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Lactic Acid Threshold Stimulator

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Date: June 7, 2019

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Lactic Acid Threshold Stimulator

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREES OF

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by

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ABSTRACT

As a person works out, the threshold of lactic acid will build causing anywhere from discomfort to pain. Reducing the discomfort caused by lactic acid could greatly improve an individual's performance while working out. Reducing this discomfort may be done through Electrical Muscle Stimulation (EMS), which is the procedure of contracting muscles through sending electrical signals. Our team's goal is to create LATS, a wearable and mobile application that alleviates discomfort and aids muscle recovery during the intense parts of a workout. The system consists of a heart rate monitor to measure lactic acid levels, a garment that is worn on the leg to stimulate muscles using EMS, and an app that allows the user to monitor their data. The user will control the hardware components through the app on their mobile device while exercising. Over time, our goal is that through the use of LATS, the user will be able to work through the muscle discomfort and push on to meet any workout goal that they set. While we were not able to carry out our test plan to reach any conclusive results, we hope to one day have approval from the Institutional Review Board to see just how effective our planned solution really is.

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Acknowledgements

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Chapter 1

Introduction

1.1 Background

1.1.1 Electrical Muscle Stimulation

Electrical Muscle stimulation is the elicitation of muscle contraction using electric impulses. This works by impulses being generated by a device and delivered through electrodes on the skin near to the muscles being stimulated.[1] The electrodes are generally pads that adhere to the skin. The impulses mimic the action potential that comes from the central nervous system, causing the muscles to contract and then relax which then improves blood circulation. When muscles are stimulated it sends signals from the nerves to the brains creating endorphins which are the ”happy” feelings humans experience.

1.1.2 Lactic Acid Threshold

A person's lactic acid threshold is the exercise intensity at which the blood concentration of lactate and/or lactic acid begins to exponentially increase. This occurs at 85 percent of a persons maximum heart rate. The way this is calculated is with a 30 minute timed trial [2] conducted on a treadmill or stationary bike. The heart rate is recorded at 10 minutes in and at 30 minutes. Once the time trial is over those two heart rates are added together and divided by 2 to give the lactic acid threshold.

1.2 Motivation

People have always strived to achieve body perfection through dieting and intense workouts. This has come from a desire to emulate that which they see as beautiful as defined by society whether it be Victoria's Secret models or athletes competing at the Olympics. Unfortunately, this has led people down an unhealthy and potentially life-threatening path of overexertion in workouts. A common misconception is that the more you work out, the more fit you will be. This is incorrect and recovery is a key element of working out. The body needs time to rebuild and strengthen in order to achieve the best results. Our team hopes to alleviate part of the problem of overexertion, which can cause Rhabdomyolysis [3], by introducing an improved technique in how the body recovers after exercise and to prevent any detrimental injuries. Often, people decide to end their workout due to the discomfort they feel in their muscles. This discomfort is due to the buildup of lactic acid, which is what causes the burning feeling during exercise related to the common phrase “feel the burn.” Reducing the discomfort caused by lactic acid could greatly improve an individual’s performance while working out. It is important to note that each individual has their own limits, and our aim is to reduce the discomfort such that they may continue to workout within those personal boundaries.

1.3 Solution

Our team’s goal was to create the Lactic Acid Threshold Stimulator, or LATS, a wearable and mobile application that alleviates discomfort by combining electrical muscle stimulation and lactic acid threshold detection to aid muscle recovery during the most intense part of a cardio workout. The system consists of a heart rate monitor to measure lactic acid levels, a sleeve that is worn on the leg to stimulate muscles, and an app that allows the user to monitor their data. Any person working out, whether for personal health or as a professional athlete, can wear the LATS sleeve and heart rate monitor during any cardiovascular workout such as running, cycling, or rowing. By combining lactic acid detection and electrical muscle stimulation (EMS), LATS will help prevent severe muscle damage from discomfort, a problem that many people do not realize is caused by their daily workouts [4]. As a result, people can improve their health and fitness without harming their body through our solution. There are some EMS devices already on the market, but most do not offer the same features. For example, the *PowerDot* is an EMS system that requires users to pick a workout plan beforehand, which can cause an issue for inexperienced users. Other products, such as *Ultimate Abs* can be a simpler option, but it does not offer the same variety. Our solution does not require any knowledge of when the stimulation should be turned on due to its communication with the heart rate monitor and its automatic activation of the stimulation. It is able to be moved to different parts of the body, giving it more flexibility. Overall, our device offers a fresh take on EMS through lactic acid detection and takes some of the best features from other devices to combine them into a more user-friendly experience to aid your body.

Chapter 2

Project Requirements

2.1 Application Requirements

The user application will be used on the client's mobile device to interact with their LATS stimulator. We need the app to behave in a certain way and include various necessary features.

2.1.1 Functional Requirements

- Ability to connect to new devices via Bluetooth
- Ability to log in and log out of accounts
- Memory to save personal information to a database
- Ability to control the device with the push of a button

2.1.2 Non-Functional Requirements

- Overall appearance
- Clear account

2.2 Sensor Requirements

The sensor hardware as part of the LATS simulator will also be used in conjunction with the application and the client's mobile device. This piece of equipment will need its own set of device-specific requirements as well.

2.2.1 Functional Requirements

- Wires connecting from power source to skin pads
- Water resistant pads

- Portable
- Durable

2.2.2 Non-Functional Requirements

- Overall appearance: Color, style, size, portability

2.3 Other Important Features

Since this project will involve people's personal and private information, we will make sure to ensure their privacy and to explicitly say that we will never share their personal info with anyone. Also, as this utilizes human subjects, we will make sure this project follows correct human testing protocols and remains as ethical as possible, as defined by the Institutional Review Board (IRB).

Chapter 3

Use Cases

3.1 The User

The first use case involved in our implementation involves the user. When the user opens the app for the first time, the user will have an option to calibrate or connect their device for the first time. Then they can enter their personal information and proceed to main home screen. There, four options appear for the user: calibrate their device, go to settings, begin their exercise and get previous data, given the condition that they have data stored from before. The settings menu allows access to a number of features for the user including: editing their info, connecting a new device and clearing their info. As long as the app remains open, the user can cycle through these options any number of times.

3.2 The Mobile Application

The mobile companion app has two distinct uses: getting data from the sensor to display on screen and prompting the user to allow permission to begin electrical pulses. When the user selects a workout, the app will then grab the pertinent data from the sensor and securely send it to the database for user access later on. If there is no internet connection to the phone, the process will not work. During the workout, once the sensor has sensed that lactic acid levels have reached a pre-set threshold, the app will know to alert the user to ask for permission to begin EMS pulses. If the user accepts, the pulses will begin; in any other case, nothing will occur.

3.3 The Stimulating Device

Our stimulator only has one use case: stimulation of the muscles. If the user agrees to the procedure, the device will begin sending EMS pulses to the user's muscles and begin the alleviation process. If no permission is granted, the device will continue to monitor as normal but not stimulate the user.

These use cases are summarized in Figure 3.1.

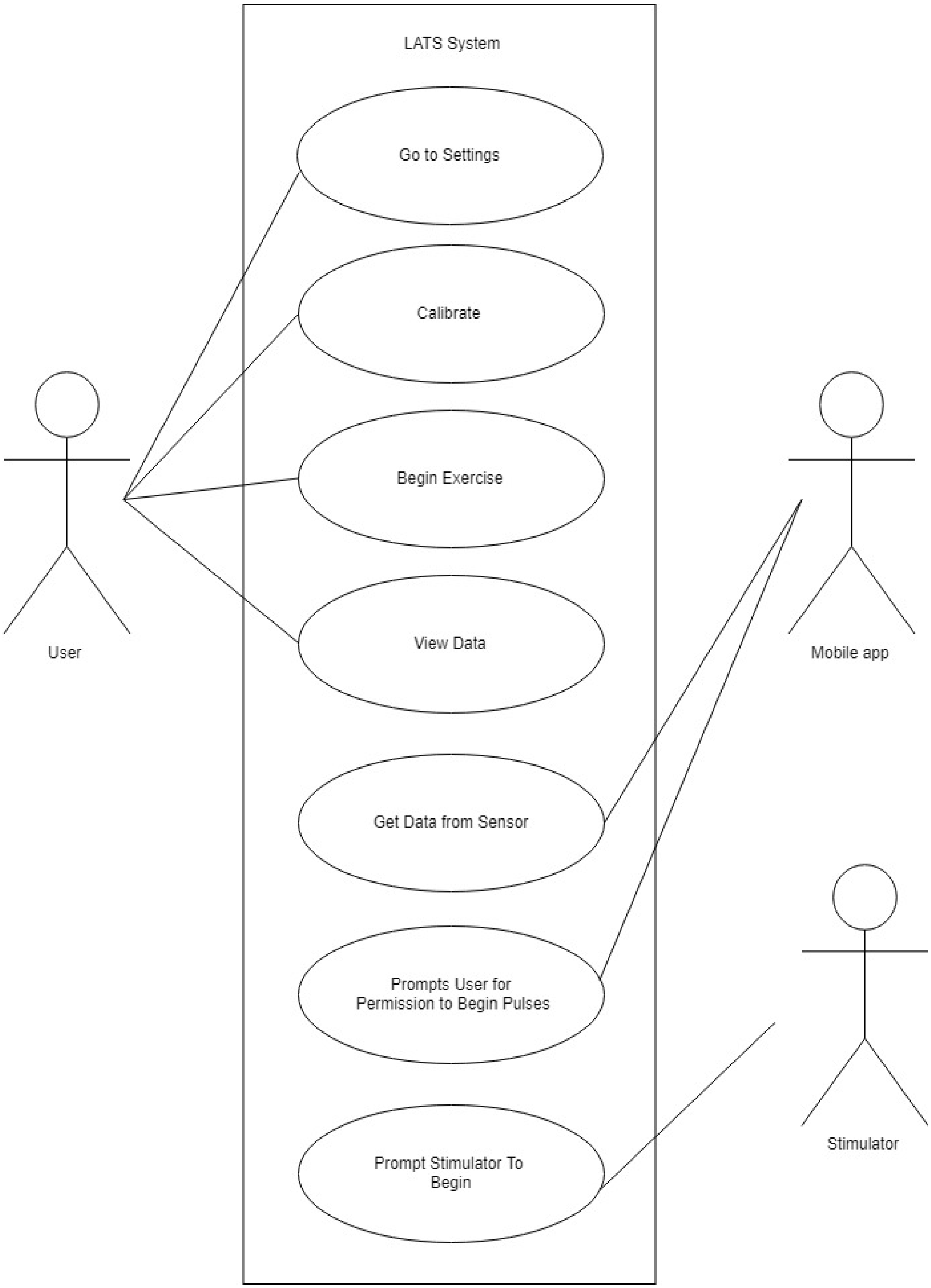

Figure 3.1: Use Case Diagram

Chapter 4

Activity Diagram

For our activity diagram shown in Figure 4.1, we're using a swim lane diagram which allows us to depict the flow of actions between each actor. There are lanes each for the user, the mobile application, and the stimulator. Our activity diagram begins with the user prompting to calibrate and connect the mobile app with the stimulator device. Once this occurs, the user enters personal information and then is taken to the home screen of our mobile app. On the home screen, the user has the option to either begin a workout, view heart rate, or calibrate once again. The diagram then enters the mobile app lane if the user chooses either to begin workout or view heart rate. These decisions prompt the mobile app to get data from the sensor by then prompting for permission from the user to begin stimulation. If given permission, the mobile app then prompts the stimulator to begin, and the control switches to the stimulator. The stimulator continuously sends pulses until the workout ends, and the control goes back to the user.

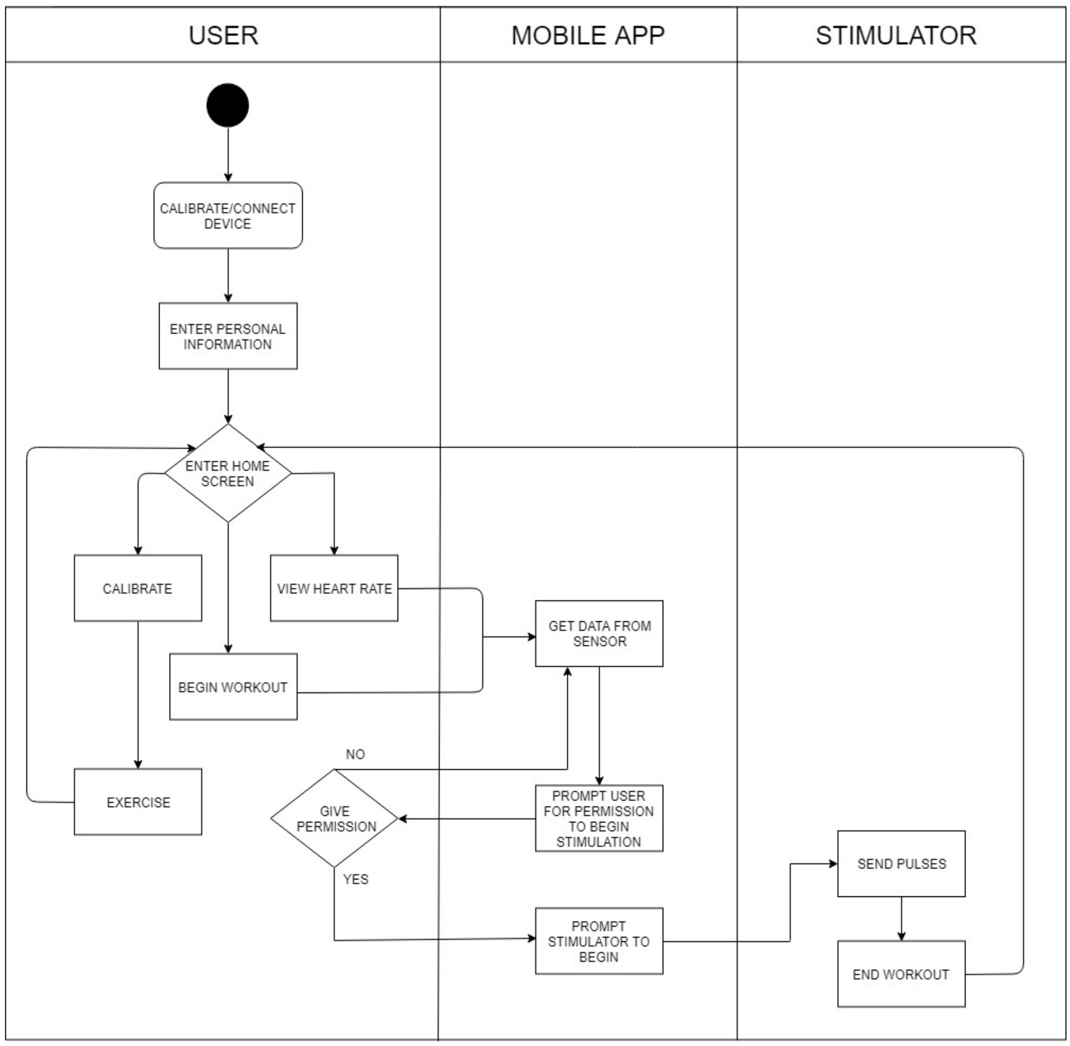

Figure 4.1: A diagram depicting the interactions between the user, mobile application and sensor hardware.

Chapter 5

Technologies Used

5.1 Software

For the sensor's software, we are developing an application for use on mobile devices running Android 8.0 and later using the Java language within the Android Studio environment. The information collected from the application will be stored in a realtime online database hosted by Firebase from Google.

5.2 Hardware

Our device is a combination of an off the shelf EMS device and an Arduino Nano micro-controller that will work in conjunction with a heart rate monitor. The device uses a 4.0 BLE bluetooth module which is connected to the Arduino in order to create wireless communication between the LATS hardware and the LATS app on the user's mobile device. All hardware used is summarized and shown in Table 5.1

5.2.1 EMS Device- iRelievThe electrical muscle stimulation device that we decided to use for this project is the combination TENS-EMS Unit Muscle Stimulator. TENS and EMS are two different types of muscle stimulation. TENS stands for transcutaneous electrical nerve stimulation and is usually used for physical therapy. EMS stands for electrical muscle stimulation and is used for strength training workouts. Since we used EMS for our project, we had 6 preset programs to choose from on this device. Program 5 fit best with our system because it works to improve fatigue resistance during long duration exercise. The settings for program five include a pulse width of 200 microseconds, which is how long each pulse lasts. The pulse rate is how often those pulses happen, and for this program it is between 4 and 20 Hertz depending on what intensity level is chosen by the user prior to their workout. The amount time these short quick pulses lasts is about 6 seconds with a 1 second time off.

5.2.2 Arduino Nano

The microcontroller that we chose to go with was the Arduino Nano because it fit our desire for compact size as well as its wide range of abilities. The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328P (Arduino Nano 3.x). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one.

5.2.3 4.0 BLE Bluetooth Module

The bluetooth module we chose for this project was the 4.0 BLE Bluetooth Module. We needed to implement this component to create the line of communication between the MyLATS app and the Arduino microcontroller. Since the communication occurs between the heart rate monitor and the app, then from the app to the arduino we had to ensure that this component was foolproof and worked with all our other communication pathways.

5.2.4 N-MOS Transistor

These transistors were used in place of the actual device buttons originally manufactured by the company who makes the iReliev. After a certain threshold voltage is met, these transistors activate and are in their active state or "on" position.

Table 5.1: Hardware Used

Hardware	Description
EMS Device - iReliev	FDA Approved EMS device
Arduino Nano	Microcontroller
4.0 BLE Bluetooth Module	Communication module that provides Arduino with bluetooth capabilities
N-MOS Transistor	Device buttons that activate

Chapter 6

Architectural Design

For our design project, we decided to go with a simple design to make it easy to implement and reduce the potential for bugs. Our data-centric model contains one database at the center with both the sensor device and the user mobile device having access to all the stored information. Each piece of data collected from the user will be stored securely and not accessed by any outside sources. Only the one user and their devices will have access to their own personal data. Besides the simplicity of the design, we also favored the advantage of being able to easily add and remove clients to and from the project and the advantage of centralized communication between all actors. The drawback is that there is a single point of failure; if the database goes down, every user will be affected. However, we are confident in our implementation that the benefits involved far outweigh the risk in using this architecture in our project.

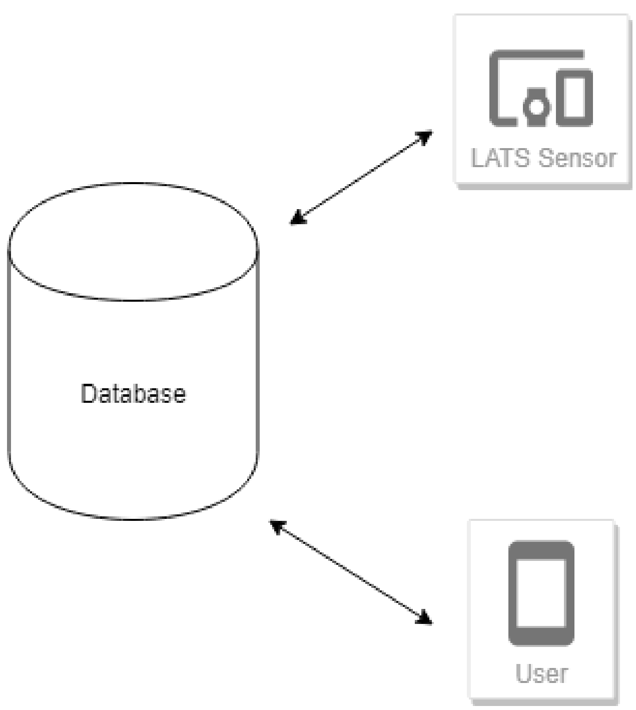

Figure 6.1: An overview of our data-centric architecture

Chapter 7

Design Rationale

7.1 Arduino

The team decided to use an Arduino platform primarily based off of our familiarity and comfort using it. Arduino is an open-source electronic platform with the ability to read inputs and react to them, both through analog and digital signals. Our group members have had past experience using Arduino, which directly translates to our needs for LATS. In addition, Arduino offers exactly what we need for the commands that LATS will issue. Its overall simplicity will allow us to be able to troubleshoot potential bugs quickly and maximize our success.

7.2 Bluetooth

We chose to include Bluetooth in our application in order for the application to easily communicate with the user's phone. For LATS specifically, we needed a short range connection with a focus on reliability. Bluetooth offers both of those features and will be the easiest for our users to use. In addition, Bluetooth offers wireless connection, which is important for users who are working out and do not want to carry their phones with them.

7.3 Android

We decided to develop in the Android Studio environment because of the ease-of-use with the Integrated Development Environment(IDE) and because of the tools we had access to during the development period. All members possessed only PCs and no Mac computers to use, so the choice for Java and the Android platform was an easy one for our team to make. With plenty of documentation available online regarding Java and Android, the team had no major issue in learning a new environment for this project. The libraries available still allowed for Bluetooth compatibility and Firebase access and still fit the need for fast updating with the live app LATS.

7.4 Firebase

Part of our LATS design is storing user information so that they can view their data. Data includes personal information of the user such as the user's height, weight, and age. For this backend portion of our mobile app, we decided to use Firebase as our database. Firebase allows for easy implementation with mobile applications and Android Studio. In addition, Firebase's secure authentication ensured that the user's data was stored safely. We also decided to use Firebase because their service is free to use, and all that is needed is an email to create an account. Lastly, the accessibility of Firebase made it easier for collaboration. All members of our team can be given permission to access the database, can be accessed from any computer by simply logging in.

7.5 Design Process

During this process we went through three different design phases: an initial design, a refinement, and then a final design. Our initial design started with an Arduino by itself using the built-in pulse width modulator to control our output signal (Figure 7.1). However the operating voltage of a standard EMS device is about 30V and the Arduino only outputs a maximum of 5 volts. So we had to change our design to include a boost converter to step up the voltage (Figure 7.2). As we continued to configure this design we ran into safety blocks from the institutional review board. Since our project involved sending electrical current to a human body, they wanted to make sure we were taking as many precautions as possible. This brought us to the final design, and the decision to replace the boost converter with an off the shelf FDA approved EMS device and control its buttons with the Arduino (Figure 7.3).

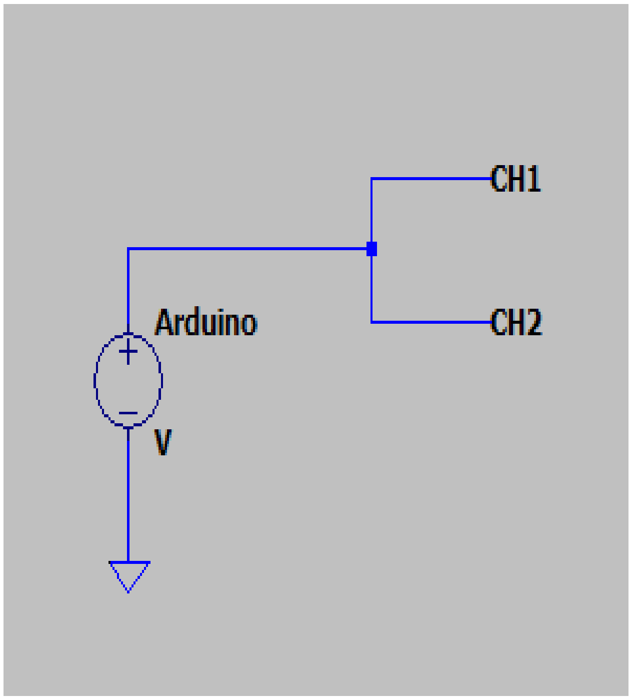

Figure 7.1: The initial design featuring only an Arduino Nano

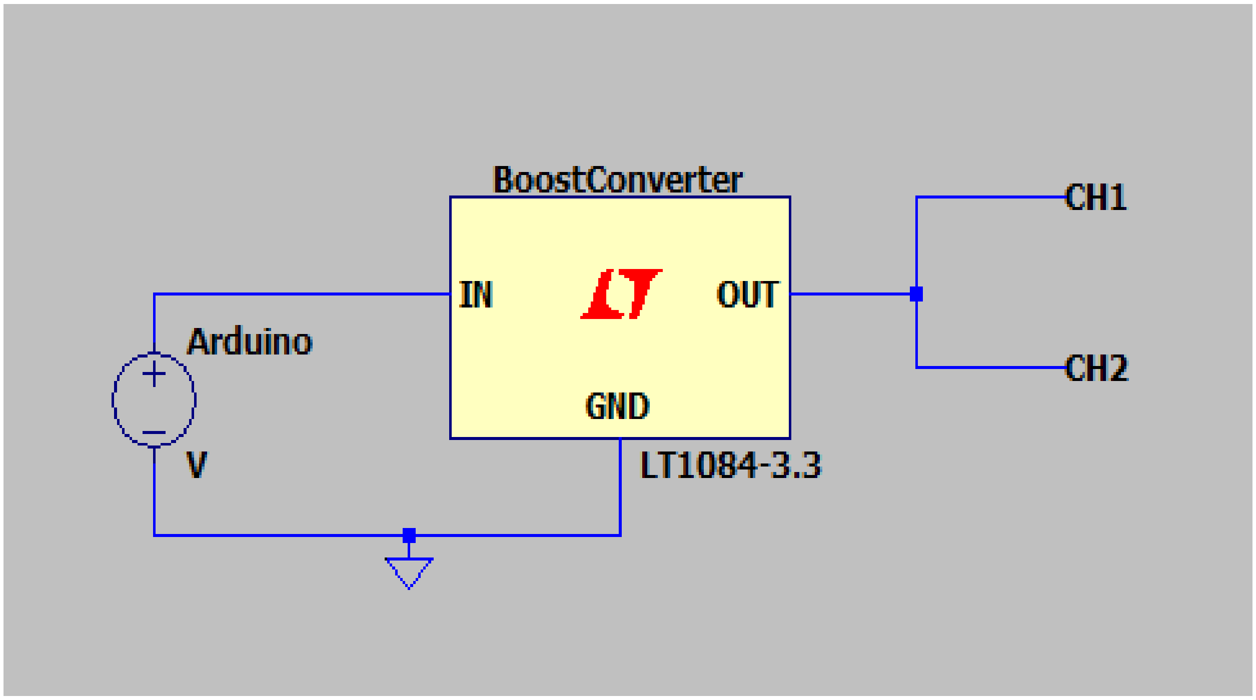

Figure 7.2: The second iteration that added a boost converter to produce higher voltages

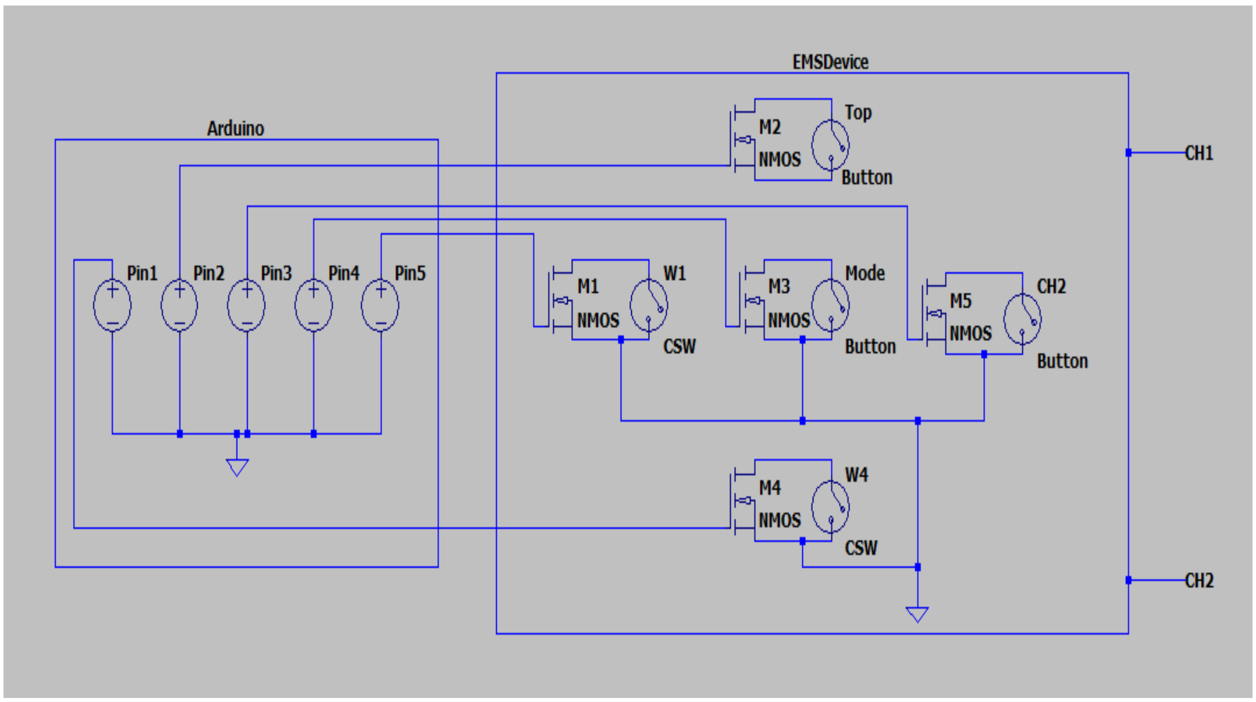

Figure 7.3: The final design including the EMS device approved by the FDA

Chapter 8

Description of System Implemented

8.1 User Authentication and Home Screen

When the user launches the application for the first time, they will be prompted to create a new account with our authentication system managed by Firebase (Figure 8.1). All the app requires for registration is a valid email and a password at least six characters long; if they have already registered, they can skip to the login screen instead and entire valid credentials (Figure 8.2). Once through to the main menu (Figure 8.3), the user can choose a variety of options such as connect their heart rate monitor, connect and control their LATS device, enter personal information to uniquely identify them, delete their account from our database or log out of the app. Each of these sub-menu screens will have a button to go back to the home menu screen while still logged in.

8.2 The Sub-Menus

As the activity diagram (Figure 4.1) described, the user has another multitude of options at their disposal when entering any of these sub-menus.

8.2.1 Connect Bluetooth Device

Within this sub-menu, the user can select the heart rate monitor from a drop-down list of all available Bluetooth devices around them (Figure 8.5). Once the monitor has been found and selected, the MAC address and heart rate data will be displayed on the screen; press the return button to return the to the main menu.

8.2.2 Begin Workout

Once the user is ready to begin using their LATS device in a workout scenario, the stimulation will begin once the user's heart rate has reached the lactic acid threshold as given by the heart rate monitor's data. From there, the user has manual control over how much voltage is being applied to their skin in order to reach maximum relief from the use of the device (Figure 8.6).

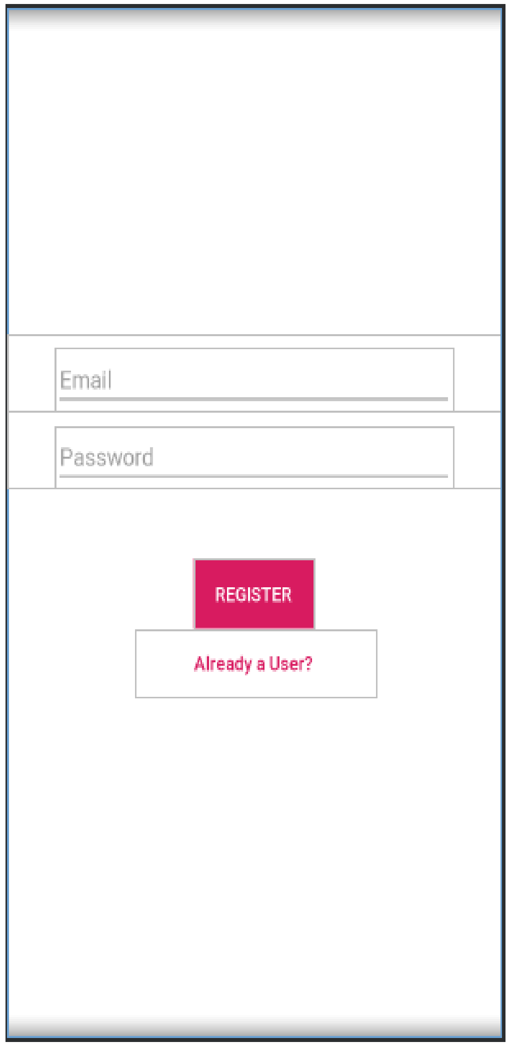

Figure 8.1: Registration screen for new users is the first screen on app launch

8.2.3 Enter Personal Info

Here in the personal information section, any user can enter their own unique identifying information that can be stored securely in our realtime database hosted by Firebase. They can choose a profile picture, enter their name and email, record their weight and age and select what gender they are (Figure 8.4). Once they are satisfied with the results, they can press the send button to automatically update the database with new information.

8.2.4 Delete User

Should there be a need for the consumer to no longer require LATS device use, there is an easy one-click process that will delete their account from our authentication protocols. All that needs to happen is a sign in and a push of the delete user button.

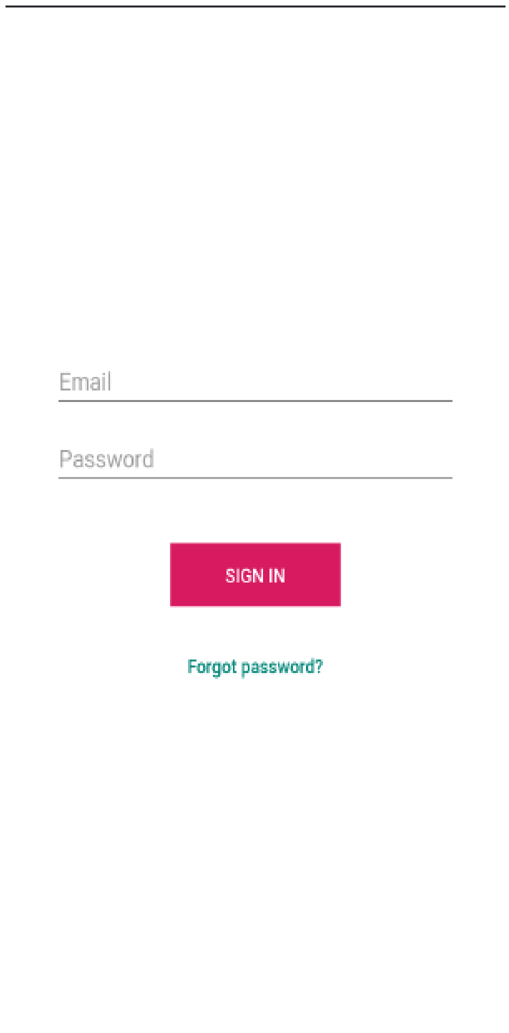

Figure 8.2: For users that already have registered they can login through this screen

8.2.5 Logging Out

Finally, the last option on the main menu for our targeted user is the logout button. Selecting this option will save their information and safely log their LATS account out of the device they are currently using; simply closing the app will not fully log them out.

8.3 The Wearable Device

As explained in the previous chapter, the hardware component of the LATS project underwent many iterations in its design before finally reaching a suitable version for use. The Arduino is connected to the stimulation device and both of them are sewn into the spandex shorts the user would need to put on. Electrode pads would extend out from the stimulator and attach to the front and back of each thigh, four on each side for a total of sixteen pads. For the remaining

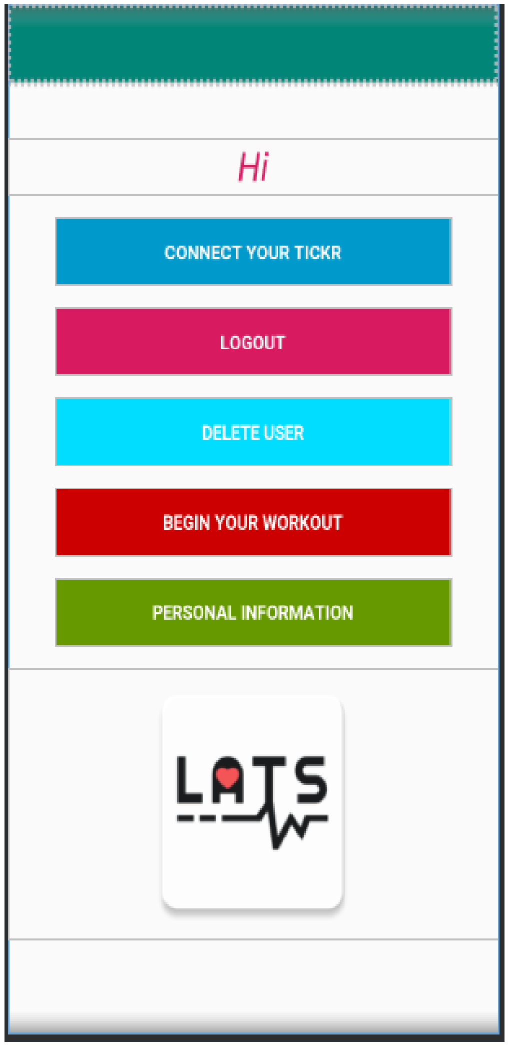

Figure 8.3: The main menu screen seen after successful login and authentication

devices, the heart rate monitor is worn by the user around the middle area of their chest and the mobile device is held securely on their person as well.

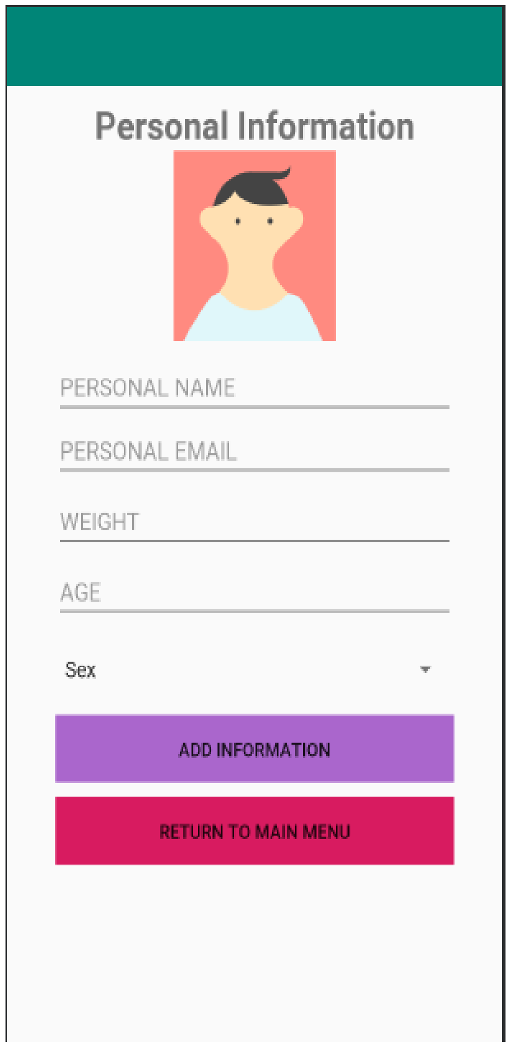

Figure 8.4: How the personal information page for users looks like

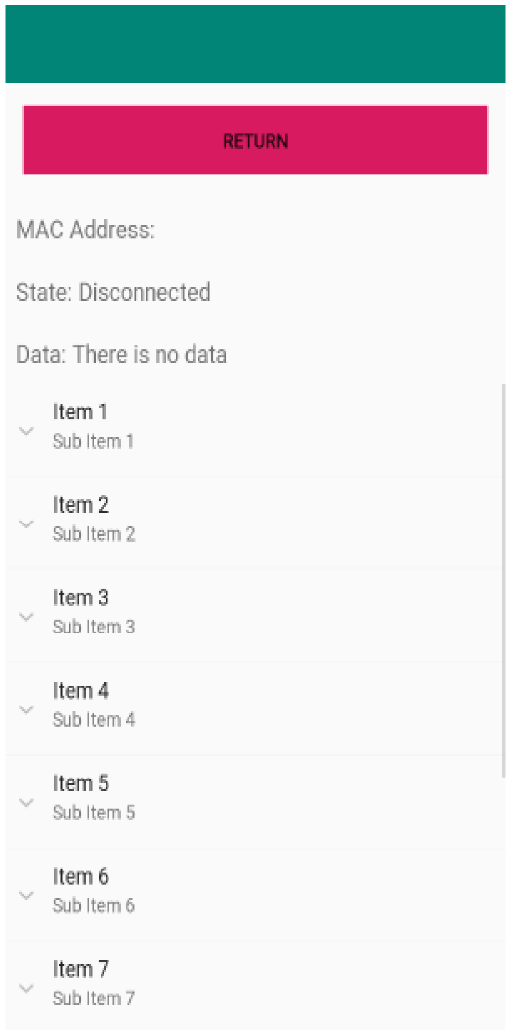

Figure 8.5: View seen on device as a user connects their device via Bluetooth

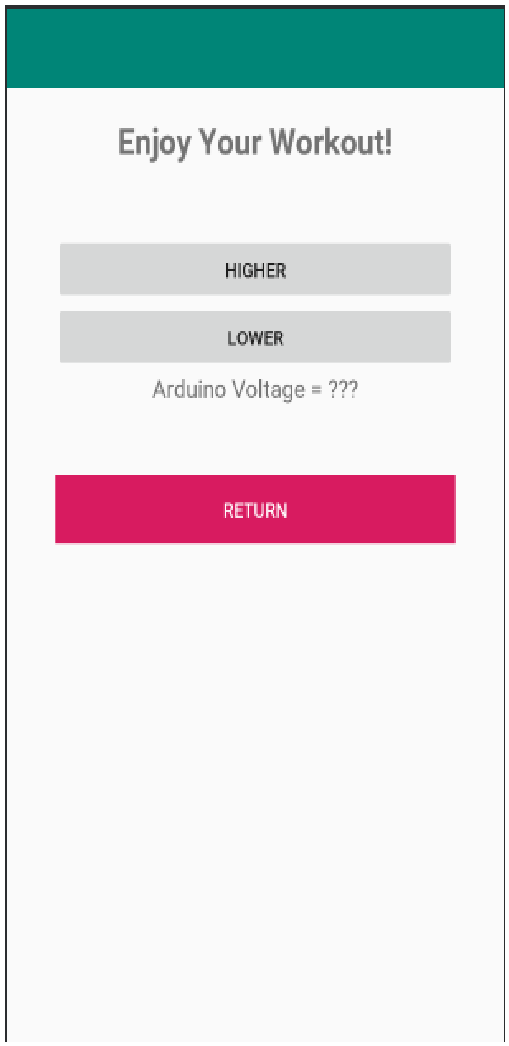

Figure 8.6: Workout screen that users can use to manually control their LATS Arduino device

Chapter 9

Test Plan

9.1 Software

To test the software of our system, we implemented different methods such as testing boundary values, exercising each line of code, and inputting special/unexpected values. In addition, we tested our system so that it could perform the different actions for each user based off our activity diagram (Figure 4.1). Lastly, our team tested our data so that it was correctly stored into our database.

9.2 Hardware

To test the hardware of our system, it is essential to determine the strength of the materials. Since the system is designed to be used during physical activity, the hardware will be tested by users performing various cardiovascular workouts in a variety of environments to ensure that it is durable. In addition it is important to guarantee that the hardware accurately collects data.

9.3 Human Subjects

To test on human subjects, we are going to have a total of 4 subjects. These four people will include 2 men and 2 women of different ages and physical abilities. This range is desired so that we can compare and contrast the data between the different physiological makeups. The testing period will last for about 4-5 weeks and we will retest each of the subjects lactic acid threshold every week, which is a 30 minute cardio time trial. The way we are going to keep track of each of the subjects progress is by monitoring what energy they expend and consume, which means tracking their exercise and steps as well as their food and drinks.

Chapter 10

Development Timeline

The Gantt chart in Figure 10.1 shows off the approximate timeline and milestones that we as a team accomplished during the development of this project. We began with the design and idea conception in the fall of 2018 and continued to refine that design into the middle of the winter quarter. We began seeking approval from the IRB in late January 2019 and could not reach a definite decision on testing which meant we had to change our original ideas in mid-February 2019. Development on the companion application began in early March and continued until the end of April, with the current version being the final source code used to present during the design conference. Meanwhile, regarding the hardware, designing and building began in late January and continued all the way through the end of April. We were able to come close to completing an operational system by the design conference, the one missing piece being the hardware device powering up the stimulating TENS device. However, we were able to reach the deliverables goal for early June with a more complete idea for our solution and the design report complete.

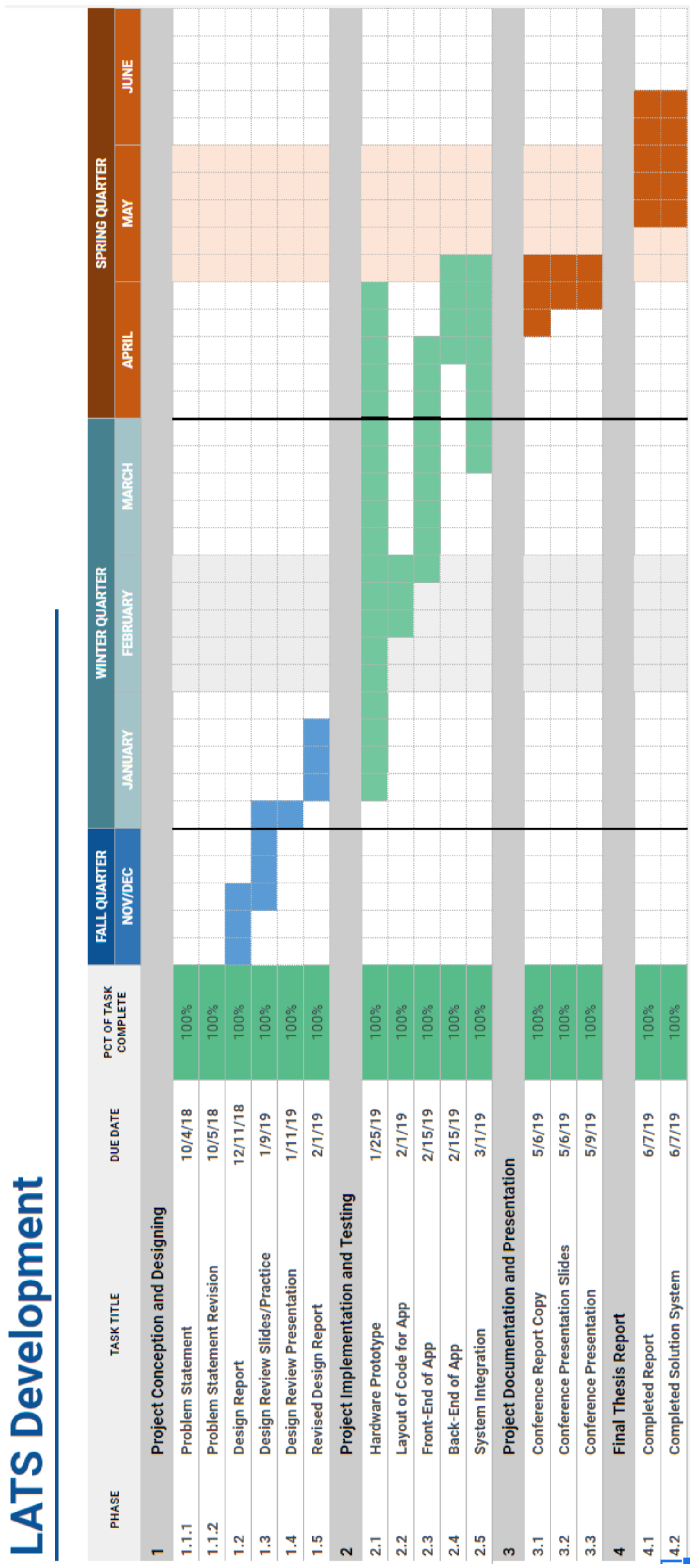

Figure 10.1: Gantt Chart Development Timeline

Chapter 11

Analysis of Societal Issues

11.1 Ethical

11.1.1 Description of Larger Context

The primary groups of people that this would affect are the athletes, the merchants who carry our product, the developers, and the test subjects for our product. It is important to focus not only on the actual use of stimulation on humans, but also on how the product is developed from production to consumer. Our vision is to produce a product with high reusability in hand with low waste production. This will ensure that we are putting minimal strain on our resources, as well as keeping our footprint small. After the production point, we want this product to be accessible for as many people as possible. By doing this we want to set a price that is both fair for the producers, as well as the consumers. Finally, there is a heavy ethical agreement between us, the producers, and the consumers. This trust that the consumer is placing in us is backed by several cautionary protocols that will be outlined through the rest of the description. Ethical steps must be taken when any form of electrical energy is being put into the human body.

11.1.2 Choosing a Project

Our group wanted to choose a project that had the potential to affect the everyday person. In designing this specific project, we sat down and discussed the ethical dilemmas our project would face. In doing so we discussed the highly difficult word to understand, Ethics, in the scope of the five commonly accepted perceptions:

The Utilitarian Approach to Engineering Design

In this scope, we discussed whether or not this product would bring more good to the people affected (the stakeholders) than bad. This approach starts when we begin using the resources to build the wearable aspect of the device. Immediately the resources that are being used leaves a new footprint on the planet. We are able to justify this footprint by planning on spending more to develop the product using recyclables and providing detailed instructions on how to keep the device working for as long as possible.

The Rights Approach to Engineering Design

When discussing the privacy we wanted to ensure our users, we discussed how we were collecting data and information about the users in the scope of the rights approach. For the application half of our project, we are collecting data and storing it in order for the users to track and monitor their progress. We understand that the individual has a right to privacy, which gives us the responsibility of making sure that we provide the consumer with complete protection of their data, as well as the right to redact that data.

The Fairness or Justice Approach to Engineering Design

Our group quickly identified that there would be similar competitors on the market. We designed LATS with the intent that it would be both competitive as well as unique to these other designs. We have made sure from the start that we are not infringing on any existing copyrights.

The Common Good Approach to Engineering Design

One subcategory of the common good approach in regards to engineering is the healthcare industry. LATS was designed with the intent to provide muscle recovery stimulation at a fraction of the cost that people are typically charged for the same product. We want to make what was once a commodity, accessible to all.

The Virtue Approach to Engineering Design

In regards to virtue, we mainly discussed compassion. Due to the need to test our design to ensure that it is both effective as well as safe, we have to make sure that we do not harm anyone or anything in the process. Possibly the biggest ethical dilemma of our project is ensuring that it is tested with compassion.

11.1.3 Ethical Analysis

After deciding to move forward with LATS, we first needed to ensure that our idea was unique and provided a new benefit to the consumer. With every new product comes the big issue of making sure the design is not someone else's repackaged idea. Because our idea was to track a persons lactic acid threshold and to prompt stimulation only when it would be most effective to users, this separated us from competitors, who typically only offer stimulation through a manual, simple on and off switch. Our group did thorough research on other devices on the market to guarantee that the idea we created is unique and we could therefore move on with the design and implementation process.

One key element to our design is monitoring the users lactic acid level so that our device could decide when the stimulation should start. This raises an ethical issue unique to our device because the device is the one that makes the decision rather than the user. Many people may find this element alarming due to the fact that the device basically monitors a persons lactic acid level and has control over when electric pulses will be sent to the user. To mitigate this fear, we designed some features to give some control back to the user. One of the most important features we included was a prompt in the software application that asks the user for consent once their lactic acid level reaches their threshold, to begin the use of stimulation during their workouts. This stimulation would then slowly begin to increase intensity until the perfect amount of stimulation for the users body type is achieved. This allows the user to be fully notified and not caught off guard by the stimulation. The user also has the option to decline the stimulation if they wish, or to automatically shut off the stimulation at any time. Lastly, we designed the interface to show the users current lactic acid level at all times during their workout, so they can personally monitor it along with the device. We made the decision to include this feature in order to give the user more comfort and control over their use of our product.

Another ethical issue that comes with most software applications is user privacy. Every decision we made for the application had their privacy in mind. For someone to use our device, an account needs to be created that connects to our database. All we ask for is an arbitrary email address and password. Then, in order to customize their stimulation, we ask for their body type information. This minimal amount of information is important in case of a security breach. In addition, users can be assured that their information is not being shared, since we are not asking for profitable information such as credit card information. There is no way the user can be identified by any of the information they voluntarily give. Another feature to give the user more privacy is an option to clear their account data. Account information is stored in a database, so when the user chooses the option to clear their account, all of their information will be wiped from our database, rather than the account just disappearing to the user. In addition, it is important to note that the user is not tied to any of the information they provide.

Once we completed the conceptual design of our device, we realized that part of our testing process required testing the device with human subjects. To ensure our testing process was executed ethically, we decided the best approach was to get approval from the Institutional Review Board (IRB). Including this in our testing process was crucial for us to feel comfortable enough to release this product to the public. This process was comprised of three separate submission and reviewal phases of our protocol. The first round of feedback we got after our first submission to our IRB consisted of many concerns regarding the hardware of our product. Our original idea was to develop our own EMS device, but this was called into question by the IRB due to our experience levels. They were concerned with the technicality of how much voltage goes into each pulse for the stimulation, since we essentially wanted to create a device that sent electrical pulses to shock the user with voltage. This brought up many safety concerns, so to alleviate many of the issues presented, we decided to go from our own EMS device to an already tested and marketed EMS device. This solution was accepted by the IRB, and the second phase brought into question our testing procedure and data collection. From this we needed to create multiple forms that protected the safety of the subjects data and the subjects. The forms that were included in this process were: informed consent, test subject questionnaire, testing procedure, and a HIPAA release form. The third phase required that we acquire approved personnel. For this, the IRB wanted us to have a physician or registered nurse present for all of the testing sessions to ensure that no medical harm was done to the subjects. It was important that we went further than just having an EMT or physical trainer.

After going through the process with the IRB and deciding on using a marketed EMS device, our team continued our design process and made more design decisions with the users safety in mind. We decided it was best to leave the control of the voltage to the device developers rather than the user. The stimulation is specifically designed for each body type and in order to ensure our device is being used correctly, the user should not be able to upsurge the voltage however they want. Another important thing to note is that because users enter their own information, a user can easily enter the wrong information to get a stimulation that is not right for their body type. We decided to include a warning that informs the user that inputting wrong information may cause harm due to the calculations that go into customizing the stimulation. By informing the user of this, our team would not be legally responsible if the user misuses the device and gets hurt. However, our team agreed that it is ethically our responsibility to emphasize the dangers of misusing the product and/or entering wrong information. To do this, we decided to include more than one small warning in more than one area.

After completing the testing phase, we were faced with another ethical issue of advertising our product. We wanted to find an ethical way to advertise our product without misleading the users with information just to make a profit. We tackled this issue by researching multiple case studies on electric muscle stimulation and used them to measure the viability of our product. For the most part, these reports mainly agreed on the same principles: the stimulation is good for alleviating discomfort but not necessarily for pain elimination. Also, we wanted to be clear that these reports also stated that the effects really depend from person to person. To make sure people do not end up feeling cheated or lied to, we were able to include information from those various studies in our reports and papers to alert the users of what to expect when using our device. Another aspect of this advertising phase was designing the product to the best of our abilities. We made sure to eliminate all possible ambiguities in order to give our consumers exactly what they were paying for.

11.1.4 Concluding Remarks

For the course of this project, we as a team knew the type of ethical dilemmas we would come across as we undertook this massive task. However, we did not exactly know the scale at which they would come at us. So many aspects of the project were tested ethically, from the hardware hooked up to the user to the software installed on the users device and even the advertising of our product in any disclaimers or papers included in the product.

Whenever each new ethical problem would come up, we would need to step back and take in the perspective of the user and decide how we would feel if a company acted in this way towards us. We want to let the user know that we are trying to work with them and be on their side so that we deliver what we promise to them in a safe manner. Even when the IRB had sent our proposal back 3 separate times to re-do some of the procedures and change some of the decisions, we stuck with our idea and made the necessary changes to try and meet the IRB suggestions. Despite the numerous solutions that we came up, we know there will be many more down the line as this project continues to evolve and enter the testing phase. For these reasons, we will continue to solve any ethical issues that arise from our design project and always remember to think ethically and to make any decisions with an ethical mindset.

11.2 Social

The previous section on ethics covers this topic in detail. Whatever effects this could have on society, we do our best to ensure maximum benefits for our users while minimizing any risks involved with using LATS.

11.3 Political

Our product is not intended to have a political affect on society.

11.4 Economic

We have designed this product to save the consumer money through more cost-effective materials and parts used in the construction of the device. The total amount to make this ended up being a little over $100 which would be sold at a little higher price; however, this is much less than most of the similar devices found on the market today which can end up being as high as $400 or so.

11.5 Health and Safety

In order to ensure the best health and the greatest safety, we took all steps and precautions advised to us such as getting approval through the IRB and creating various waivers and forms for the test subjects to fill out. Our goal is for all appropriate users to get the most out of using our product in order to better themselves.

11.6 Manufacturability

This project helps with manufacturability from using low-cost materials and cost-effective solutions. The total costs are outlined in Table 12.2.

11.7 Sustainability

Some of the most important parts of hardware from our senior design project were the Arduino, electrodes, and the EMS device. The Arduino is the "brains of the operation" and composed of electrical components soldered to a printed circuit board or PCB. The electrodes are made out of polyurethane film and an adhesive backing. The EMS device is made of many of the same parts as the Arduino and of course contains extra plastic material due to the encasing. Since all of these components are made of mostly plastic they will release greenhouse gas emissions during production and decomposition. With this in mind we worked to limit the amount of excess materials in our project, like using too many wires or throwing out repairable parts. For our project we needed to take apart the plastic encasing that surrounded the printed circuit board of the electrical muscle stimulator device that all the electrical components are covered by.

Our original plan was to take apart the case and design a new one that would fit with the additional components and modifications we made to the physical board. However, after finding out that a lot of carbon dioxide pollution comes from burning plastic waste such as this encasing, we decided to keep the plastic and adapt our design to work with the existing shell. Once our product grows out of its infancy, we want it to be built to last. Since it will be used on a regular basis we are going to ensure that the materials we pick in the future for production are able to withstand whatever workout environment the user chooses to be in. This is not only for the sake of the user but also the larger world around us. We don't want to design a product that is built to last only a short amount of time and contribute to the existing waste in the world. We want the LATS device to withstand the elements and time along with being repairable if and when any hardware problem occurs.

11.8 Environmental Impact

We used recyclables in our materials for the compression shorts, though the rest of the materials might be harder to recycle due to their electronic nature. We are aware of the environmental impact that LATS can have on this planet and must make sure to advise our users to properly dispose of their product at e-waste facilities when they no longer have a need for it.

11.9 Usability

LATS was originally designed to be an alternative to the bulky and complex systems of electrical stimulation that anyone can find on the market today. With an installation guide and user manual included, along with prompts given by the companion app in easy-to-understand language, the hope is that anyone with knowledge of how to work a mobile device will be able to use LATS with no trouble.

11.10 Lifelong Learning

This project definitely made all of us on the team learn how to quickly adapt and learn a new tool or environment in order to complete it. Reverse engineering was needed for the hardware construction and an entire unfamiliar integrated development environment had to become second nature when working on the software. The lessons we learned from the design project process are detailed in the next chapter.

11.11 Compassion

Our goal for compassion through LATS is not by directly ending someone's emotional suffering; our perspective on compassion is to help them help themselves by providing a means to aid their physical workouts and alleviate any physical suffering preventing them from achieving the goals they set for their physique. The team is spreading its compassion for society through physical means which could end up not only reducing their physical suffering, but suffering in other aspects of the people's lives as well.

Chapter 12

Conclusions

This design project may not have accomplished everything that our team had set out from the very beginning, but with every team project, some compromises and alternate plans needed to be made. Overall, we are satisfied with the progress we ended up making on LATS, despite not being able to conduct testing on human subjects or implement every feature we would have liked to have had in the companion app. Through this experience, we encountered many obstacles along the way and picked up valuable lessons for our future careers in engineering. These obstacles and lessons, along with the planned future for LATS, are explained in the sections that follow.

12.1 Obstacles Encountered

As with every project, our team encountered many obstacles throughout the design and implementation stages. Many of them were common technical issues engineering teams face, such as various bug encounters and problems with transistors.

For bugs within our software, we continuously unit tested in order to pinpoint where exactly the bugs were and how it was affecting our design. We did this by testing each activity, such as the settings or login activity of our application, separately.

One of the largest obstacles our team encountered was getting approved for human testing by the Institutional Review Board (IRB). Our team initially applied for an exempt review, but because of the nature of our project, we decided to extend our review to a full review. This prolonged the approval process and forced us to go through many iterations of our design. Overall, we had to delay our human testing in order to follow as many safety protocols as possible.

Table 12.1: Obstacles encountered along with the solution

Obstacle	Solution
Various Bug Encounters	Continuously unit tested, read through debugging logs
Problems with Transistors	Pins were high when not triggered; still fixing
Unfamiliarity with Technology Used	Used written documentation on Android and Arduino libraries as well as pre-made libraries
Human Testing	Tried for IRB review; Human testing delayed

12.2 Lessons Learned

12.2.1 Reverse Engineering

With our finalized design, we ran into a couple of technical issues. While we were trying to troubleshoot the transistor to act as a switch, we saw that the device would turn on by itself. This meant that the N-MOS transistor was receiving a voltage at its drain that was always high and triggering the button. When we were reverse engineering the problem, we ran into a roadblock of being unable to backwards analyze the traces on the circuit board. Since this is a marketed product which belongs to a company, we could not access the schematic for because it was proprietary information they dont release to the public. Because of this small but valuable piece of information, we were unable to resolve this issue. From this experience, we learned that if we are going to use an off the shelf device for our prototype we need to have the schematics and all the component information so that we have the ability to see what the electrical characteristics of this product are and how we can use them in conjunction with our design.

12.2.2 Task Planning

While working with the Institutional Review Board we learned that things can and will take longer than you anticipated, and you need to be prepared to make changes on the spot. Due to the numerous design iterations, we had to frequently change our ideas and testing plans. This taught us that it is important to start completing the requirements for testing early on in order to could start human testing as soon as possible. Getting approval from the IRB earlier would also allow us to finalize designs earlier. In addition, it is important to have ideas start small first. This would allow us to tackle tasks at a smaller scale, rather than always having to modify our big picture design.

12.2.3 Version Control

Another important lesson that we learned is managing version control. For this project, we had three programmers working on our code, so it was essential that our versions of code were always synced. We all need to be working on the same, current version of the software and version control allows us to ensure none of us are modifying the same code to reduce software bugs.

12.3 Advantages and Disadvantages

The main advantage of our LATS device compared to similar workout devices is our implementation of the stimulation with the user's lactic acid. Stimulation devices on the market today require the user to have background knowledge of Electrical Muscle Stimulation (EMS). The user has to manually turn on the stimulation, and may not know when the right time do to that is. Our device allows the EMS to begin when the user's lactic acid threshold is reached, which is calculated with the measurements of our heart rate monitor. In addition, a large advantage of LATS is the cost which would be based off the total cost of our hardware, shown in Table 12.2. On the market, similar EMS devices can cost up to $400, which puts the price of our LATS device at a significantly lower price.

Table 12.2: Hardware amounts and total costs

Material	Quantity	Cost/Unit
Heart Rate Monitor	1	$49.90
Bluetooth Adapter	1	$9.99
Arduino Nano	1	$4.62
iReliev EMS device with electrodes	1	$79.95
Electronic Components	1	$10.00
Compression Shorts	1	$16.98
	Total Cost	$171.44

The main disadvantage to our approach would most likely have to be the physical limitations imposed on humans when using a device that provides electrical stimulation directly to their person. Unfortunately, any prospective users with an underlying or existing heart condition, nervous system disorder or implanted medical device that delivers electrical pulses such as a pacemaker, are strongly advised against using our LATS product for personal use without supervision of their primary care physician or other qualified personnel. Other disadvantages may include the need for a calibration test every now and then to ensure the device is as accurate as possible and the possibility of injury occurring from either direct or indirect use of LATS (health and safety regarding our project is explained in great detail in Chapter 11).

12.4 Direction of Future Work

Most of the work involved with this project will be spent on getting our testing approved, conducting our testing on human subjects to produce results and further refining the technology used in both the hardware and the companion app. The testing plan has already been created; all that is left is approval and selecting viable candidates for testing through our own process. For now, the Arduino is running in conjunction with an already available product so we will eventually create our own circuit to power the stimulation on its own without the need of another device. Finally, the companion app will be expanded on to include other activity trackers such as sleep and nutrition, the user interface will be overhauled to give it its own unique feeling for the user to enjoy and the app will be ported over to other platforms such as the iOS environment.

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Appendix A

Installation Guide

For the current state of the project, all an individual would need to install before acquiring LATS for their own use is a computer with Internet access, a mobile Android device and a Bluetooth heart rate monitor. First, they would need to download the latest version of Android Studio from Google online and install it on to their personal computer. Next, they would need to visit `github.com/fguerra0` and visit the *myLATS* repository and download or clone the entire repository to their local device. Once those two pieces have downloaded, they now need to import the Github project into Android Studio as a new project and plug in their mobile Android device into their computer via USB. Finally, they would set up their device as an environment to run the application and build and run the app on their device. With the app installed and the heart rate monitor turned on, all that is left to do is to search within the menus and connect the heart rate monitor via Bluetooth. This individual is now ready to own and use their own LATS device for their next workout.

Appendix B

User Manual

Begin by making sure all of the parts are together and functional. In order for LATS to work properly, you must have the wearable device, the heart rate monitor, and an Android phone capable of Bluetooth. Begin by turning on all of the devices. Once they are on, strap on the heart monitor across your chest for best results. Carefully put the wearable clothing on, making sure it is on comfortably. Next, connect your phone to the device through typical Bluetooth protocol. Once it is connected follow the prompts on the application in order to use as desired.

Appendix C

Source Code Implemented

Our complete source code used in this project involves the Java code for the application in Android Studio. The Java code can be found at `www.github.com/fguerra0` under the *myLATS* repository.

Appendix D

Complete List of Parts Used

Refer to Table 12.2 in Chapter 12 for the complete list of all hardware parts used in this project.