Deliverable G: Prototype 2 and Customer Feedback

GNG 1103 Group 12C

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Date
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To: Prof. David Knox, Ms. Rani Damuluri, Mr. Saelameab Demilew

This report will showcase components of our LifeLine product and provide a simplified prototype.

Introduction:

The goal of this deliverable is to create a prototyping test plan such that we can design prototypes focused on achieving certain objectives regarding each aspect of our device. Each of the aspects discussed in the last deliverable were developed and converged into 3 components: device frame prototype, main code, and phone application automated texting feature. Several trials were conducted in order to determine if each objective was feasible. The device frame and phone application automated texting feature were both improved by further expanding their abilities in order to better appease the client's requests. For the main code, it was a learning process to see how the components operated together using a breadboard and ensuring that the pulse oximeter was functional and accurate. Lastly, we discuss our plans for prototype three, specifically the tasks we need to complete and how we plan to achieve them.

There have been a few changes with our initial plan for our prototype 2. Our last deliverable had aimed to achieve progress regarding the failsafe, speed of overdose detection, and complete exterior frame. However, several of these aspects are dependent on the main code which we encountered issues with. Specifically not the functionality of the code, but rather the ability to test it. This is because the code is dependent on the functionality of the circuit and its components which we needed to solder. Several methods of implementing the components on the board have been tested (use of resistors vs without) and we had been finally able to get it working. However, due to the slow progress made, we were unable to make time for these dependent aspects, thus they will be moved to deliverable H.

Initial Plan for this Deliverable (From Project Schedule: Deliverable E):

Prototype	**Changes**
Coding the alarm & response failsafe	Will be moved to Deliverable H.
Oximeter Accuracy and Placement	Will only test accuracy due to time constraints.
Creating the main code	No Change
Interior Device Frame	Due to our change in our device frame design, both the interior and the exterior are merged.
Exterior Device Frame (Refer to Figure 1.)	
Speed of Overdose detection	Will be moved to Deliverable H.

New Plan for this Deliverable:

Prototype	Description	Person/s Responsible
Sealing Mechanism Of the Device Frame	Finding the best way to close the device frame after components have been enclosed.	Antonia
Creating the Main Code + Connecting Components	Writing an arduino code that gets blood-oxygen levels off the MAX chip.	Yomna/Alyssa/ Abdullah
Testing Pulse Oximeter Accuracy	Whether the readings from the MAX chip and an actual pulse-oximeter match.	Abdullah/Alyssa
Testing the Emergency Contact Text Order	The application is able to send an automated text message to a preset emergency contact chosen by the user.	Spencer

<u>Device Frame Prototype</u>

<u>Materials Used and Cost:</u>

TinkerCad and Cura to design and get our printing time, and then the Ultimaker 2 + 3D printers. No cost.

<u>Current Progress:</u>

Some changes have been made to the original design such as the inclusion of holes for the pulse oximeter and the USB charging port. We decided on one design that was the most favourable based off of the client, survey results, and team opinion. As you will see in *Figure 3.*, we have designed our device again to see if we like the placement of these changes.

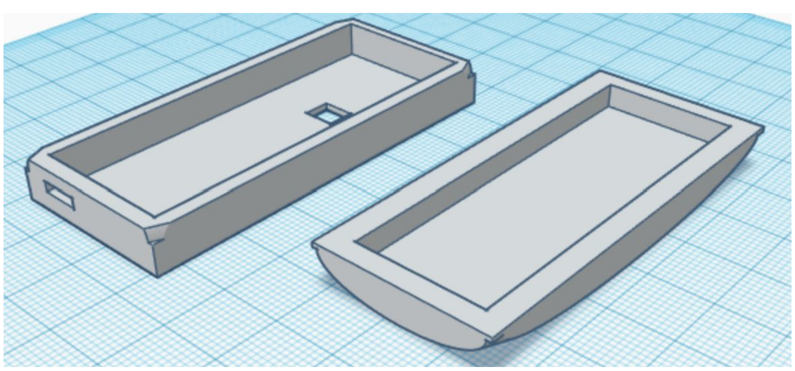


Figure 1

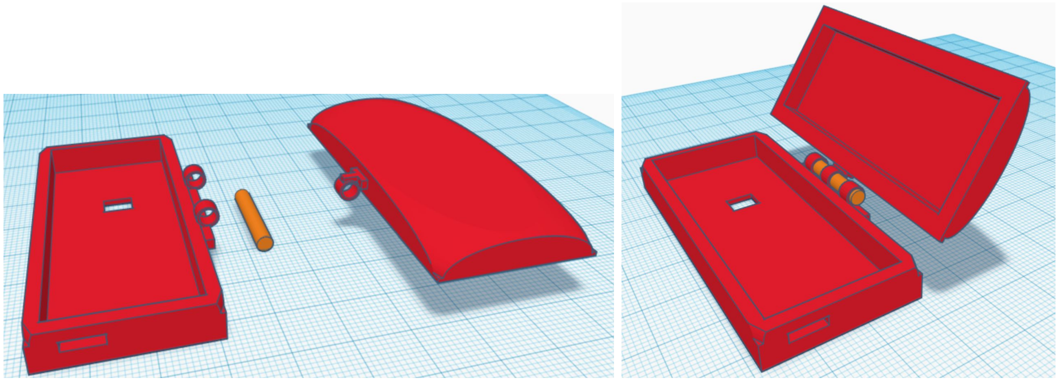


Figure 2

Figure 3

Why:

Many designs were made so that we can compare our stopping criteria for all of them and pick the best ones that we want. Also, 3D printing the prototype allows us to gain a better idea of how the device will look and determine how well the device will print.

How we tested it:

The idea for this prototype is to make sure that all of the newly added components are visually appealing and that they work together. Once we had our device printer, we also put it on using some elastic bands as a temporary band for an hour to test the comfort level.

Stopping Criteria:

Making sure that there are holes that fit well for the USB port and pulse oximeter.

Test results:

We realized that adding hinges would add unnecessary bulk to our device, which is already bigger than we would like due to the battery size. Also, we don’t need the device to be able to open and close so we will probably take this feature out and glue the device shut once all the components are inside. So we decided that we would carry on with the design of *Figure 1*. Also, we went with this design because of feedback given by our client (see more on this in the Client Feedback section).

Next step for this:

We need to determine how we are sealing our device frame together. Initially, we planned on including hinges, however, we decided that it is too bulky and are possibly gluing it. We will also need to add a ledge for the oximeter to sit on so that it doesn't fall out of the box. And looking forward, to keep it from falling into the box, we will probably tape it down to the box edges. Because of our uncertainty as to which batter we will be using, the dimensions of the device frame are subjected to change in the later prototype. Since not all of our components are done being soldered and put together, the location of the USB and pulse oximeter chip are also subject to change based off of the set up of the inside.

For the next prototypes we will add the watch band as well as the finishing touches and dimensions to the final look.

In the future, we may be adding an on/off switch to our device per client request, so another hole will need to be created so that our user has access to the switch.

Main Code & Connections

Materials Used and Cost: Arduino nano, MAX30100, Wires, Breadboard. Soldering set up. Cost = ($11.99 for MAX chip, $7 for Arduino Nano, free breadboard, $2.44 wires)= $21.43

Current Progress:

Using the coding template from the previous deliverable, we have written an arduino code that communicates between the MAX30100 chip and the arduino nano to get pulse oximeter readings.

Current Code:

```
#include <Wire.h>
#include "MAX30100_PulseOximeter.h"

#define REPORTING_PERIOD_MS     1000

// PulseOximeter is the higher level interface to the sensor
// it offers:
//  * beat detection reporting
//  * heart rate calculation
//  * SpO2 (oxidation level) calculation
PulseOximeter pox;

uint32_t tsLastReport = 0;

// Callback (registered below) fired when a pulse is detected
void onBeatDetected()
{
    Serial.println("Beat!");
}

void setup()
{
    Serial.begin(115200);

    Serial.print("Initializing pulse oximeter..");

    // Initialize the PulseOximeter instance
    // Failures are generally due to an improper I2C wiring, missing power supply
    // or wrong target chip
    if (!pox.begin()) {
        Serial.println("FAILED");
        for(;;);
    } else {
        Serial.println("SUCCESS");
    }
```

```
    // Initialize the PulseOximeter instance
    // Failures are generally due to an improper I2C wiring, missing power supply
    // or wrong target chip
    if (!pox.begin()) {
        Serial.println("FAILED");
        for(;;);
    } else {
        Serial.println("SUCCESS");
    }

    // The default current for the IR LED is 50mA and it could be changed
    //   by uncommenting the following line. Check MAX30100_Registers.h for all the
    //   available options.
    // pox.setIRLedCurrent(MAX30100_LED_CURR_7_6MA);

    // Register a callback for the beat detection
    pox.setOnBeatDetectedCallback(onBeatDetected);
}

void loop()
{
    // Make sure to call update as fast as possible
    pox.update();

    // Asynchronously dump heart rate and oxidation levels to the serial
    // For both, a value of 0 means "invalid"
    if (millis() - tsLastReport > REPORTING_PERIOD_MS) {
        Serial.print("Heart rate:");
        Serial.print(pox.getHeartRate());
        Serial.print("bpm / SpO2:");
        Serial.print(pox.getSpO2());
        Serial.println("%");

        tsLastReport = millis();
    }
}
```

Figure 4 (a),(b).

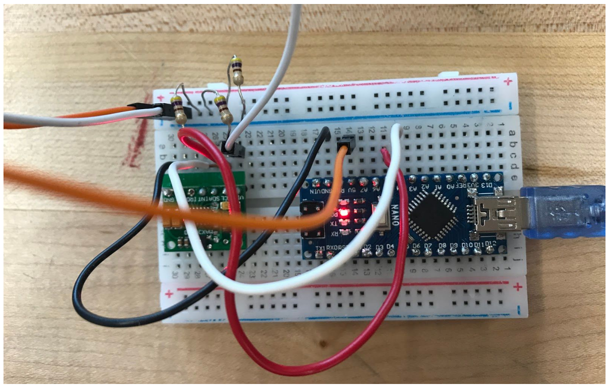
<u>Why:</u>

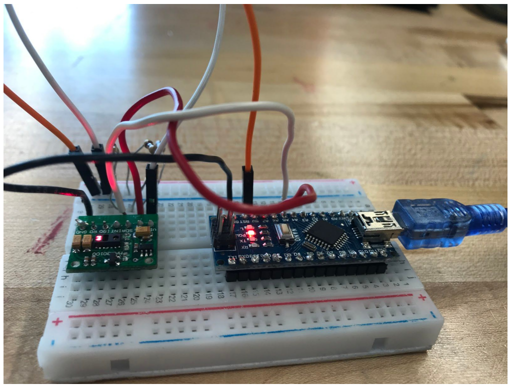
This is a critical system of our device, as the project depends on the arduino nano being able to get the blood-oxygen level readings from the user. This code does not include the connection to the HC-05, or the decided upon intervals of blood-oxygen levels retrieval yet.

<u>How we tested it:</u>

In order to test out whether our code was working, we had to solder some connections between the arduino nano and the pulse oximeter chip. We did this by using the circuit diagram made from the last prototype.

The Setup:





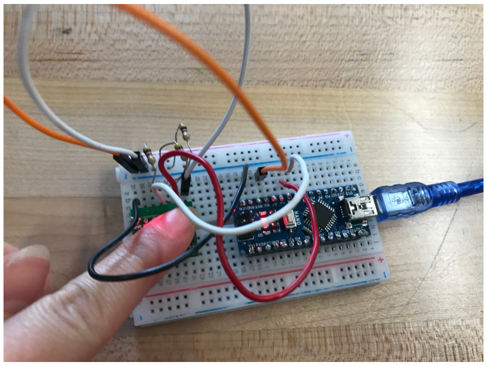


Figure 5(a),(b),(c).

<u>Stopping Criteria:</u>

The goal is to have the connection between the two electric components good enough for the serial monitor of the arduino to display the heart rate and the spO_2 (blood-oxygen %) readings.

<u>Test results:</u>

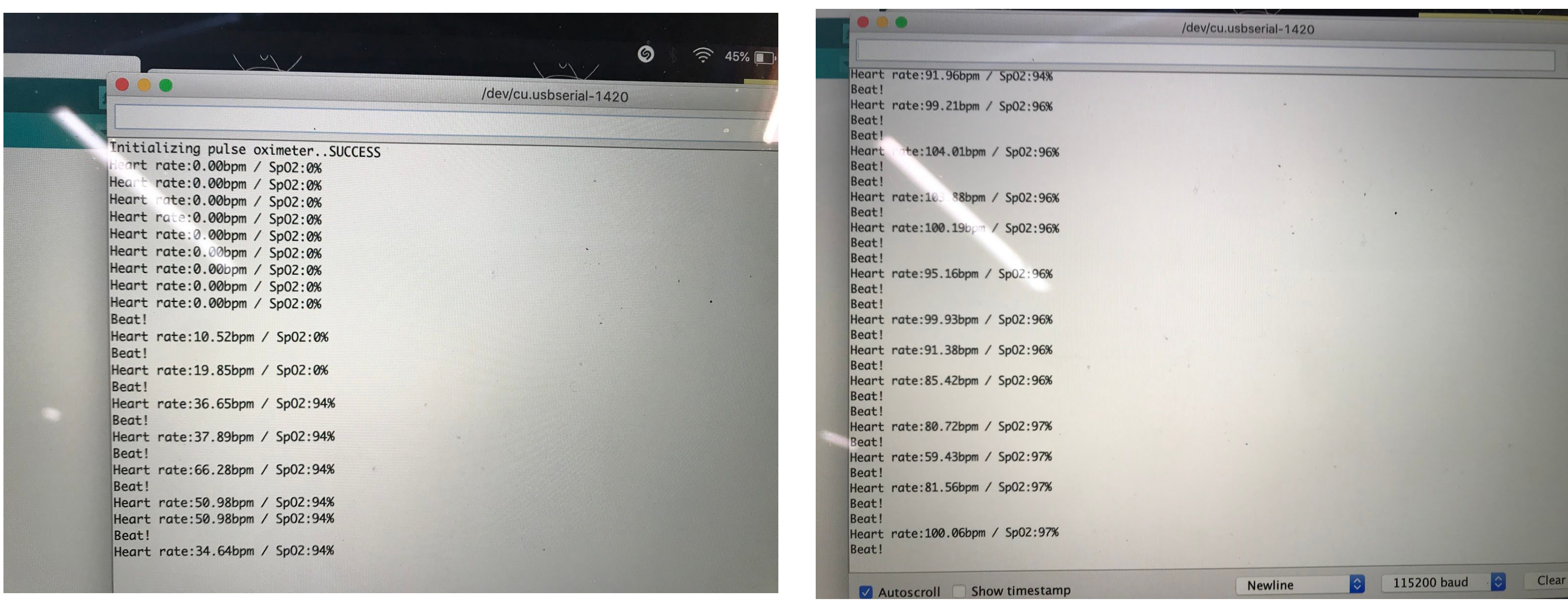


Figure 6(a),(b).

<u>Next step for this:</u>

Now that we know the connections work, and that the MAX30100 chip can send the readings to the arduino, the code has to be altered so that it can take the reading level and deem if it's an overdose or not. This involves some sort of if statement that checks the spO_2 and if it is a dangerous level, then the code must send out a warning to the bluetooth module.

We also must integrate the bluetooth module and make sure the readings get sent to the app through the HC-05.

LifeLine App Automated Text

Using the MIT app inventor site from the previous prototype and the companion app that came with it, we have added a variety of different options to choose from on the application, including instructions on how to use naloxone and how to give CPR. We have also slowly been trying to implement an "emergency contact" which allows the app to send an SOS text to the emergency contact the user had preset in the app.

Materials Used and Cost: The MIT app inventor and the companion app cost $0.

Current Progress:
So far, we have managed to text an alert to someone about the user overdosing, and have added a few more options into our application including more settings such as instructions on how to use naloxone.

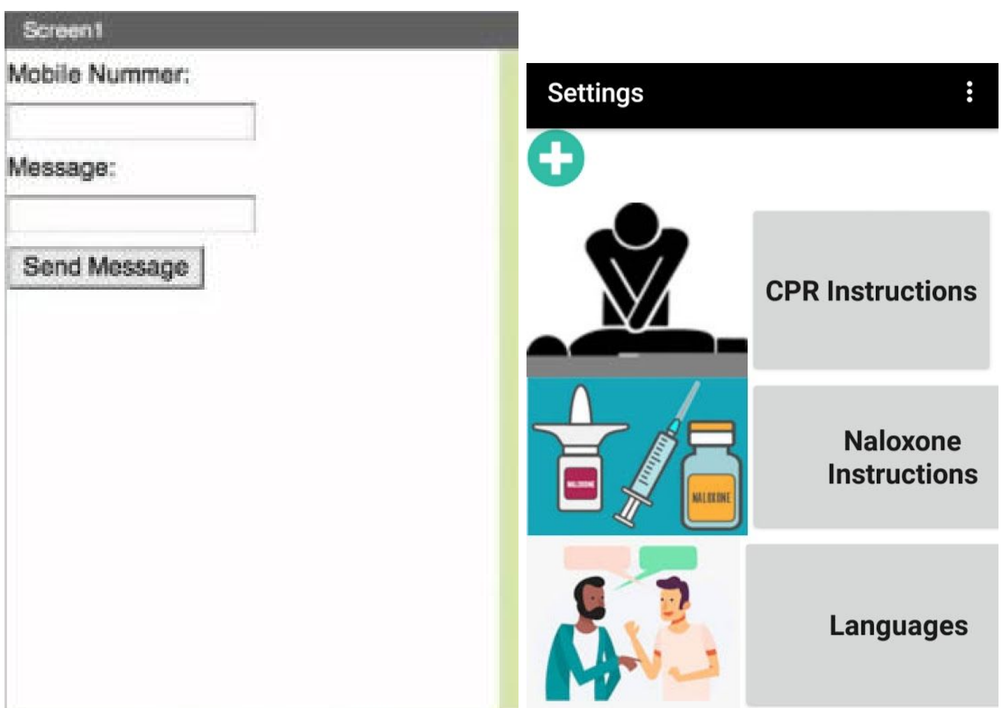


Figure 7(a),(b).

Why?:
Sending out the text to a loved one is one of the most crucial components to our application. Not only has our client requested for something like this to be implemented into our application, but it is necessary to making our application feel complete and useful to users.

How we tested it:

By continuously building the code through the MIT app inventor website, and then scanning the QR code and opening the files up on my phone, we were able to make sure that the application itself had no errors, and that the application ran as we wanted it to.

Stopping Criteria:

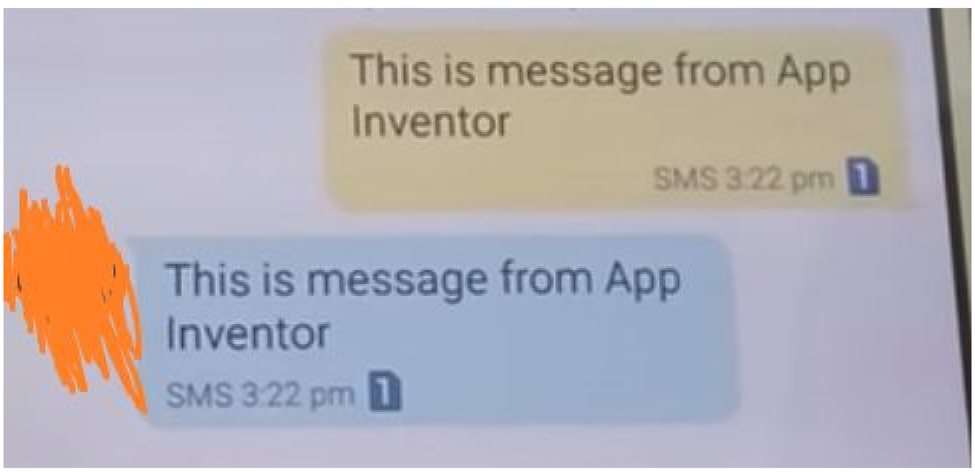


Figure 8.

Test results:
We were able to switch between a lot more screens and added a bunch of new options to our device. Our device doesn't crash, and runs everything including the bluetooth connection without failure.

Next step for this:
By the next prototype, we are hoping to have figured out how the arduino code would trigger the test, complete the final crucial components including the geolocator into our application, and work on making our app look more visually appealing.

Testing Oximeter Accuracy

Materials Used and Cost: Arduino nano, MAX30100, Wires, Breadboard. Soldering set up. Cost = ($11.99 for MAX chip, $7 for Arduino Nano, free breadboard, $2.44 wires)= $21.43

Current Progress: Testing was conducted to measure the accuracy of pulse oximetry reading across different placement locations (Ear, Palm, Fingers, Wrist). Conclusive testing results support the accuracy of all placement options in the following order from most accurate to least accurate.

1. Index Finger.
2. Wrist.
3. Palm.
4. Ear.

Why:

The goal of this experimental prototype was to find an optimal placement strategy for the oximeter and recommend a final frame design that optimizes the device for best possible pulse oximetry accuracy without compromising the device's ability to be discreetly worn.

How we tested it:

The accuracy of readings were tested using an experimental model. Data was collected from the MAX30100 chip and another standard medical finger oximetry device as subjects performed breath holding exercises that cause blood oxygen saturation to drop. We collected data over 150 seconds in each trial to compare accuracy and latency from several placement options.

Collected Data:

Table 1. Pulse Oximetry comparison collected from right index finger.

Time(s)	Max30100 (pO2)	Standard Oximeter (pO2)
0	95	97
5	97	97
10	97	98
15	97	97
20	98	98
25	99	97
30	99	98
35	96	98
40	97	98
45	97	97
50	96	97
55	97	96
60	98	96
65	95	95
70	95	95
75	96	95
80	97	97
85	98	97
90	95	96
95	94	94
100	93	94
105	93	92
110	93	91
115	91	89
120	89	87
125	84	86
130	85	85
135	85	83
140	84	83
145	83	82
150	84	81

Table 2. Pulse Oximetry comparison collected from right wrist.

Time(s)	Max30100 (pO2)	Standard Oximeter (pO2)
0	98	98
5	97	98
10	98	97
15	96	97
20	95	96
25	98	96
30	97	98
35	97	98
40	96	98
45	96	97
50	95	98
55	95	98
60	95	98
65	97	94
70	97	95
75	96	95
80	94	97
85	94	97
90	92	96
95	91	94
100	94	94
105	94	92
110	93	91
115	92	89
120	85	87
125	88	86
130	84	84
135	85	85
140	82	85
145	81	82
150	81	80

Table 3. Pulse Oximetry comparison collected from right palm.

Time(s)	Max30100 (pO2)	Standard Oximeter (pO2)
0	95	97
5	97	97
10	97	98
15	97	97
20	98	98
25	99	97
30	99	98
35	96	98
40	97	98
45	97	97
50	96	97
55	97	96
60	98	98
65	95	98
70	95	98
75	96	97
80	97	97
85	98	96
90	95	96
95	94	94
100	93	94
105	93	92
110	93	91
115	84	89
120	85	87
125	85	81
130	82	85
135	80	84
140	82	83
145	83	80
150	84	79

Table 4. Pulse Oximetry comparison collected from right earlobe.

Time(s)	Max30100 (pO2)	Standard Oximeter (pO2)
0	98	97
5	99	97
10	99	98
15	96	97
20	97	98
25	97	97
30	96	98
35	97	98
40	97	98
45	97	97
50	96	97
55	97	96
60	98	98
65	95	98
70	95	98
75	96	97
80	97	97
85	98	96
90	92	96
95	95	94
100	97	94
105	97	92
110	96	91
115	94	89
120	94	87
125	92	81
130	85	85
135	88	85
140	80	83
145	82	80
150	83	81

Stopping Criteria:

In this prototype a contrast was obtained from comparing readings taken from both our own prototype and the standard medical oximeter as blood oxygen saturation dropped during the breath holding exercises. The readings of the fingertip oximeter were considered to be of true value and the accuracy of our protoype's readings were dependent on matching the data collected from the standard oximeter.

We were looking to see which prototype placement would produce readings that are most matching to those obtained from the standard oximeter and if any latency in the interpretation of oximeter readings was exhibited. We also kept in mind our commitment to make this device stealthy and discreet.

Next step for this:

Under the pretext of the results collected from the oximetry accuracy prototype. We can definitively confirm the viability of design options that utilize finger, earlobe, palm and wrist placements in terms of accuracy. However, comfort and stealth constraints suggest that the wrist placement might be most optimal for an effective product that has the best chance to succeed.

A contrast test against the standard finger oximeter will be re-conducted after integrating the bluetooth module into the system to ensure that the system's wireless synchronization is seamless and that latency is minimized.

Client Feedback and Comments

We fortunately had the opportunity of presenting all our ideas and prototypes to our client, Tali Cahill, during this week. The team showed our plans for the failsafe and alarm, the application, and the first prototype of the device frame. Regarding the device frame, the client disapproved of one of our bulkier prototypes (*Figure 9.*), as she thought it was not very aesthetically pleasing nor was it very discrete. The client stated she preferred the more rounded off device frame we had, so we have decided to move forward with that design instead (*Figure 1&2.*)

The client also gave us feedback on the phone application. As we paid careful attention to user experience, we were pleased to see her compliment the simplicity of the app. She also suggested setting up the app to display naloxone administration instructions with our alarm system so that any bystander is able to help the user in the case of an overdose.

Regarding the arduino code, the intervals of when the blood-oxygen level readings are taken are important for battery consumption, as readings every second would drain the battery quicker than readings every twenty seconds. This was a concern of ours, as time is crucial in this case because of the fact that overdoses can happen in as little as three minutes. If the blood-oxygen levels are taken too slowly, then the user's window of survival becomes smaller. With this concern in mind, we asked the client–who is a registered nurse and has worked at opioid safety clinics–how fast a person's blood-oxygen level can drop. She said the quickest she has ever seen it drop is within 30 seconds. This led our team to decide that we will program our device to measure the blood-oxygen level every 30 seconds, but with the condition that if a low blood-oxygen level is detected, then readings will be taken every 5-10 seconds to confirm if an overdose is really underway.

Lastly, the client emphasized how important it is that the device lasts a long time. We suggested a possible on/off switch to conserve battery and asked if it was reasonable to ask that of users. She approved of the idea, as it would save a lot of battery if someone wasn't planning on using it for a while. People are not likely to use every day, so it would be wasteful to not implement an on/off switch.

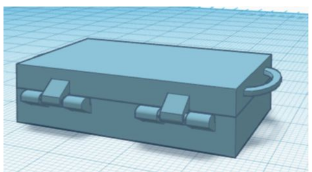


Figure 9.

Conclusion:

This deliverable outlines how each aspect of our device has been developed and progressed since the last prototype. The device frame was improved by incorporating a hole for the oximeter chip and USB port. With the client feedback, we were able to better shape the device to appeal more to her requests as best as we can while still considering important factors like discreteness and battery lifespan. The phone application was advanced by the development of more features. We were able to progress with one of the requirements of the client which was being able to contact help when an overdose is detected. The texting feature is only the beginning of what we hope the app can do. Also, we were able to establish a working code and circuit for the pulse oximeter. The accuracy of it was tested and compared to the results of an actual oximeter, however the data collected carries a lot of fidelity due to the inaccuracies between real life opioid overdoses and our simulation. Further testing will be conducted in the next deliverable with different methods and placements in hopes to increase accuracy and lessen the margin of error. Ensuring that these aspects are functional and can be developed further is critical for the following prototype and the overall outcome of our device. The progression made in this stage will define how well we manage our time and reduce the amount of issues moving forward.

Plan for Deliverable H:

Prototype	Description	Person(s) Responsible
Implementing an on/off switch and battery/battery charger to the device.	Connecting them to circuit and assuring its functionality.	Abdullah/Antonia
Coding Overdose Detection System	Adding to the arduino code to check if the blood-oxygen level is safe or not.	Yomna/Alyssa/Abdullah
Setting up the connection between the HC-05 and arduino	Adding to the arduino code so that all blood-oxygen readings are sent to the app via the HC-05.	Alyssa/Yomna /Spencer
Testing Pulse Oximeter Placement Accuracy and Speed of overdose detection	To see if the pulse-oximeter readings are the same on the finger and wrist and how long it takes to detect an overdose.	Abdullah/Antonia
Testing Comfort with Device Frame	Will make sure the device isn't intrusive or uncomfortable.	Antonia
Setting up failsafe and alarm	Designing the app so that it asks the user to confirm the overdose and setting off an alarm if overdose is confirmed.	Spencer/Yomna/Alyssa
Building the device	After the previous are done, the last step will be to finalize the building.	All