, that indicate what button will get the customer to what section. Also, each of the buttons is of a different colors so it is possible to distinguish them even while having impaired vision.

Schedule – a calendar that shows the customer what events they have planned. Underneath the calendar, there are thee windows: Medication Alert, that shows customer the time at which they will be reminded of the medication; Doctor's Appointment, that can displays the timing of the upcoming medical appointment and Reminder, where an event of a different type than the two mentioned can be sheduled.

New Event – in this activity the customer will be able to add new events, such as what pill to take, when (date and time) and how many times per day. The customer can also add here the doctor appointments.

Progress – shows the overall progress that the customer has made throughout the treatment. The overall progress is displayed by the circular progress bar at the top of the screen. Underneath it, we can find progress bars for individual activities.

Achievements – here the customer can view their achievements that they have earned during the treatment. We also included a profile option, so that the customer can collect points and get promoted to the next level.

Settings – in this activity, it is possible to customize some features of the application, such as language and font size. It is also where one can mute the application, introduce their username, input emergency contact, as well as rate the application.

Bluetooth Settings – in this activity, the customer will be able to connect the application to the box using Bluetooth.

The screens of the activities in our application are shown in Figure 13.

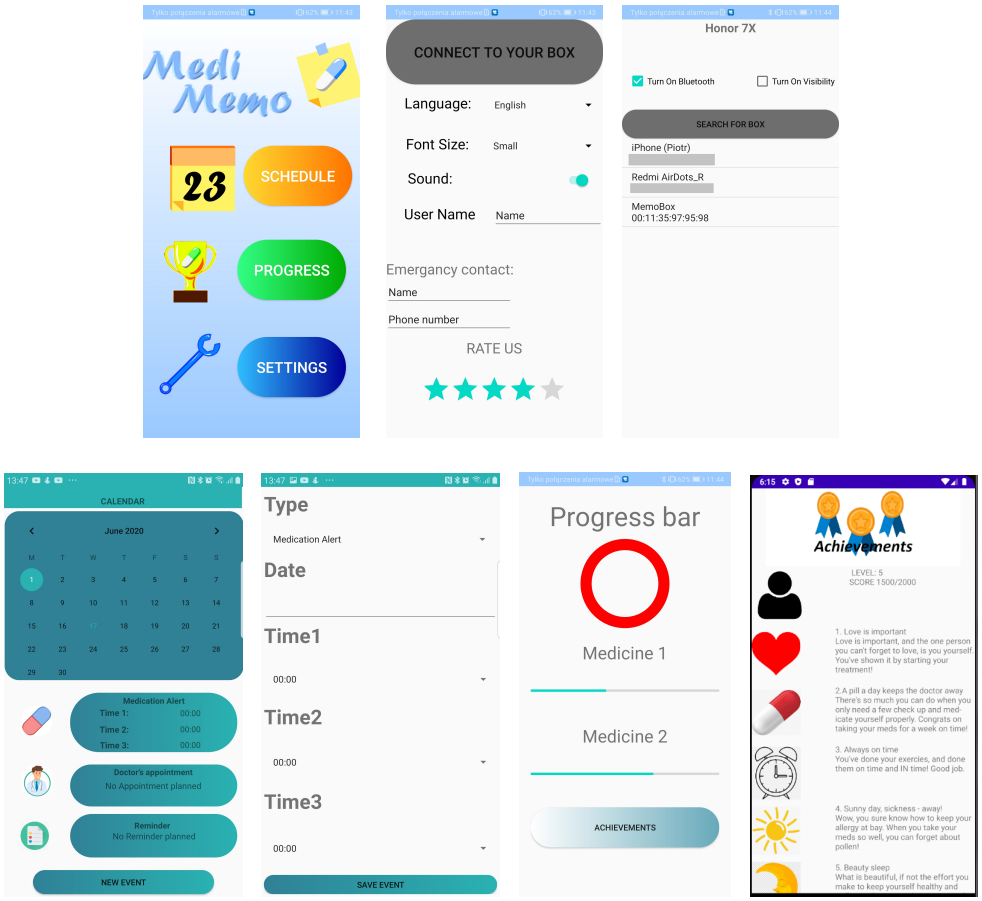

Figure 13: Screens from the working prototype of our mobile application: the main menu (top left), the settings screen (top middle), the Bluetooth screen (top right), the calendar (bottom first from the left), the "new event" screen (bottom second from the left), the progress screen (bottom second from the right), the achievements screen (bottom first from the right).

The application will be connected with the MemoBox. MemoBox reminds the customer about the medications using built in Light-Emitting Diodes (LEDs) and a buzzer. The box is also equiped with a potentiometer to allow regulation of the volume of the alarm, as well as a power switch.

We decided to use a box with two layers. The bottom layer is for the circuitry and the battery. The circuitry was arranged so the battery is easily accessible when one must replace it. The top layer is used to store medications, its dividers are removable, which allows the customer to adjust the number and the size of compartments. There can be up to 10 compartemnts at once. The top layer is also removable. The box is closed using plastic latch lock, to prevent its contents from spilling. A picture of the working prototype of our box is shown in Figure 14.

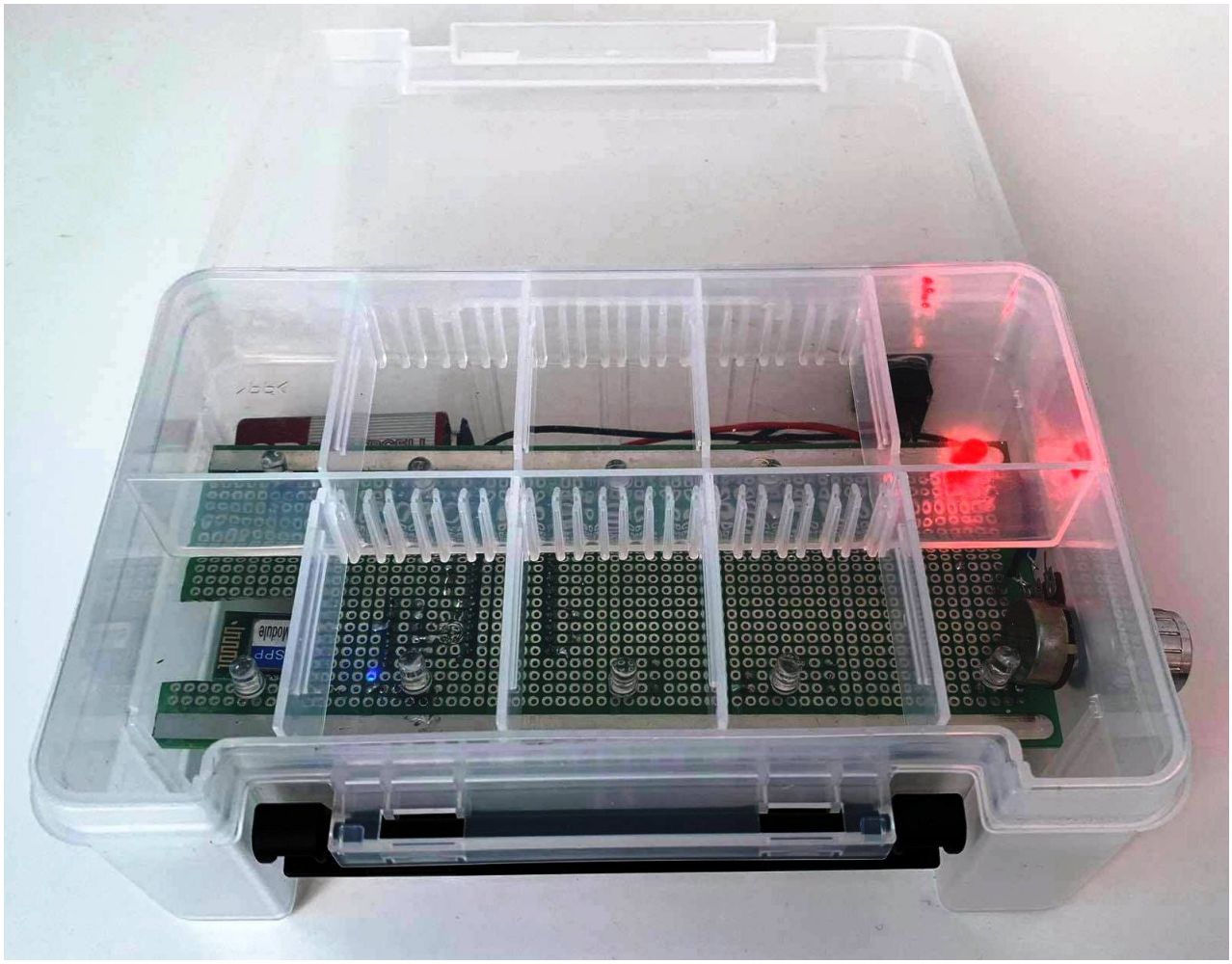

Figure 14: Working prototype of the MemoBox.

The internal circuitry consists of:
- ten red diffuse LEDs;
- ten 470 Ω resistors;
- an Arduino Nano;
- an XM-15 Bluetooth module;
- an UM-06 circuit board;
- a 5 V buzzer;
- an on/off switch;
- a 51 kΩ potentiometer;
- wires;
- a 9 V battery.

Layout of the circuit board is shown in Figure 15.

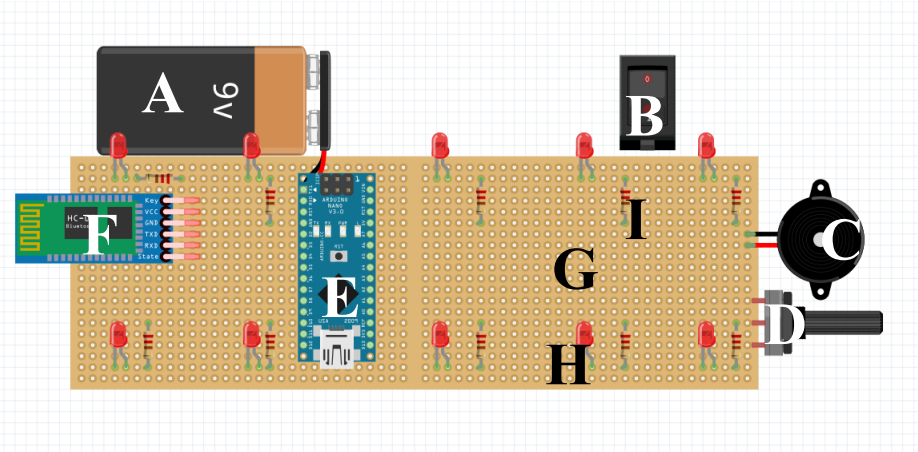

Figure 15: Layout of the circuit board: A – the 9 V battery, B – the on-off switch, C – the 5 V buzzer, D – the 51 kΩ potentiometer, E – the Arduino Nano, F – the XM-15 Bluetooth module, G – the UM-06 circuit board , H – a red diffuse LED, I – a 470 Ω resistor.

Figure 15 shows the layout of the components on the board. In order to hide all the circuitry from view, we placed most components on the bottom side of the circuit board and left LEDs on the top part for visibility. We cut off a part of the board, as the traces were blocking the XM-15's antenna. The connections of our circuit are shown in Figure 16.

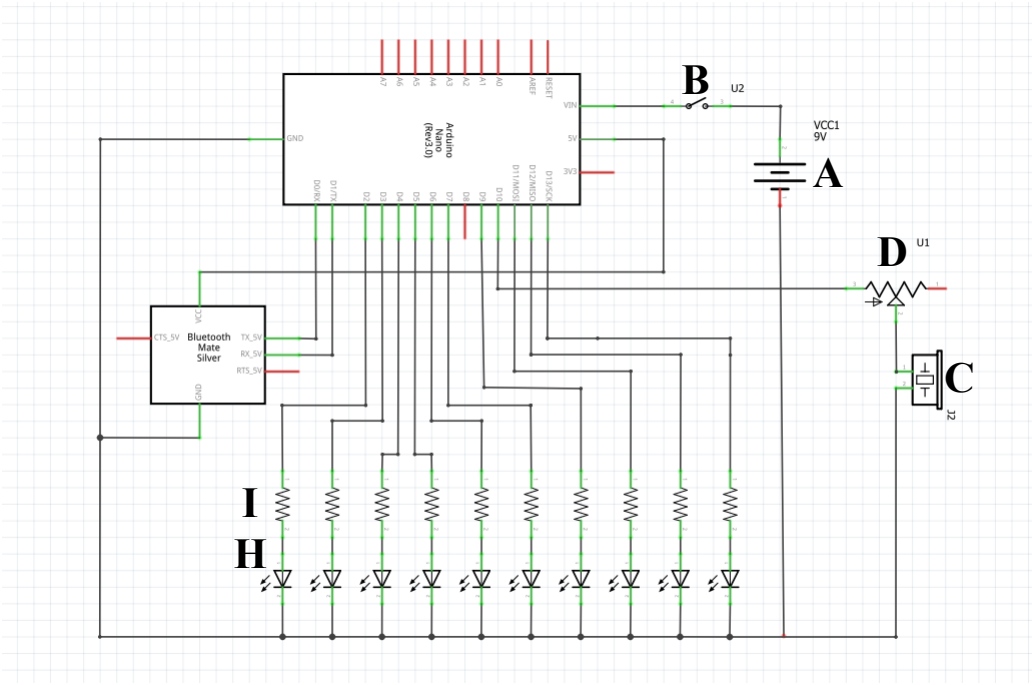

Figure 16: Connections of the MemoBox's circuit: A – the 9 V battery, B – the on-off switch, C – the 5 V buzzer, D – the 51 kΩ potentiometer, H – a red diffuse LED, I – a 470 Ω resistor.

3.2 Ways of verification

To check if our MediMemo application and MemoBox are indeed needed, we conducted an interview. We found an interviewee that belonged to our target group, an elderly man with heart-related health issues

that require long-term medication. During the interview, we presented our products and their features. Then we asked the interviewee if they would be useful for him:

- the application would be useful if he deemed he needed electronic assistance,
- the reward system would be motivating,
- a picture displayed along with the reminders could be motivating, but not necessarily,
- he would like to be able to see his progress through the treatment,
- he would like to share his progress with other people.

In the next step of verification we delivered a ready box along with the application to test to the same person that we interviewed earlier. Thanks to this, we found some important information:

- the light that is emitted by the leds is easily visible,
- the volume of the alarm is not too loud nor too quiet,
- the application is easy to navigate,
- there were no problems with connecting it with the box.

The interviewee stated that he would use the final product and recommend it to the people he knows.

4 Conclusions and perspectives

Our project was completed, despite the global pandemic of COVID-19. We had problems with buying some components and then working individually on separate parts of the mobile application. We had to learn a lot for this project, for example, how to use the Android Studio.

When we came up with the idea of making a pill dispenser and we researched the market, we found out that similar solutions exist already but we wanted to develop something even better. For instance, all the pill boxes that are available on market have to be programmed using the buttons on the screen. Considering our focus on senior members of society, many of them do not have much knowledge about technology and could get confused by a complicated device.

Our solution could still be improved. Some of our ideas for its further development include Braille letters on top of the box and a system to communicate with others within the mobile application, to show off one's progress.

Our solution got a positive opinion of a person from our target group. This means that it is headed in the right direction and, if introduced, could potentially alleviate the problem of medical non-adherence.

Bibliography

[1] https://cite.case.law/f-supp-3d/241/857/

[2] https://www.fda.gov/drugs/special-features/why-you-need-take-your-medicationsprescribed-or-instructed

[3] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3068890/

[4] Sabaté E, editor. , ed. Adherence to Long-Term Therapies: Evidence for Action. Geneva, Switzerland: World Health Organization; 2003. [Google Scholar]

[5] https://liquid-state.com/medication-management-leveraging-mhealth-apps/

[6] https://www.reuters.com/article/us-who-finance/one-billion-people-cannot-affordhealthcare- who-idUSTRE6AL1GV20101122

[7] https://www.ncbi.nlm.nih.gov/pubmed/7870659

[8] https://www.consumerreports.org/drug-prices/the-shocking-rise-of-prescription-drugprices/

[9] https://www.diabetesselfmanagement.com/blog/nine-reasons-people-dont-take-their-medicines/

[10] https://www.kevinmd.com/blog/2017/12/4-reasons-patients-dont-take-

[11] https://www.psychologytoday.com/us/blog/medicine-in-translation/201006/why-don-t-patients-take-their-meds

[12] https://medipense.com/en/top-10-reasons-seniors-do-not-take-their-medications/?__cf_chl_jschl_tk__=87bd124706e2ce11164f0586d47892ea0a99fc74-1584542836-0-AQoqLok0SJAm_4ol2tTqxwc65r2fUwzZCcv2KyB3ynRlg9WQ-5cMx30W1_LuMeFG0tM16_Klpo-2UrCaS7krzmmzj-vhIxs3mrSSiYbKGPTYzpzgzWQMNuXJYRwpAebO0KM53fJy3BGlOdrSRPz_uDdVX-BIHcLQjqoykDNKvJ4m5VH-cQC7cjHqP3D8qZ9-kvWi-IvyBONIf4vzgjjfm105pD11B5O58sgn9rzA0kF7XyeJ5uBlId2m59KLRP4sHgP5FZh3BQrtULmDKcM76hPWfvv47qOAIJ1TapJ2bD98H1GvPdGYYqgvljLQQGrSqE61LhPkrknwym6gCZAPceut4bknj6PV1uVsviQdnQSc

[13] https://www.researchgate.net/publication/304783901_Self-medication_A_major_cause_of_health_Issues?fbclid=IwAR02Kx3TzOPSICWuMTW2Xo8PkgdiWuJI7fJb_erRJDQAObNQDBqYBD4wbS0

[14] https://www.researchgate.net/publication/304783901_Self-medication_A_major_cause_of_health_Issues

[15] https://www.macworld.co.uk/feature/iphone/iphone-vs-android-market-share-3691861/

[16] https://www.healthdialog.com/blog/overcoming-barriers-medication-adherence-helping-patients-time-management

[17] https://play.google.com/store/apps/details?id=com.irwaa.medicareminders

[18] https://play.google.com/store/apps/details?id=com.medisafe.android.client&hl=en

[19] https://play.google.com/store/apps/details?id=eu.smartpatient.mytherapy&hl=en

[20] https://play.google.com/store/apps/details?id=com.irwaa.medicareminders&hl=enhttps://medqpillbox.com/

[21] https://www.epill.com/medsmartplus.html

[22] https://www.medelert.com/products/medelert-automatic-pill-dispenser-with-alarm

[23] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1661624/; Martin, L. R., Williams, S. L., Haskard, K. B., & Dimatteo, M. R. (2005). The challenge of patient adherence. Therapeutics and clinical risk management, 1(3), 189–199.

[24] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1495476/ ; Pearson, S. D., & Raeke, L. H. (2000). *Patients' trust in physicians: many theories, few measures, and little data.* Journal of general internal medicine, 15(7), 509–513. https://doi.org/10.1046/j.1525-1497.2000.11002.x