Design of a Device to Help Patients With Severe Mental Illness Quit Smoking

Mid-semester Report Spring 2013

BME 301
University of Wisconsin-Madison
Department of Biomedical Engineering

Team:
Scott Carson (Leader)
Gustavo Zach Vargas (Communicator)
Douglas Ciha (BWIG)
Paul Strand (BSAC)

Clients:
Joelle Ferron (Dartmouth College), and Mary Brunette (Dartmouth College),
David Gustafson (University of Wisconsin-Madison)

Advisor: Amit Nimunkar (University of Wisconsin-Madison),

Table of Contents

Acknowledgements

We would like to send a special thank you to our advisor, Professor Amit Nimunkar. This project would not be possible without his guidance. Another big thank you goes to Professor Michael Morrow, Professor Joseph Krachey, and Professor Marc Allie from the University of Wisconsin-Madison, whose invaluable knowledge of circuits has helped this project move forward. Our gratitude also goes out to Dennis Barr for helping with the case design, Caleb Durante for helping additional PCB design help. Finally, we would like to thank our clients, Professor Mary Brunnette, Professor Joelle Ferron, who are both from Dartmouth College, and Professor David Gustafson, an emeritus professor at the University of Wisconsin-Madison for the opportunity to work on this project.

Abstract

We propose a design for a system, called the Pack Pal, to help patients who are severely mentally ill quit smoking. The proposed system consists of a cigarette case and a smartphone application. The case is equipped with multiple sensitive tactile switch sensors. Another button will indicate an opening attempt and the tactile switch sensors will detect the number of cigarettes removed. Upon being accessed, the case interacts with the smartphone wirelessly via Bluetooth (v4.0), sending ASCII characters corresponding to sensor activation. Each time the user accesses the case; the smartphone application will take the data sent from the case and format it appropriately.

A copy of the formatted data will be reported weekly to the patient's healthcare professional. Data will also be available through the smartphone application in an easily accessible and understandable manner for the users so that they can monitor their progress throughout the quitting process. Overtime, the users will gain knowledge about their smoking habits and will be able to hold themselves accountable for their cigarette use. They will practice coping techniques (e.g., playing a video game, listening to music or engaging in another related activity), to deter them from smoking.

Problem Statement

The objective of this project is to design a case for holding cigarettes that is augmented to specifically help people with severe mentally illness (SMI) quit smoking. The case is called “Pack Pal”. It will house two trypes of sensors. The first sensor is used to detect if the user attempts to open the case. The second sensor will find out how many cigarettes are removed from the case after an access atempt is made. The data from access attempts will be continuously transmitted to a smartphone wirelessly. This is done via bluetooth (v4.0) as serial characters code for various responses to sensors. For example, character 'a', would represent access to the case. In this way, the smartphone will detect opening and closing of Pack Pal. Each time the user accesses the case, the phone application will ask the user a series of questions about his/her desire to smoke, the environmental or emotional cue that prompted the urge, and to rate the salience of the urge. Overtime, the users will gain knowledge about their own use and will then be able to use skills (aquired via the application) to cope with not having a cigarette. One of these skills could be to do something else (e.g., playing a video game, listening to music or doing another activity that the participants have indicated helps them avoid smoking), or to remind them of the reasons that they want to quit (e.g., the access attempts, opening and closing of Pack Pal, and displaying a picture of their child, pet or loved one). In addition, the application will send daily updates to the subject and/or to any clinician or provider the subject specifies.

1.0 Introduction

1.1 Background

Our clients for this project are Dr. David Gustafson, an emeritus research professor of Industrial and Systems Engineering, director of the Center for Health Enhancement Systems Studies at the University of Wisconsin-Madison and his colleagues from Dartmouth College, Dr. Mary Brunnette (MD), an Associate professor of psychiatry, and Dr. Joelle Ferron, an Assistant professor of psychiatry.

A major issue with mental health patients that is often improperly acknowledged is tobacco and/or drug addiction. The rate of cigarette smoking is much higher among people with severe mental illnesses than that of the general populace [3]; 45%–90% in the severely mentally ill (SMI) as opposed to only 20% in the general populace [2]. According to Dr. Ferron “approximately three-quarters of people with severe mental illnesses smoke cigarettes” [3]. Bridget Grant from the National Institutes of Health conducted a study to view the correlation between SMI (defined as DSM-IV Axis I and II disorders) and nicotine addiction. In an assessment of 43,093 subjects through face-to-face interviews, Grant determined that individuals with comorbid addiction and mental illness consume a large percentage of the total cigarettes consumed by the smoking population [5]. This statistics shows that cigarette addiction is not only more prevalent in the SMI but it is also a more serious problem in this group.

Individuals who are addicted to nicotine and suffer from SMI have more severe addiction. Individuals with SMI inhale more deeply per puff causing particularly harmful effects [3]. The cumulative effects of this severe smoking behavior cause death 25 years earlier in individuals with SMI (versus 14 years earlier in smokers in the general population) mostly due to cardiovascular diseases (generally caused by smoking) [4]. Individuals with Schizophrenia, a well studied SMI, have particular difficulty managing smoking. In fact, about 75% of people with schizophrenia smoke cigarettes.

Schizophrenia will be particularly focused on in this project because of the depth of research on this disease and because of the high overlap with nicotine addition. Schizophrenia is a major psychiatric disorder characterized by several breakdowns in normal brain function. These breakdowns are classified into positive and negative symptoms. Positive symptoms refer to symptoms that are not often experienced by persons without Schizophrenia. Positive symptoms include hallucinations both auditory and visual (though not very common), delusions and distinctive disorderly actions. Typical negative symptoms (those symptoms that are deficits of normal function) include lack of emotion, poverty of speech, lack of desire to form relations and inability to experience pleasure. Cognitive deficits are particularly distinctive of Schizophrenia these include disorganized speech and grossly disorganized behavior.

Smoking cigarettes is extremely harmful and causes 87 %of lung cancer deaths, and causes other forms of cancers and health problems, including lung disease, heart and blood vessel disease, stroke and cataracts (8). Higher rates of smoking in mentally ill people lead to particularly high rates of diseases caused by smoking, resulting in shorter life expectancy in this population (8). There is little doubt that smoking has many adverse impacts on one's health and that this problem is particularly prevalent in mentally ill people.

Quitting smoking is very difficult due to the strong psychological and physical addictions this habit creates. In the population of smokers who do not quit, nearly half will die of smoking-related problems. After quitting smoking, circulation begins to improve, and blood pressure starts to return to a normal, lower state. Short-term problems such as anxiety or irritability can occur when one tries to quit smoking (8). It is common for smokers to attempt to quit more than once and often to seek aid in the form of professional counseling and quitting programs because of the level of addiction smoking creates. The difficulty of quitting can be exacerbated by mentally illness.

Meanwhile, Dr. Ferron conducted an 11-year study in which followed 174 individuals with Schizophrenia and co-occurring substance abuse issues. 89% were smokers at the initiation of the study and 11 years later only 17% were not smoking. It is interesting to note that the sample did not use evidence proved methods to help quit including nicotine replacement and bupropion (3). This suggests that these treatments are inaccessible or unwelcome to the SMI (at least in individuals with co-occurring substance abuse problems).

Since smokers with severe mental illnesses often do not use traditional resources (to quit smoking), additional help and guidance may be necessary to aid these patients in quitting process. It has been determined that this disconnect between SMI smokers and traditional quit smoking resources is due to lack of interest (6,7), an inability to access resources (9) or other unknown reasons. Research shows that a tailored program for the mentally ill (designed and tested with the needs of the SMI in mind) struggling with addiction can improve the odds for individuals trying to quit (1,2).

In order to develop additional quitting resources, one needs to understand which resources are not used and why. Dr. Brunette also conducted surveys of websites dedicated to providing help quitting smoking (1). A team of five experts measured the usefulness (based on content) and usability of the first four hits from a Google search for quitting smoking. These sites were then presented to 16 SMI smokers who were observed and interviewed on the experience. A website that was navigable by the subjects was rated as lacking in content by the experts. One site that was rated highly by the experts in both categories was inaccessible to the subjects because they could not navigate the site to find information the experts had deemed essential in quit attempts. These results demonstrate that the SMI smokers may not take advantage of quitting resources because they cannot access them. In addition, it shows that what may seem accessible to experts is not necessarily accessible for the SMI smokers.

The prevalence of smoking in SMI smokers in conjunction with the inaccessibility of resources to this population calls for a more tailored quitting system. This system should be built from the results of the previous studies; e.g., Dr. Brunette's computer cessation aid. The system would be designed with information about how SMI individuals interpret information and be targeted toward reaching this under supported audience. The final goal would be to have a comprehensive program that assists SMI smokers in quitting ideally through constant (24 hours a day) monitoring and accessible information. A large gap in the research on this topic is why SMI people, in particular, turn to smoking and often develop addictions more than other members of the general populace. Several studies found that SMI people can use structured computer programs to aid in the quitting process (4). Additional research should be done to evaluate the usefulness of this type of additional treatment specific to the SMI smokers to help with quitting smoking.

1.2 Motivation

Research shows that SMI patients are willing to quit smoking. There are many useful quitting programs available for the general population, but there are no programs designed specifically for SMI patients. The Pack Pal acts as a coach for the user and also collects important data that aids the user in reaching their goals. The client has already received a grant and is applying to a few more with the goal of participant testing the Pack Pal this spring. Two team members will travel to Dartmouth College at the end of the semester to aid in implementation of the Pack Pal system.

2.0 Design Specifications

2.1 Case Requirements

The must be able to get through 8 hours of use without the need to be recharged. The case needs to sense two pieces of data: when the case is opened or closed, and the number of cigarettes that are removed from or added to the case. Finally, the case is required to wirelessly transmit the data to the smartphone.

2.2 Smartphone Requirements

The smartphone needs to analyze the data from the case. When the user attempts to smoke a cigarette, the smartphone needs to display countermeasures to discourage the smoking behavior. The phone could display a picture of a diseased lung, call family or friends for a distraction, or use social media for support. The phone will also record what triggered the urge to smoke and will rate the craving of the cigarette. The users will also be able to access weekly updates on how many cigarettes they have smoked that week to compare with other weeks.

3.0 Design Options and Alternatives

In order to meet the product design specifications, many design options were brainstormed and considered. Each aspect of the project had multiple routes for implementation, and each option had to be carefully analyzed. For the case, there were two main design aspects: sensing the presence of a cigarette and battery/power.

3.1 Cigarette Sensing

Accuracy and consistency of measurements in the cigarette sensing system are the two important factors that should be considered in the brainstorming process. It is necessary to have an accurate reading every time the cigarettes are checked and to have this reading be consistent between checking periods. Another issue is the size of the electronic circuitry and its power supply. In fact, the overall sensing system should be small enough to be conveniently housed into the final case. Therefore, the power consumption of the system needs to be carefully evaluated in order to select the smallest possible battery. Also, attempts should be made to minimize the number of components required to implement the electronic circuit.

3.1.1 Integrated IR LED and IR Sensor

In this design option, the IR LED and IR sensor are integrated together, forming a single detection system. The-system works under the principles of IR reflection and absorption. A schematic diagram of the cigarette handling in this system is shown in Fig. 1. As can be seen in this figure, each cigarette will have an accompanying sensor and LED. In the presence of a cigarette, the LED will transmit a light beam that reflects off of the cigarette, radiating back to the sensor where it can be read. Upon the removal of a cigarette, the LED will transmit an IR signal that is not reflected back to the sensor, indicating the absence of a cigarette.

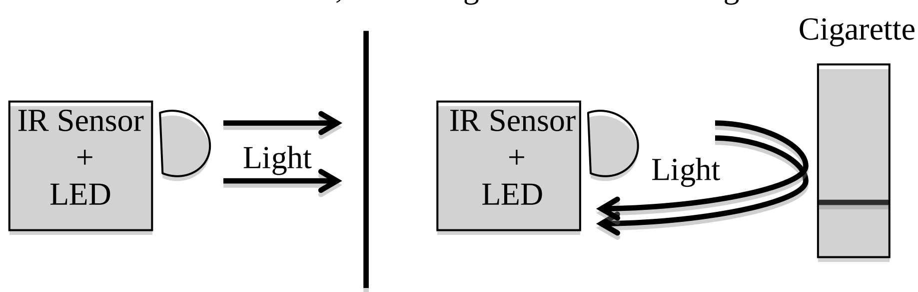


Figure 1. Cigarette handling in the integrated IR LED and IR sensor design; (a) without cigarette and (b) with cigarette.

3.1.2 Depressible Switch

In the second design option, the sensor consists of a push tab switch. They will be aligned in the case such that when a cigarette is deposited into a slot it is forced to depress the tab, as labeled in the following figure.

(a) (b)

Figure 2: (a) The tab that is depressed when a cigarette is inserted (b) and the direction of the force applied and the completion of the circuit..

Additionally, when the tab is depresses a circuit within the sensor is completed and a voltage change can be detected. Every time the case is opened or closed the microcontroller will determine which tabs are depressed and use this data to determine the number of cigarettes that were removed or added.

3.2 Battery/Power

Since Pack Pal is a portable electronic device, it will need to be battery powered. Reliability of the battery or batteries is very important for this device as well as the overall efficiency of the system. The battery unit should be cost effective to keep the price per unit at a minimum. Also, it is important to consider the cost imposed on the end user while brainstorming and comparing designs. Lastly, limiting the physical size of the battery unit is the key to fitting the whole system into a smaller space.

3.2.1 Replaceable Batteries

A power unit utilizing replaceable batteries is a simple design. It is cost effective for the development phase and prototyping; however, it is more expensive for the end user.

3.2.2 Removable Lithium-Ion Battery

The second design option considered was a lithium ion battery with an external charger. In this design, the battery would be removed each time the case needed to be charged. It is more expensive for the development phase and prototyping, but would save money for the end user.

3.2.3 Wall Charge Lithium-Ion Battery

In the third design option, a semi-permanent lithium-ion battery is utilized. In this option, the battery would always be in the case, only to be accessed if there is an error or the battery has greatly declined in charging performance. A wall-charger could then plug into the case and charge the battery much like a modern day cell phone.

4.0 Design Matrices

In each design matrix, the design traits were given different weights based on overall importance to the design. Each design option was then analyzed and given a score between one and ten for each trait. That value was then multiplied by the weight and then all of the scores were summed to produce the cumulative score. The design option with the highest score for each category was chosen as the design to pursue.

4.1 Cigarette Sensing System

In the evaluation of the design matrix for various cigarette-sensing systems, the reliability of the system in each case was considered to be the most important aspect of the design. The power consumption of the electronic circuitry was given the next highest weight due to its very important role in each design. Finally, the number of components and the ease of implementation were considered moderate factors. Results of the design matrix for various cigarette-sensing systems are summarized in Table I. From the results shown in Table I, it is concluded that the "Depressible Switch" design gained the highest score.

Table I. Design matrix for various cigarette-sensing systems

Design Factor (Weight)	Depressible Switch	Integrated IR/LED Sensor
Power Consumption (0.3)	3	0.6
Components (0.2)	1	1
Reliability (0.4)	3.6	3.6
Implementation (0.1)	0.8	0.4
TOTAL	8.4	5.6

4.2 Battery

For the selection of type of battery, the initial cost (development and prototyping) and long-term cost (for the end-user) were separated with the long-term cost given a slightly higher weight. Ease of implementation was considered to be the most important aspect of the design, followed closely by convenience. Convenience was defined by the case being operational during the battery replacement/charging period. Lastly, interaction was included to rate the amount the case would be handled during the battery replacement/charging period. Results of the design matrix for various types of battery are summarized in Table II. From the results shown in Table II, it is concluded that the "wall-charge Li" battery gained the highest score.

Table II. Design matrix for various types of battery.

Design Factor (Weight)	**Battery Type**		
	Replaceable Batteries	**Removable Li**	**Wall-Charge Li**
Initial Cost (0.1)	0.8	0.3	0.3
Long-term Cost (0.2)	0.4	1.6	1.6
Interaction (0.1)	0.3	0.3	0.8
Convenience (0.3)	1.8	0.9	2.4
Implementation (0.3)	2.1	2.1	1.5
TOTAL	5.4	5.2	6.6

5.0 Final Design

The final design of the Pack Pal system must integrate the electronic circuits with all the aforementioned sensors, switches, indicators, the Bluetooth module and other components into a handheld case. A preliminary SolidWorks model of the system can be seen below. The integrated depressible switch sensors will be used to sense the number of cigarettes in the case. In addition, there will be a LED indicator; to indicate the power level of the semi-permanent Lithium ion battery.

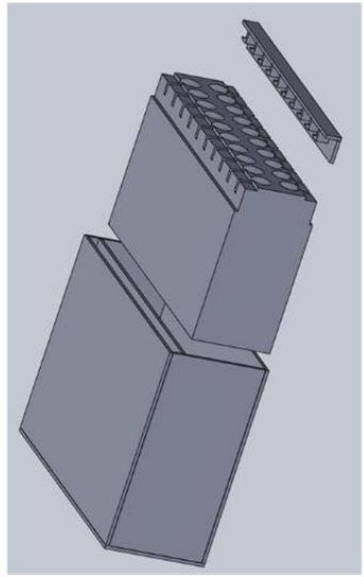


Figure 3. Solidworks model of the Pack Pal system.

The Pack Pal system will be controlled via a microcontroller, which will gather the data from each access attempt and send it wirelessly to the smartphone via the Bluetooth module. The system will be powered via a wall chargeable Lithium ion battery. The phone application will log data, analyze, and display it for the user and support contacts. The final design of the Pack Pal system will have to integrate all aspects of this design into a usable case while accompanying the smartphone application. A block diagram of the hardware components of the Pack Pal system can be found in Appendix A.5, Fig. A5-1 showing how all the aspects of the system will interact.

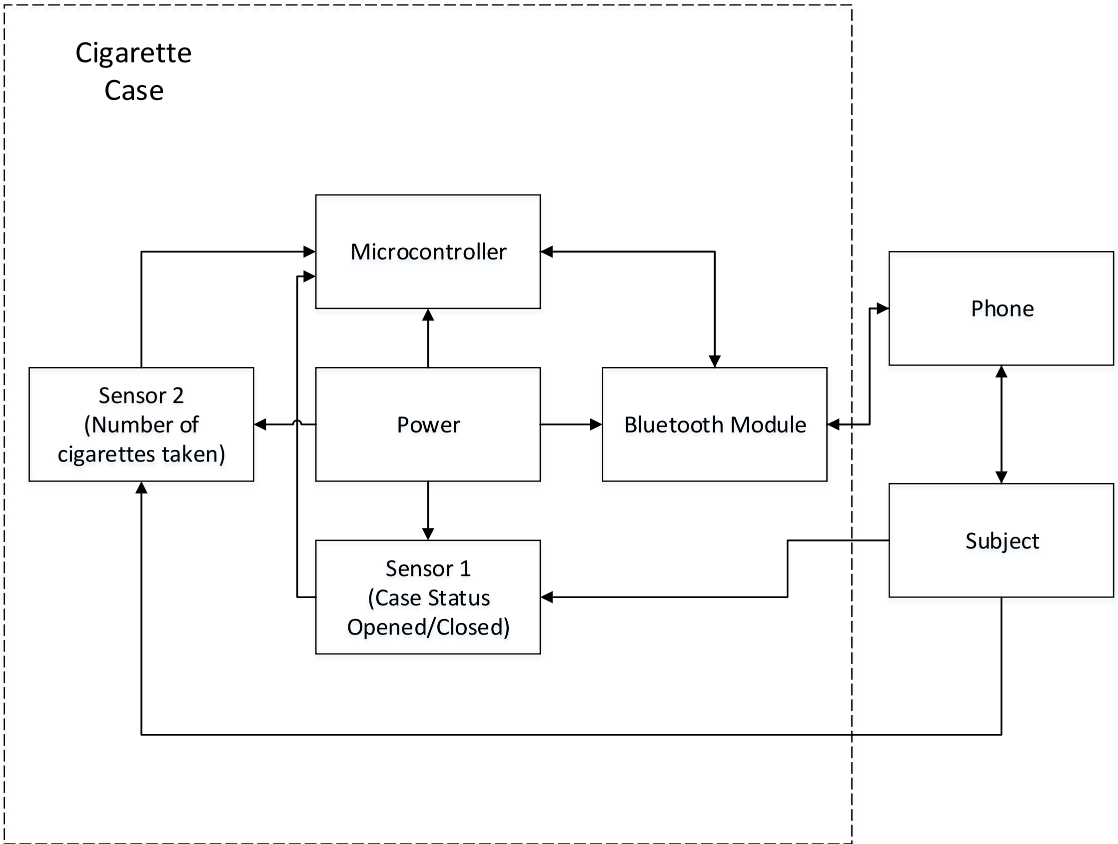


Figure 4. A block diagram of the hardware components of the Pack Pal System

5.1 Cigarette Sensing

The sensing of how many cigarettes are in the case will be accomplished via an array of depressible switch sensors. These sensors are electronic components called ESE31 each of which consists of a simple depressible switch with either an on or off designation. Technical specifications for these sensors can be found in Appendix A.1.

Transistors are used the design of the sensor circuit to aid in power consumption. A transistor can function as a digital switch, connecting a power supply to a component when it receives a signal. In this manner a much smaller signal can be used to trigger a much larger signal. This function allows for significant power saving. The Pack Pal system implements transistor switching to save power by only supplying power to the sensor array circuit for an instant just long enough to read the status of the sensors and then shut off.

5.2 Battery

The battery we chose to use has a 3.7V max and 2600 mAh capacity. Based off of the assumptions that the case will only be opened to remove cigarettes and thus will be opened a maximum of 20 times a day, the power requirements for Pack Pal usage was calculated to be 50 mAh per day. 50 mAh was determined by using .4 mA for each depressible tab sensor and 30 mA for the microcontroller. Because sensor determination only needs to occur for a fraction of a second, the power consumed is minimal. The Pack Pal has a theoretical battery life of 52 hours.

5.2.1 Battery Testing

A circuit was created using resistors that simulated the amount of power needed by the Pack Pal each hour. The battery was then set up to the circuit and allowed to discharge for 34 hours. The figure below shows the results of the discharge.

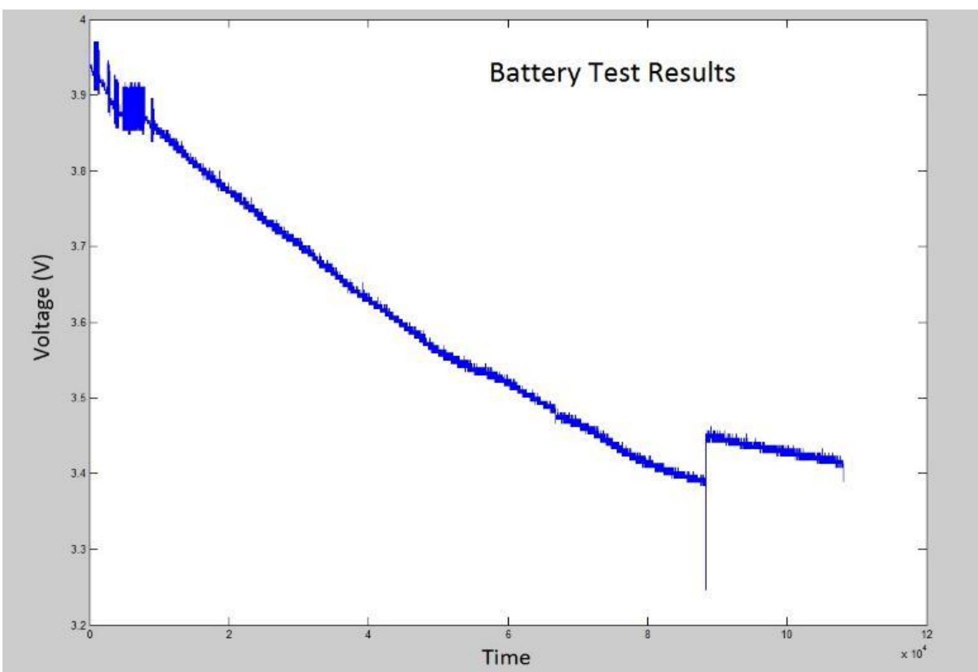


Figure 5: Battery testing performed for 34 hours using a pseudo Pack Pal circuit requiring the same amount of power.

The battery provided over the required 3.3V to run the microcontroller for the entire 34 hours except for one steep decline and rise. This has not been fully investigated but may be due to hardware issues with the circuit or data collection software and not the battery itself.

5.3 PCB Design

The Pack Pal system will require several electronic components working in conjunction with one another. The Pack Pal is designed to be a portable system with an onboard battery. As a result of these requirements, the circuit will need to be small and easily integrated into the case. These requirements led the team to decide that a printed circuit board would be needed to most effectively place these components in the case. The design of the printed circuit board (PCB) requires several steps including: component schematic design, overall circuit schematic connection, component footprint specification, PCB layout and connections between PCBs if there are multiple in the project. The team elected to use Altium, a software program for PCB design available through the University of Wisconsin Computer Aided Engineering facility.

Each component of a circuit has a specific schematic symbol that allows engineers to represent them in a simple, clear and effective manner. The schematic symbol of more complicated devices like a microcontroller involves the components pin-out diagram. The pin-out diagram of the component is a reference diagram that shows the relation between the physical layout of electrical connections and the function of each of these connections. Altium, the software program used by the team for PCB design, has many schematic symbols for a variety of different parts. However, some of the parts in the design were not available and thus had to be custom made.

Once all the components have schematic representations the electrical connections between these components must be drawn out in a schematic. Examples of some schematics are available in the Appendix A5.

In order to transfer schematics to a physical design, a physical model of each component must be designed. These models of the physical layout of components are referred to as the components footprint. Examples of some component footprints can be found in the Appendix section A5. These footprints and the connections established in the circuit schematic are then used to layout the PCB physical layout of connection and components on the board.

5.4 Microcontroller

All of the electronic components will be controlled by a microcontroller. The code for the cigarette-sensing demo can be found in Appendix A.9. The microcontroller will utilize interrupts to minimize overall power consumption and minimize code complexity. Interrupts help minimize power utilization by allowing the microcontroller to be in a sleeping state until an interrupt is received. This concept is the central part of the microcontroller code design. Once interrupted, the microcontroller will execute a function that locks the case for the specified amount of time and then allows the patient to access the cigarettes. It will then count the number of cigarettes taken after the case locks again and transmit this data to the smartphone application via Bluetooth. After the counting function completes, the microcontroller will return to sleep mode.

5.5 Application

The smartphone application is currently being developed for the Android platform. Android was chosen due to its accessibility from a developer's perspective. In the future, a corresponding application should be written for the iOS platform.
The main design consideration for the application is to create an easy to understand and easy to navigate user interface. This is how we are going to target the individuals with SMI. Having large buttons and explanative text will make the application accessible to these patients. All instructions will be very intuitive and tell the user exactly what they need to do.

Behind the scenes, this application will constantly be listening for data broadcast from the cigarette case. There are some concerns associated with this process constantly running in the background of the phone. First, having the Bluetooth adapter enabled uses a fairly large amount of power. This is an issue that is based largely on the hardware the phone runs on, however there are some ways to minimize the power consumed in software, such as saving the IP address of the case locally so that the phone does not have to always scan for the case when connecting. This alone limits the amount of power the Bluetooth adapter consumes by a large amount because scanning for Bluetooth devices is the most power-consuming function of the adapter.

Also, the app will have to register a Service with the host android device in order to continue running in the background, even when the Pack Pal application is not open. This enables it to continuously listen for Bluetooth transmissions from the case. A settings activity will also be implemented for the application that will let the researchers involved control some internal settings. These will be settings to control things such as the specific device to connect to, if it is the first time the application will be running, etc.

Finally, the application implements a Bluetooth handler that handles all incoming and outgoing Bluetooth transmissions. This class will handle everything related to Bluetooth including device discovery, connection and transmission. The purpose of this class is to asynchronously deal with the Bluetooth configuration and communication in order to let the UI remain responsive at all times. Screenshots of the UI and corresponding code is available in the appendices A.10.

6.0 Testing

For this portion of the project there was not significant testing involved in the area of data collection and analysis. Most testing done was in the form of hardware validation, verification, and debugging. For the microcontroller, testing of each pin used in the final prototype was done separately. For the analog input pins a known voltage was placed on the pin and read by the Analog-to-Digital converter (ADC). This made it simple to tell if the voltages were being read properly. The interrupt was tested by hooking a button up to the pin used to listen for the interrupt signal (p5) and attempting to trigger an interrupt. All other digital output pins were simply measured with the multi-meter to confirm they were outputting the correct voltage. The circuit was tested by reading the output of the IR sensors while covered and uncovered. This difference is what was used in the final microcontroller code to determine whether a cigarette was present or not. When the system was completely assembled, testing consisted of verifying the proper reaction to a button being pressed, multiple access attempts in a short period of time, the presence of a cigarette, and proper Bluetooth communication. If an issue was found, it was debugged and then tested again.

Additional testing on power requirements were also conducted. Battery testing was described in section 5.2.1 above. Testing of the sensors mentioned in section 3.1 above can be summarized in the table below.

Sensor	Power (mA) for one sensor	Power (mA) for 20 seonsors
IR LED and Phototransistor	11	201
Tactile Switch	.4	7.98

7.0 Conclusion

The development of the Pack Pal system involved several iterations and improvements. This system will provide an important service to individuals with mental illness who are addicted to nicotine because it will be a program tailored directly to their needs. The iterative process of design allowed the team to incrementally design each aspect of the design.

Currently the team is working to turn the functional prototype of last semesters model into a reality. This involves PCB design, building the physical case, writing the Android application and integrating all parts into in implementable product.

8.0 Future Work

8.1 Case Design

The physical layout and design of the case are finalized. Currently the team is working with an external company to create a physical prototype. The cigarette case insert that will hold the cigarettes should be 3D printed and the aluminum case will be milled.

8.2 Electronics

The preliminary prototype of the wire wrapped circuit can be seen in appendix A.4 and a final schematic diagram can be seen in appendix A.7. Finally after modeling the circuit for functionality and power behavior (battery life etc.) it can be sent for printed circuit board (PCB) printing. This PCB version of the circuit will be much smaller and can be fitted inside the completed case. The preliminary PCB design can be seen in appendix A.7.

8.3 Application

The application is currently under development. The user interface is almost completely implemented; however there is still some work that needs to be done. Connecting to the Bluetooth transmitter (WT-32) is the major focus at this point. After this is successfully implemented, the code that constantly handles the Bluetooth communication will be employed. Finally, data storage, settings and final adjustments will be made.

9.0 References

1. Brunette, Mary, Ferron, Joelle, Devitt, Timothy, Geiger, Pamela, Martin, Wendy, Pratt, Sarah, Santos, Meghan, &McHugo, Gregory (2011). Do smoking cessation websites meet the needs of smokers with severe mental illnesses? *Health Education Research* Vol.27 no.2 2012. Retrieved May 20, 2012.

2. Brunette, M., Ferron, J., McHugo, G., Davis, K., Devitt, T., Wilkness, S., & Drake, R.. (2011). An Electronic Decision Support System to Motivate People With Severe Mental Illnesses to Quit Smoking. *Psychiatric Services,62*(4), 360-6. Retrieved May 20, 2012, from Psychology Module. (Document ID: 2312884271).

3. Ferron, J., Brunette, M., He, X., Xie, H., McHugo, G., & Drake, R.. (2011). Course of Smoking and Quit Attempts Among Clients With Co-occurring Severe Mental Illness and Substance Use Disorders.*Psychiatric Services,62*(4), 353-9. Retrieved May 20, 2012, from Psychology Module.

4. Ferron, J., Brunette, M., McHugo, G., Devitt, T., Martin, W., & Drake, R.. (2011). Developing a Quit Smoking Website That is Usable by People with Severe Mental Illnesses. Psychiatric Rehabilitation Journal 2011, Volume 35, No. 2, 111–116. Retrieved June 6, 2012.

5. Grant BF, Hasin DS, Chou SP et al. Nicotine dependence and psychiatric disorders in the United States: results from the National Epidemiologic Survey on Alcohol and Related Conditions. Arch Gen Psychiatry 2004; 61: 1107–15.

6. Lucksted A, Dixon LB, Sembly JB. A focus group pilot study of tobacco smoking among psychosocial rehabilitation clients.PsychiatrServ 2000; 51: 1544–8.

7. Morris CD, Waxmonsky JA, May MG et al. What do persons with mental illnesses need to quit smoking? Mental health consumer and provider perspectives.Psychiatry Rehabilitation Journal 2009; 32: 276–84.

8. National Cancer Institute. Smoking. Retrieved June 5,2012 from http://www.nlm.nih.gov/medlineplus/smoking.html.

9. Weinberger AH, Reutenauer EL, Vessicchio JC et al. Survey of clinician attitudes toward smoking cessation for psychiatric and substance abusing clients. J Addict Dis 2008; 27:55.

10. North, Dug. Geneva Mechanism or Maltese Cross 4/28/2008; Accessed 12/1/2012 http://blog.dugnorth.com/2008/04/geneva-mechanism-maltese-cross-or.html.

10.0 Appendix

Appendix A.1:
Technical Specifications of Panasonic ESE-31 switch

Features

- Increased the mounting strength Mounting strength: 80 N
- Decreased the profile of the switch body Height: 1.7 mm
- Increased the contact reliability and lifespan.
- Lifespan: 100,000 operations or more

Recommended Applications

- Detection of media in portable electronic equipment

Specifications

- Rating 50 µA 3 Vdc to 10 mA 5 Vdc (Resistive load)
- Contact Resistance 500 m max. (Initial)
- Insulation Resistance 100 M min. (100 Vdc)
- Dielectric Withstanding Voltage 100 Vac for 1 minute
- Operating Force 390 mN max.
- Mounting Height 1.7 mm
- Poles and Throws 1-pole 1-throw
- Full Travel
- (Pushing distance) 3.2 mm (2.15 mm)
- Operating Life 50000 cycles min.
- Temperature Range –10 °C to +70 °C
- Heat Resistance +85 °C for 96 hours
- Low Temperature Resistance –40 °C for 96 hours
- Humidity Resistance +60 °C 90 % to 95 % RH for 96 hours
- Minimum Quantity/Packing Unit 2500 pcs. Embossed Taping (Reel Pack)
- Quantity/Carton 15000 pcs

Appendix A.2:

Pack Pal Design Specifications

Client: Prof. Ferron, Prof. Brunette, Prof. Gustafson
Advisor: Dr. Nimunkar
Team:
R. Scott Carson *rscarson@wisc.edu* – Team Leader
Gustavo Zach Vargas *gzvargas@wisc.edu*–
Communicator
Douglas Ciha ciha@wisc.edu- BWIG
Paul Strand pstrand@wisc.edu- BSAC
Date: March 2, 2013

Device Function

The Pack Pal is system that will use a smart cigarette in combination with an Android Smartphone application to help people with severe mental illness(SMI) quit smoking. The case will house a sensor to detect when the case is accessed or closed as well as the current number of cigarettes in the case. The date obtained from these sensors will then be communicated via Bluetooth (v4.0) to the Smartphone as serial characters that are coded for the state of the case, open/closed, and the amount of cigarettes it contains. The phone reads in this data and each time the user accesses the case, the phone application will ask the user a series of questions about their desire to smoke, the environmental or emotional cue that prompted the urge, and to rate the salience of the urge. Overtime, the user will gain knowledge about their own use and will then be able to use skills (acquired via the application) to cope with not having a cigarette. The application will assist in the user in choosing not to smoke by deploying counter measures when the case is accessed such as other activities like the option to play a video game, listen to music, or do any other activity that the participant has indicated helps them avoid smoking, or to remind them of the reasons that they want to quit (display a picture of their child, pet, or loved one). In addition, the case will send daily updates to the subject and/or to any clinicina or provider the subject specifies.

Client Requirements

- The case should be difficult to break and hold at least 20 cigarettes (should be modeled after the cases in current use).
- The case should have an onboard rechargeable battery.
- The system should interact (can be through application) with the user to help track behaviors, beliefs, and urges around smoking and support coping skills.
- The application should prompt the participant to engage in coping skills to delay and reduce smoking.
- The device and the application should be easy to use, with a simple opening/closing mechanism, uncluttered interface on the application, simple text, minimal layers of navigation, minimal requirements for abstract thinking and memory.
- Five working prototypes must be completed in Spring 2013.

Design Requirements

Performance requirements:

The device is required to be augmented for daily and frequent use. Severely mentally ill patients may attempt to access it in different time delays that vary from few minutes or sometimes few seconds in the case of severe addiction to few hours in less severe cases.

Safety:

The cigarette case should be developed for mentally ill patients so it should be totally safe and free of warnings because we cannot rely on the patient to take precautions.

Accuracy and Reliability:

The case should record and send reliable data about the access times the opening of the case and the number of cigarettes taken because this information can lead to faulty interpretations if it lacks accuracy.

Life in Service:

This case should serve the patient for the whole period of the treatment and remain useful after the treatment is done for future uses. It should work in different countries and operate 24/7 but the battery needs to be recharged every 8 hours.

Shelf Life:

The battery that is included in the case should be a rechargeable battery for efficiency and ease of use and also because it is more environmentally friendly.

Operating Environment:

The cigarette case must adapt to different working environments. It can be exposed to different temperatures and different humidity ranges. It can also be exposed to dust, vibrations and accidental hits. We have to make sure that the accuracy of the data is not affected by those factors.

Production Characteristics

Quantity:

We should have five devices for the research purpose.

Target product Cost:

The cost of this cigarette case will be higher than the cost of a normal cigarette case but has to be within the limits of the clients grant limitations.

Miscellaneous

Patient-related concerns:

The patients we are dealing with are mentally ill patients so extra considerations should be taken into account regarding the system so it is tailored to the needs of the users. The collected data should be confidential and provided only to a specified mentor, clinician and a system administrator.

Appendix A.3:
Solid Works model of the Pack Pal system

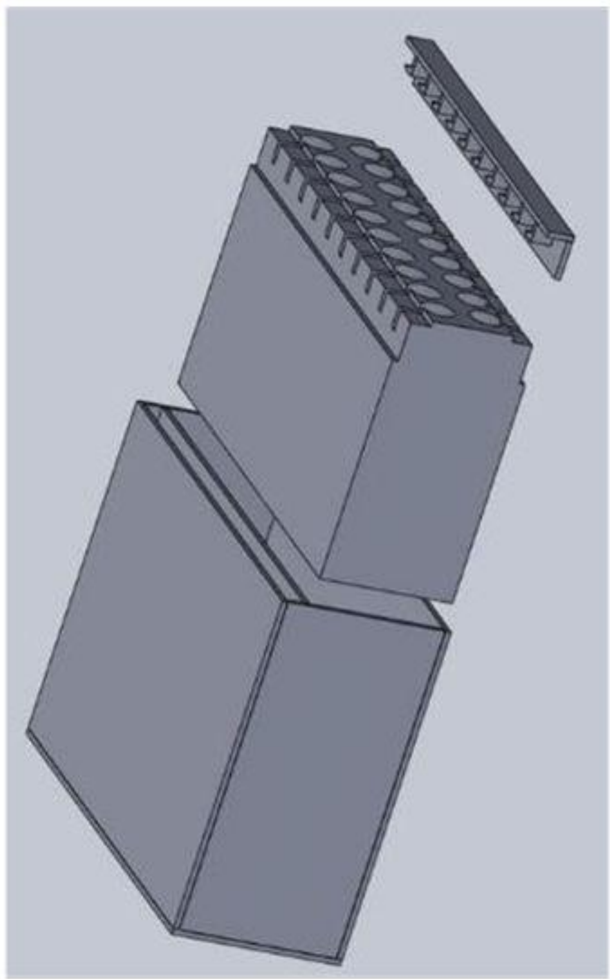


Fig. A3. A Solid Works model of the Pack Pal system.

Appendix A.4:
Breadboard Circuits

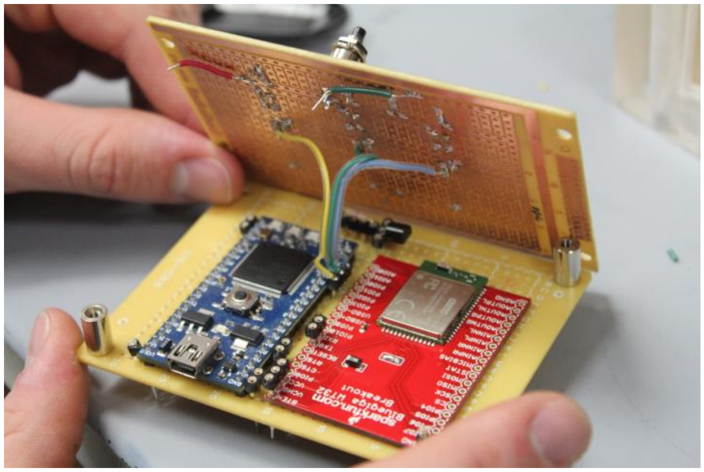


Fig. A4. A picture of the breadboard mounted electronic circuitry of the Pack Pal system.

Appendix A.5:
PCB Design

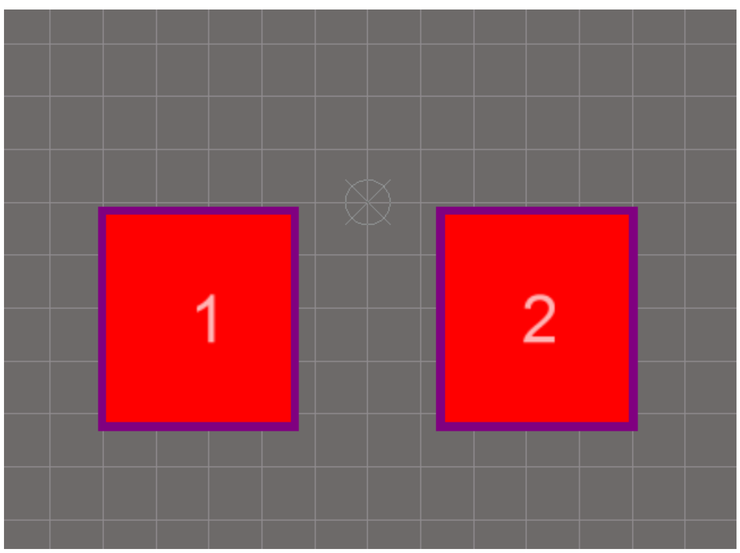


Figure A.5.1 Custom Footprint for Panasonic ESE-31

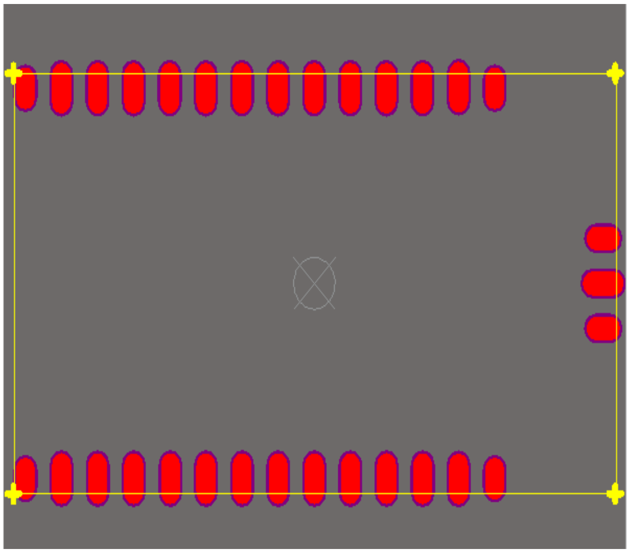


Figure A.5.2 Custom Footprint for Panasonic WT-12 Bluetooth module

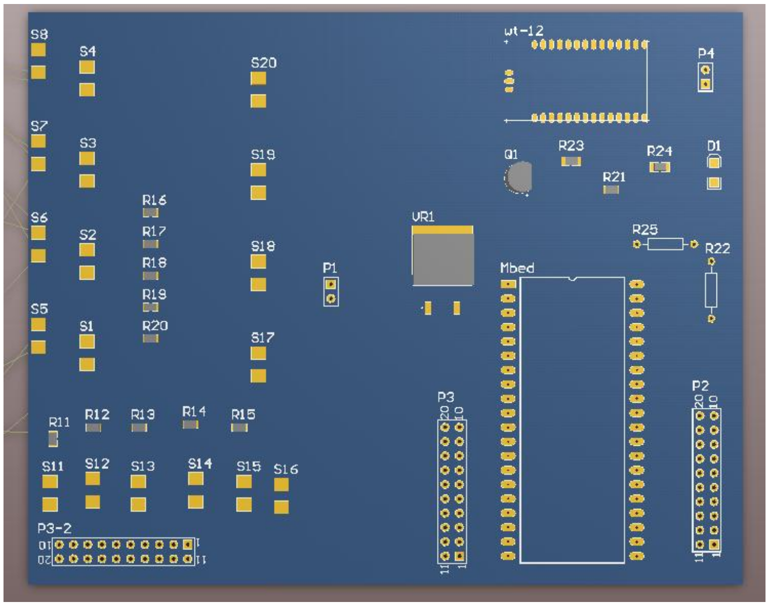


Figure A.5.3 A preliminary board layout for the PCB

Appendix A.6:
Block Diagrams

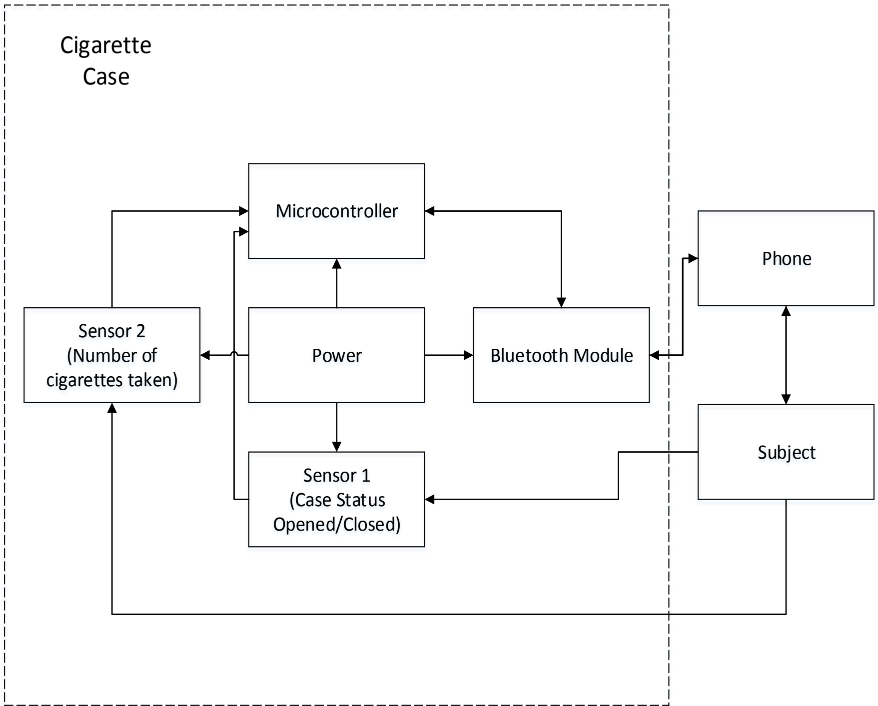


Fig. A6.1 A block diagram of the hardware modules of the Pack Pal system.

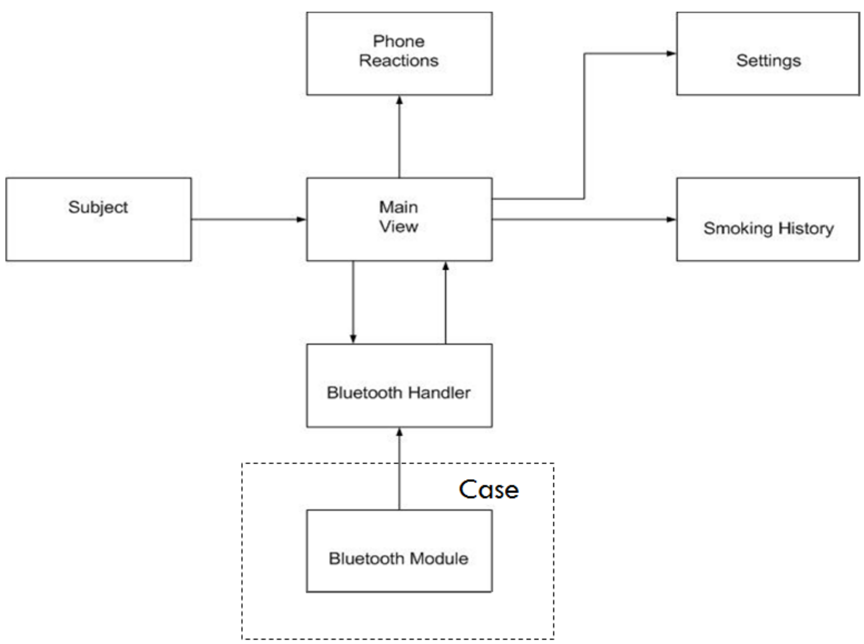


Fig. A6. A block diagram of the software modules of the Pack Pal system.

Appendix A.7:
Schematic of the electronic circuits

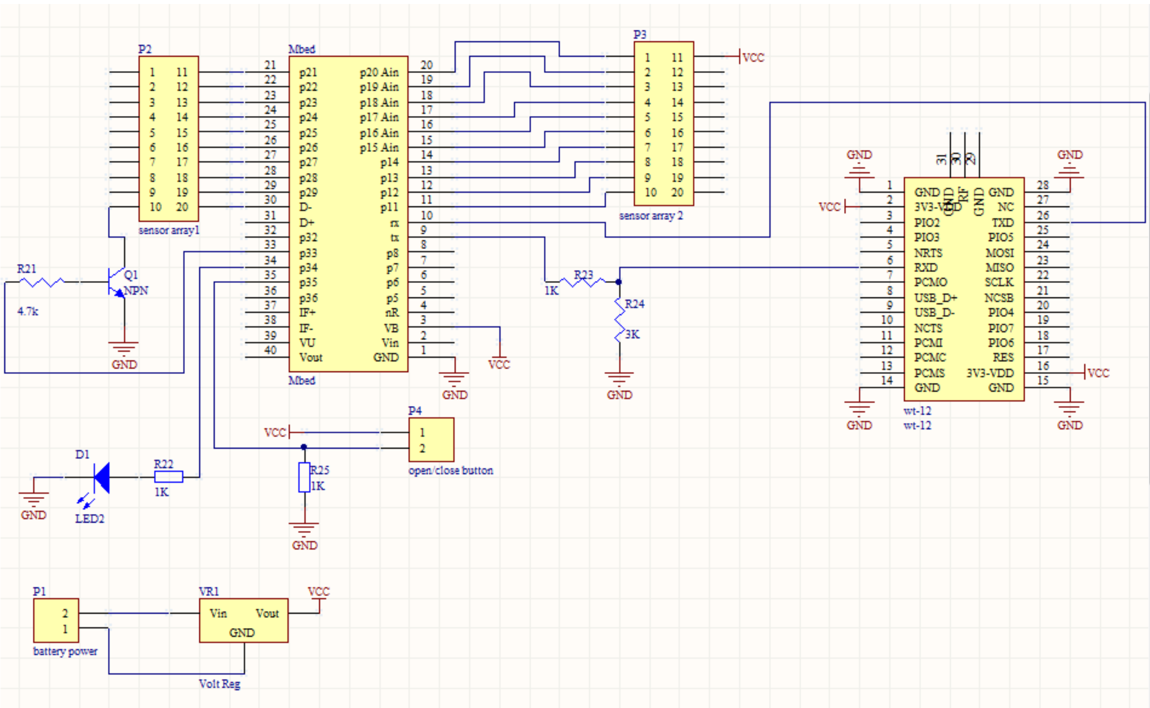


Figure A.7.1: A schematic of the main PCB.

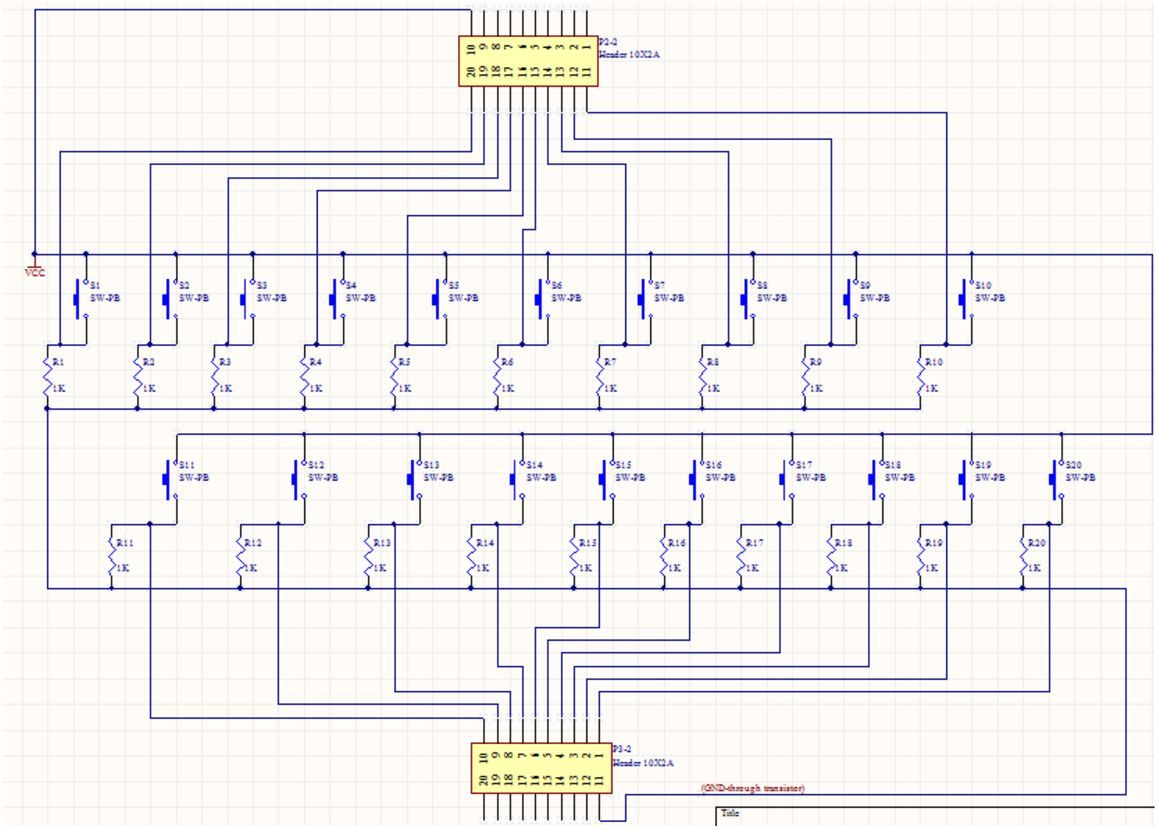


Figure A.7.2: Schematic of the sensor array including 20 switches(A.1).

Appendix A.8
Demo Microcontroller Code

```
#include "mbed.h"

void case_opened();  // Declare interrupt service routine for opening the case.
void case_closed();  // Declare interrupt service routine for closing the case.
void opened_alert();    // Delcare routine for alerting the mobile device to the case being
opened.
void closed_count();    // Declare routine for sending the number of cigarettes in the case
once it has been closed.
bool enable;    // Declare enable (interrupt lock) bit.

InterruptIn case_switch(p5); // Delcare pin 5 as the case open or closed interrupt.
DigitalIn case_poll(p5); // Also declare pin 5 as a digital input for polling.
DigitalOut sensor_power(p35);   // Delcare pin 35 as the power output to the sensors.
// Declare each of the twenty cigarette sensors and place them in an array.
DigitalIn sensor0(p8);
DigitalIn sensor1(p14);
DigitalIn sensor2(p15);
DigitalIn sensor3(p16);
```

```
DigitalIn sensor4(p17);
DigitalIn sensor5(p18);
DigitalIn sensor6(p19);
DigitalIn sensor7(p20);
DigitalIn sensor8(p21);
DigitalIn sensor9(p22);
DigitalIn sensor10(p23);
DigitalIn sensor11(p24);
DigitalIn sensor12(p25);
DigitalIn sensor13(p26);
DigitalIn sensor14(p27);
DigitalIn sensor15(p28);
DigitalIn sensor16(p29);
DigitalIn sensor17(p30);
DigitalIn sensor18(p33);
DigitalIn sensor19(p34);
DigitalIn sensors[20] = {sensor0, sensor1, sensor2, sensor3, sensor4, sensor5, sensor6,
sensor7, sensor8, sensor9, sensor10,
   sensor11, sensor12, sensor13, sensor14, sensor15, sensor16, sensor17, sensor18,
sensor19};

Serial wt_32(p9, p10); // tx, rx: used for bluetooth communication
DigitalOut myled(LED1);
int main()
{
   wt_32.baud(115200);
   case_switch.rise(&case_closed);
   case_switch.fall(&case_opened);
   while(1)
   {
      sensor_power = 0;
      enable = 1;
      deepsleep();
   }
}

// Function designed to confirm the case was opened.
void case_opened()
{
   wait_ms(15);    // Wait for bouncing to stop.
   // Ensure that the switch is still unpressed and the interrupt isn't locked.
   if (!case_poll.read() && enable)
   {
      enable = 0;
      opened_alert();
   }
```

```
}

// Function designed to confirm the case was closed.
void case_closed()
{
   wait_ms(15);    // Wait for bouncing to stop.
   // Ensure that the switch is still pressed and the interrupt isn't locked.
   if (case_poll.read() && enable)
   {
      enable = 0;
      closed_count();
   }
}

// Function designed to send an alert to the mobile device the case has been opened.
void opened_alert()
{
   wt_32.putc('a');
   while(!wt_32.writeable()){ /* wait */}
   wt_32.putc(13);
   while(!wt_32.writeable()){ /* wait */}
   wt_32.putc(10);
   myled = 0;
   wait_ms(10);
}

// Function designed to count the cigarettes in the case and send that value to the mobile
device.
void closed_count()
{
   int cigarettes = 0;  // Initialize cigarette count to zero.
   int i;  // Loop counter.
   sensor_power = 1;   // Turn on sensors
   wait_us(150);   // Ensure sensors are fully powered.
   DigitalIn *curr;    // Variable to point to various digital sensor inputs.
   for(i = 0; i < 20; i++)
   {
      curr = &sensors[i]; // Point to current sensor.
      wait_us(20);
      if(curr->read())
      {
         cigarettes++;
      }

   }
   wt_32.putc('c');
```

```
    while(!wt_32.writeable()){ /* wait */}
    wt_32.putc(13);
    while(!wt_32.writeable()){ /* wait */}
    wt_32.putc(10);
    myled = 1;
    wait_ms(10);
}
```

Appendix A.9
Application Code Example

Code for Activity Choose Day Layout in Android Application:

```
<LinearLayout xmlns:android="http://schemas.android.com/apk/res/android" xmlns:tools="http://sc
hemas.android.com/tools" android:layout_width="match_parent" android:layout_height="match_paren
t" android:orientation="vertical"android:paddingLeft="16dp" android:paddingRight="16dp" tools:c
ontext=".ChooseDay">
<ImageView android:layout_width="wrap_content" android:layout_height="wrap_content" android:adj
ustViewBounds="true" android:paddingTop="5dp" android:src="@drawable/what_day_text"/>
<LinearLayout android:layout_width="match_parent" android:layout_height="wrap_content" android:
orientation="horizontal" android:layout_weight="1" android:paddingBottom="20dp" android:padding
Top="20dp">
<ImageView android:id="@+id/monday" android:layout_width="wrap_content" android:layout_height="
wrap_content" android:layout_weight="1" android:adjustViewBounds="true" android:src="@drawable/
monday"/>
<ImageView android:id="@+id/tuesday" android:layout_width="wrap_content" android:layout_height=
"wrap_content" android:layout_weight="1" android:adjustViewBounds="true" android:src="@drawable
/tuesday"/>
</LinearLayout>
<LinearLayout android:layout_width="match_parent" android:layout_height="wrap_content" android:
orientation="horizontal" android:layout_weight="1" android:paddingBottom="20dp" android:padding
Top="20dp">
<ImageView android:id="@+id/wednesday" android:layout_width="wrap_content" android:layout_heigh
t="wrap_content" android:layout_weight="1" android:adjustViewBounds="true" android:src="@drawab
le/wednesday"/>
<ImageView android:id="@+id/thursday" android:layout_width="wrap_content" android:layout_height
="wrap_content" android:layout_weight="1" android:adjustViewBounds="true" android:src="@drawabl
e/thursday"/>
</LinearLayout>
<LinearLayout android:layout_width="match_parent" android:layout_height="wrap_content" android:
orientation="horizontal" android:layout_weight="1" android:paddingBottom="20dp" android:padding
Top="20dp">
<ImageView android:id="@+id/friday" android:layout_width="wrap_content" android:layout_height="
wrap_content" android:layout_weight="1" android:adjustViewBounds="true" android:src="@drawable/
friday"/>
<ImageView android:id="@+id/saturday" android:layout_width="wrap_content" android:layout_height
="wrap_content" android:layout_weight="1" android:adjustViewBounds="true" android:src="@drawabl
e/saturday"/>
</LinearLayout>
<ImageView android:id="@+id/sunday" android:layout_width="wrap_content" android:layout_height="
wrap_content" android:layout_gravity="center_horizontal" android:adjustViewBounds="true" androi
d:paddingTop="20dp"android:paddingBottom="20dp" android:src="@drawable/sunday"/>
</LinearLayout>
```

Code for Activity Choose Day Function in Android Application:

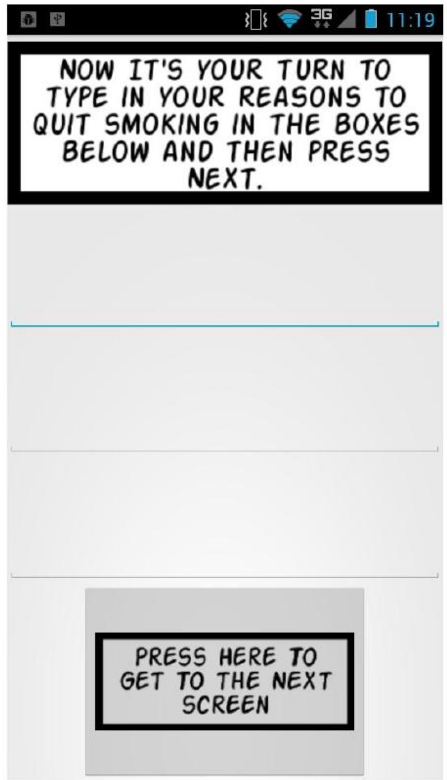
```
package com.beginnersluck.packpal.uiactivities;

import com.beginnersluck.packpal.R;
import com.beginnersluck.packpal.R.layout;
import com.beginnersluck.packpal.R.menu;

import android.os.Bundle;
import android.app.Activity;
import android.content.Intent;
import android.view.Menu;
import android.view.MotionEvent;
import android.view.View;
import android.view.View.OnTouchListener;
import android.widget.ImageView;

public class ChooseDay extends Activity {
@Override
protected void onCreate(Bundle savedInstanceState) {
super.onCreate(savedInstanceState);
setContentView(R.layout.activity_choose_day);
listenForButtons();
}

public void listenForButtons(){
final ImageView monday = (ImageView)
        findViewById(R.id.monday);
final ImageView tuesday = (ImageView) findViewById(R.id.tuesday);
final ImageView wednesday = (ImageView)
        findViewById(R.id.wednesday);
final ImageView thursday = (ImageView)
        findViewById(R.id.thursday);
final ImageView friday = (ImageView)  findViewById(R.id.friday);
final ImageView saturday = (ImageView)
        findViewById(R.id.saturday);
final ImageView sunday = (ImageView)  findViewById(R.id.sunday);
monday.setOnTouchListener(new OnTouchListener() {
@Override
public boolean onTouch(View v, MotionEvent event){
switch(event.getAction()){
case MotionEvent.ACTION_DOWN:
case MotionEvent.ACTION_MOVE:
monday.setImageResource(R.drawable.monday_pressed);
break;
case MotionEvent.ACTION_UP:
monday.setImageResource(R.drawable.monday);

Intent intent = new Intent(ChooseDay.this, DateChosen.class);
startActivity(intent);

break;}
return true;}});

tuesday.setOnTouchListener(new OnTouchListener() {
@Override
```

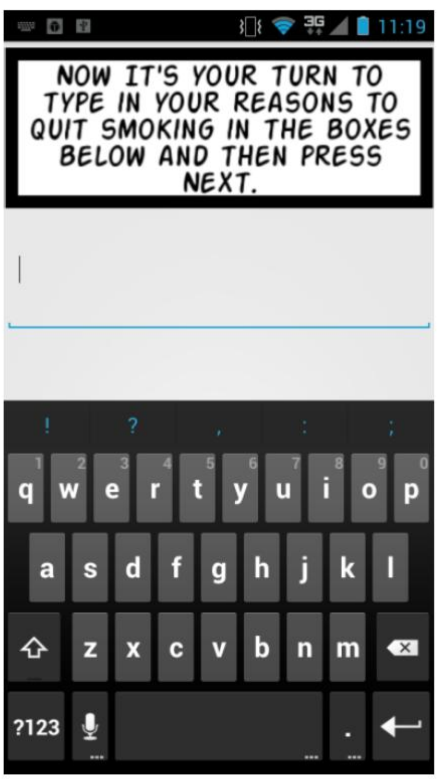
```
public boolean onTouch(View v, MotionEvent event) {
switch(event.getAction()){
case MotionEvent.ACTION_DOWN:
case MotionEvent.ACTION_MOVE:
tuesday.setImageResource(R.drawable.tuesday_pressed);
break;
case MotionEvent.ACTION_UP:
tuesday.setImageResource(R.drawable.tuesday);

Intent intent = new Intent(ChooseDay.this, DateChosen.class);
startActivity(intent);

break;}
return true;
}});

wednesday.setOnTouchListener(new OnTouchListener() {
@Override
public boolean onTouch(View v, MotionEvent event) {
switch(event.getAction()){
case MotionEvent.ACTION_DOWN:
case MotionEvent.ACTION_MOVE:
wednesday.setImageResource(R.drawable.wednesday_pressed);
break;
case MotionEvent.ACTION_UP:
wednesday.setImageResource(R.drawable.wednesday);

Intent intent = new Intent(ChooseDay.this, DateChosen.class);
startActivity(intent);

break;}
return true;}});

thursday.setOnTouchListener(new OnTouchListener() {
@Override
public boolean onTouch(View v, MotionEvent event) {
switch(event.getAction()){
case MotionEvent.ACTION_DOWN:
case MotionEvent.ACTION_MOVE:
thursday.setImageResource(R.drawable.thursday_pressed);
break;
case MotionEvent.ACTION_UP:
thursday.setImageResource(R.drawable.thursday);

Intent intent = new Intent(ChooseDay.this, DateChosen.class);
startActivity(intent);

break;}
return true;}});

friday.setOnTouchListener(new OnTouchListener() {
@Override
public boolean onTouch(View v, MotionEvent event) {
switch(event.getAction()){
case MotionEvent.ACTION_DOWN:
case MotionEvent.ACTION_MOVE:
friday.setImageResource(R.drawable.friday_pressed);
```

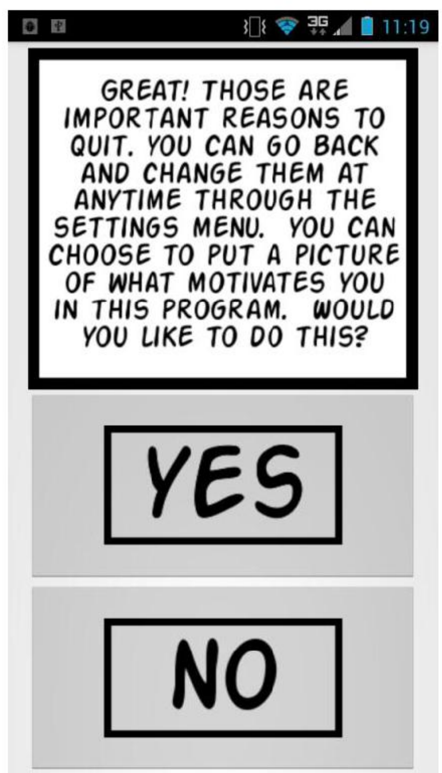
```
break;
case MotionEvent.ACTION_UP:
friday.setImageResource(R.drawable.friday);

Intent intent = new Intent(ChooseDay.this, DateChosen.class);
startActivity(intent);

break;}
return true;}});

saturday.setOnTouchListener(new OnTouchListener() {
@Override
public boolean onTouch(View v, MotionEvent event) {
switch(event.getAction()){
case MotionEvent.ACTION_DOWN:
case MotionEvent.ACTION_MOVE:
saturday.setImageResource(R.drawable.saturday_pressed);
break;
case MotionEvent.ACTION_UP:
saturday.setImageResource(R.drawable.saturday);

Intent intent = new Intent(ChooseDay.this, DateChosen.class);
startActivity(intent);

break;}
return true;}});

sunday.setOnTouchListener(new OnTouchListener() {
@Override
public boolean onTouch(View v, MotionEvent event) {
switch(event.getAction()){
case MotionEvent.ACTION_DOWN:
case MotionEvent.ACTION_MOVE:
sunday.setImageResource(R.drawable.sunday_pressed);
break;
case MotionEvent.ACTION_UP:
sunday.setImageResource(R.drawable.sunday);

Intent intent = new Intent(ChooseDay.this, DateChosen.class);
startActivity(intent);

break;}
return true;}});
}

@Override
public boolean onCreateOptionsMenu(Menu menu) {
// Inflate the menu; this adds items to the action bar if it is
present.
getMenuInflater().inflate(R.menu.activity_choose_day, menu);
return true;}}
```

Appendix A.10
Application User Interface


SECOND, MAKE A LIST OF YOUR TOP 3 REASONS TO QUIT. WE WILL USE THIS LIST TO HELP REMIND AND MOTIVATE YOU WHY IT'S IMPORTANT FOR YOU TO QUIT. SOME EXAMPLES OF WHY PEOPLE WANT TO QUIT ARE:
1) TO LIVE A HEALTHIER LIFE.
2)TO LIVE LONGER FOR SOMEONE YOU CARE ABOUT (LIKE A CHILD, BROTHER, SISTER, OR PARTNER).
3)TO ENJOY EXCERCISE AGAIN.
PRESS HERE TO GET TO THE NEXT SCREEN
PRESS HERE TO GO BACK TO THE LAST SCREEN


NOW IT'S YOUR TURN TO TYPE IN YOUR REASONS TO QUIT SMOKING IN THE BOXES BELOW AND THEN PRESS NEXT.
PRESS HERE TO GET TO THE NEXT SCREEN

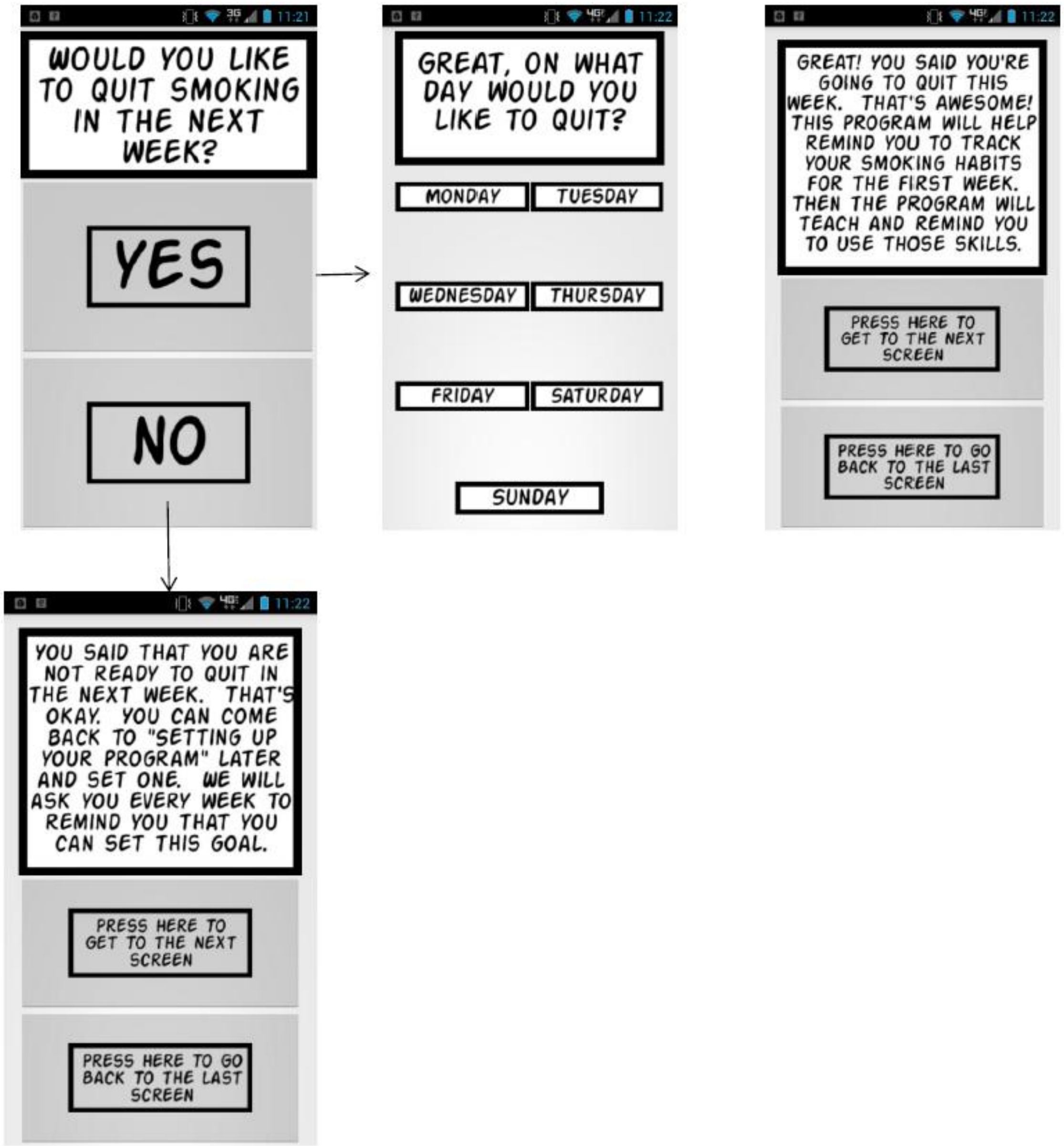

NOW IT'S YOUR TURN TO TYPE IN YOUR REASONS TO QUIT SMOKING IN THE BOXES BELOW AND THEN PRESS NEXT.


GREAT! THOSE ARE IMPORTANT REASONS TO QUIT. YOU CAN GO BACK AND CHANGE THEM AT ANYTIME THROUGH THE SETTINGS MENU. YOU CAN CHOOSE TO PUT A PICTURE OF WHAT MOTIVATES YOU IN THIS PROGRAM. WOULD YOU LIKE TO DO THIS?
YES
NO


11:20
NOW, IT'S IMPORTANT TO LEARN ABOUT THIS PROGRAM.
THIS PROGRAM IS HERE TO HELP YOU TRACK YOUR SMOKING, TO TEACH YOU WHEN AND WERE YOU SMOKE, AND TO HELP YOU LEARN NEW SKILLS TO REPLACE THE SMOKING HABIT.
PRESS HERE TO GET TO THE NEXT SCREEN
PRESS HERE TO GO BACK TO THE LAST SCREEN


11:20
IN ORDER TO HELP YOU TRACK YOUR SMOKES, YOUR PHONE WILL SEND YOU MESSAGES WHEN YOU OPEN YOUR ELECTRONIC PACK. THESE MESSAGES WILL HELP YOU TRACK YOU SMOKING AND GIVE YOU OTHER THINGS TO DO INSTEAD OF SMOKING WHEN YOU ARE READY. IT'S YOUR CHOICE.
PRESS HERE TO GET TO THE NEXT SCREEN
PRESS HERE TO GO BACK TO THE LAST SCREEN


11:20
IN ORDER TO HELP YOU TRACK YOUR SMOKES, YOUR PHONE WILL SEND YOU MESSAGES WHEN YOU OPEN YOUR ELECTRONIC PACK. THESE MESSAGES WILL HELP YOU TRACK YOU SMOKING AND GIVE YOU OTHER THINGS TO DO INSTEAD OF SMOKING WHEN YOU ARE READY. IT'S YOUR CHOICE.
PRESS HERE TO GET TO THE NEXT SCREEN
PRESS HERE TO GO BACK TO THE LAST SCREEN


WOULD YOU LIKE TO QUIT SMOKING IN THE NEXT WEEK?
YES
NO
GREAT, ON WHAT DAY WOULD YOU LIKE TO QUIT?
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
SUNDAY
GREAT! YOU SAID YOU'RE GOING TO QUIT THIS WEEK. THAT'S AWESOME! THIS PROGRAM WILL HELP REMIND YOU TO TRACK YOUR SMOKING HABITS FOR THE FIRST WEEK. THEN THE PROGRAM WILL TEACH AND REMIND YOU TO USE THOSE SKILLS.
PRESS HERE TO GET TO THE NEXT SCREEN
PRESS HERE TO GO BACK TO THE LAST SCREEN
YOU SAID THAT YOU ARE NOT READY TO QUIT IN THE NEXT WEEK. THAT'S OKAY. YOU CAN COME BACK TO "SETTING UP YOUR PROGRAM" LATER AND SET ONE. WE WILL ASK YOU EVERY WEEK TO REMIND YOU THAT YOU CAN SET THIS GOAL.
PRESS HERE TO GET TO THE NEXT SCREEN
PRESS HERE TO GO BACK TO THE LAST SCREEN