# Mission Folder: View Mission for 'The Three Musketeeretts'

| | |
|---|---|
| **State** | Oregon |
| **Grade** | 9th |
| **Mission Challenge** | Technology |
| **Method** | Engineering Design Process |
| **Students** | |

## Team Collaboration

***(1) Describe the plan your team used to complete your Mission Folder. Be sure to explain the role of each team member and how you shared and assigned responsibilities. Describe your team's process to ensure that assignments were completed on time and deadlines were met.***

To efficiently complete our mission folder we decided to delegate specific roles for each member. However, it did not seem right for one person to write a whole section. Instead, we assigned a "Lead" for each of the three sections of the Mission Folder, who would distribute the tasks of her section and oversee its progress by checking up on weekly deadlines. Because each Musketeerette had a section to "Lead" we were able to smoothly follow our action plan as there was always a person distributing work and keeping everyone in check before moving on. We also assigned a "Reviewer" to critique and appraise each section.

Musketeerette 1: Community Benefit Lead + 'Problem Statement' + 'Experimental Design' + Documented Bibliography + (Team Collaboration Reviewer)

Musketeerette 2: Engineering Design Lead + 'Building Prototype' + 'Testing Prototype' + Completed IRB and Survey form + (Community Benefit Reviewer)

Musketeerette 3: Team Collaboration Lead + 'Drawing Conclusions' + Mission Verification + Abstract + (Engineering Design Reviewer)

Our Plan:
Week 1: Select a Topic
Week 2: Find a Problem
Week 3-7: Research + Criteria/Constraints
Week 7- End: Design First Prototype + Testing + Complete Mission Folder

We used the Rose/Thorn/Bud technique to evaluate our work throughout the competition. One Musketeerette shared their work, then the other two Musketeeretts would say one positive thing/something to keep (Rose), one constructive thing/something to remove (Thorn), and one new step following the work the member shared (Bud). This method was a nice way to encourage one another, appreciate each member's work, and make our feedback more helpful and motivating, so there was less pressure in sharing our ideas.

For example, Musketeerette 2 thought of the elementary problem statement "How can we depreciate the cost of a prosthesis for amputees using VR?" When the other two musketeeretts evaluated this, they agreed that depreciating cost and using VR was a unique idea (Rose) but prosthesis was a topic a little too big for this project (Thorn). From there we decided to improve the problem statement by trying to minimize phantom pain (Bud).

With each member's set of tasks, our team always assisted and encouraged each other to keep ourselves on target and ease the pressure off our specific duties.

One specific example was when Musketeerette 1 was working on the Bibliography. All of her research links formatted into MLA, but she needed help to make it more coherent. After reviewing it, Musketeerette 3 had the idea to add small descriptions of each link to make it easier to find information and helped Musketeer 1 add them in. Musketeerette 2 also found links she had used personally to add. Together as a team, we were able to keep Musketeerette 1's work on the right track efficiently, and we could continue with our schedule.

Uploaded Files:

- [ View ] **Team Collaboration content with graphics** (By: 321666, 02/22/2017, .pdf)
  *Our Team Collaboration folder with all graphics included.*

## Engineering Design

Problem Statement

***(1) What problem in your community did your team try to solve? Why is this problem important to your community?***

The growth in the technological and medical field has been quite significant this decade. However, even as humans are making significant breakthroughs in certain matters, new issues are quickly rising.
One obstacle on the rise, perhaps one of the most rapid, is amputations. It is hard to imagine that "Currently, 1.9 million people are living with limb loss in the United States, and an average of 507 people continue to lose a limb every day. This increase results in an estimated 185,000 amputations per year." (Source 1). Moreover, this is certainly

not an issue that is planning to slow down anytime soon. The increases in diabetes, peripheral arterial diseases, vascular diseases, trauma and (believe it or not) lawn mower accidents has triggered a rise in amputations. What's even more frightening is that the number of amputations per year "is expected to double by the year 2050". In our state of Oregon, there has been a 38.96% increase in amputations performed from 2000 to 2013 (Source 1). That is no minuscule number, and it is important not to forget that.

The number of amputees is escalating much faster than anyone has ever expected, with such a significant population of people suffering from the effects of amputation we wanted to make a solution that would change the way amputees face his or her challenges.

Our problem statement: How can we minimize Phantom Limb Sensation/Pain for amputees using VR technology, cost effectively?

***(2) List at least 10 resources you used to complete your research (e.g., websites, professional journals, periodicals, subject matter experts). Use multiple types of resources and do not limit yourself to only websites.***

Before we began designing our solution it was essential that we had a strong background of our topic. To do so, our team divided our research into the types of sources we should collect; Websites, Books, Case Studies, Articles, and Expert Discussions. By using a variety of sources we got a strong understanding of the problem we were trying to improve before improving it and we were able to pick up a lot of information we could have otherwise not noticed.

Websites:
1. "Oregon Fact Sheet." Amputee Coalition . Amputee Coalition , Apr. 2016. Web. Dec. 2017. http://www.amputee-coalition.org/resources/oregon-2
This site covers facts about amputees in Oregon/United States of America, as well as daily and yearly limb loss trends in amputees. Data is also available for the types of amputations performed and demographics for the factors of gender, race, and age, on amputations. Lastly, it covers the current the current health care costs. This source is imperative for backing our design's importance/usefulness.

2. Firm, Pisanchyn Law. "Types of Amputations." Types of Amputations| Amputation Types | Pennsylvania Amputation Lawyers. Pisanchyn Law Firm, 08 Mar. 2013. Web. 15 Jan. 2017.
http://www.catastrophicallyinjured.com/pennsylvania-amputation-attorneys/amputation-types.html
We wanted to conduct research on the types of amputations before prototyping. This website shared the common types of amputations and their effects on the amputee. The broad range of amputations enforced us to design a prototype for a particular amputation before expanding.

3. "Managing Phantom Pain." Amputee Coalition. Amputee Coalition, n.d. Web. 15 Jan. 2017.
http://www.amputee-coalition.org/limb-loss-resource-center/resources-for-pain-management/managing-phantom-pain
To understand the concept of Phantom Limb Sensation and Phantom Limb Pain (as well as the difference), we used this site for an aggregate explanation. It covers a broad range of reasons for Phantom Limb Sensation/Pain, including non-amputation related conditions. Lastly, it describes current therapy and medications for PLS/PLP and their effectiveness. This resource had provided an essential background before we began designing a solution.

4. "Phantom Limb Pain: Mirror Therapy Treatment." MedicineNet. N.p., n.d. Web. 15 Jan. 2017.
http://www.medicinenet.com/script/main/art.asp?articlekey=88097
To fully understand mirror therapy, a form nonpharmacological of treatment for Phantom Limb Sensation/Pain, we read about Jack Tsao's tests on amputees and a breaking down of why it works. Before finalizing our solution, we wanted to know the successfulness of the current therapies for PLS/PLP.

Books:

5. Ramachandran, V.S. The Tell-Tale Brain. N.p.: Norton, W. W. & Company, Inc., 2012. Print.
This book provided us with a range of information. V.S Ramachandran explains his theories on the origin of Phantom Limb Sensation/Pain; The area in the brain deprived of sensory inputs becomes hungry for new sensations. We also learned about his methods in 'unlearning' phantom limb pain- an in-depth analysis of mirror therapy. This book was both an informative and fascinating read.

6. Murray, Craig, ed. Amputation, Prosthesis Use, and Phantom Limb Pain: An Interdisciplinary Perspective. London: Springer Science & Business Media, 2010. Print.
The text offers a broad and innovative exploration of the entire process surrounding limb loss and eventual recovery. We were able to read in-depth on the adaptation to amputation and prosthetics, as well as post-amputation phantom limb sensation/pain recovery period.

Case Studies:

6. "Phantom Limb Pain." Phantom Limb Pain. Minnesota Department of Health, Aug. 2016. Web. Fall 2016.
The Minnesota Department of Health created a study covering completed clinical trials, and observational studies on PLP, which we used before conducting our tests.

7. Nejatkermany, Mahtab Poor Zamany, Ehsan Modirian, Mohammadreza Soroush, Mehdi Masoumi, and Maryam Hossein. "Phantom Limb Sensation (PLS) and Phantom Limb Pain (PLP) among Young Landmine Amputees." Iranian Journal of Child Neurology. Shahid Beheshti University of Medical Sciences, 2016. Web. 27 Dec. 2016.
This study provides the results and methods used for better understanding in Phantom Limb Sensation and Phantom Limb Pain. It also includes referable results/statistics on the PLS/PLP period.

8. Virtual Reality Prosthetics. N.p., n.d. Web. 27 Dec. 2016.
To ensure our design was unique, we investigated similar projects- and their effectiveness. This link provides an example of a VR solution used for amputees before prosthesis; It includes videos on the community benefits and goals of the product. Our design does not share the same approach nor intentions, but it was important to confirm the differences.

9. "Virtual Reality for Phantom Limb Pain." Virtual Reality for Phantom Limb Pain - Tabular View - ClinicalTrials.gov. N.p., n.d. Web. 27 Dec. 2016.
We wanted to find a complete study of Phantom Limb Sensation/Pain and discovered this proposed government plan, for studying amputees and VR. We aim to create a more cost-effective study than their proposed project. The goal of this project is to offer a distraction from the PLS/PLP. Our goal is to provide a therapy for PLS/PLP.

Articles:

10. "Developing the World's Most Advanced Prosthetic Arm Using Model-Based Design." Developing the World's Most Advanced Prosthetic Arm Using Model-Based Design - MATLAB & Simulink. N.p., n.d. Web. 27 Dec. 2016.
This article provides a description of a complete simulation of a virtual prosthetic arm run by Matlab and Simulink. This article includes the design process, i.e., creating the integration environment, interfacing with the nervous system. The aim of this project was to develop a virtual prosthetic arm (not used for therapy) that will move with the correct physics of an identical prosthetic arm. Though not directly relating to our solution, we still wanted to discover new technologies for amputees, and it helped us get ideas for our project.

11. Greenwald, Will. "The Best VR (Virtual Reality) Headsets of 2017." PCMAG. N.p., n.d. Web. 15 Jan. 2017.
To keep our design cost- effective, we scrutinized the many types of VR headsets. This article distinguished the available technologies for displaying our VR app to the

amputee and narrowed our choice. Following this reading, we decided on the Google Cardboard as it fit our needs as well as stayed on budget.

12. Ramachandran, V. S., and W. Hirstein. "The perception of phantom limbs. The D. O. Hebb lecture." Perception of phantom limbs. The D. O. Hebb lecture. | Brain | Oxford Academic. Oxford University Press, 01 Sept. 1998. Web. 15 Jan. 2017.
This article explains how the brain perceives phantom limb pain and also different medical technology that shows cortical topography in the patient/amputee. It also covers more advanced operations and imaging procedures.

Expert Discussions:

13. Hayes, Karen, Ms. "Expert Discussion with Karen Hayes." Personal interview. 9 Feb. 2017.
To learn more about the community of amputees we met up with the director of the American Amputee Foundation of Oregon, and an amputee herself. We shared our project with Karen, gave her a chance to try out the prototype and got our questions about amputees and Phantom Limb Pain/Sensation answered.

14. Seibert, Tom, Mr. "Expert Discussion with Tom Seibert." Personal interview. 9 Feb. 2017.
During our meeting with Karen, she recommended we speak to Tom at Advanced Arm Dynamics, who (as an amputee who had lost his lower left arm) could be of real help in testing our prototype out. We met up with Tom at the Advanced Arm Dynamics office where we presented our design to him and the whole clinic team!

***(3) Describe what you learned in your research.***

We began our research by thinking of the current problems we face in our community and the world. For each of these problems, we brainstormed possible solution then chose the most important ones to research further- including the relevance to our eCybermission.
To determine the importance of our problem in the community, now and in the future, we did extensive research on the amputee population, our state of Oregon in particular. We wanted to see the magnitude amputations had near us; the results left us with consternation. Source 1 told us that amputations performed in Oregon were at a high of 1,687, according to hospital discharge data. It is an issue that is not only relevant in our state but also throughout the globe; as there are nearly 10 million people worldwide suffering from the effects of amputations.

First, we began by studying the major challenges faced by amputees. As side effects of an amputation, amputees Amputees face many negative cognitive changes such as phantom limb sensation (PLS) and phantom limb pain (PLP). PLS/PLP can be described as “Pain that is experienced in a missing or amputated limb” (Source 6). To narrow down our research and problem topic, we chose to target minimization of PLP and PLS as they frequently occur in many amputees and can be very damaging to the amputee’s mental and physical condition. A study about the frequency of PLP and PLS concluded that “Phantom limb sensation and pain… appear to be common even after years of amputation” (Source 4).

Next, we researched the current methods of pharmacological treatment for PLP. We first found the use of opioids, a drug that relieves pain in the brain (Source 6). However, this treatment has proved to only have moderate success in reducing Phantom Limb Sensation/Pain and was only effective in reducing PLS/PLP short term. We found that non-pharmacological treatments were more beneficial in reducing PLS/PLP. For example, Mirror Visual Therapy is a process where an amputee places their corresponding non-amputated limb in a mirrored box, which gives the effect that they have reinstated their limb. This treatment has proven to be effective in reducing PLP, although there have been no formal trials conducted using this treatment. A similar procedure called guided imagery, asks for the amputee to use their mental imagery to create an image in which the amputee can feel their missing limb.

With a clearer idea of our problem, we thought of using Virtual Reality (VR) technology to better implement a combination of mirror visual therapy and guided imagery treatments for PLP. We found a similar study had been conducted using VR for amputees. The cost of this solution was inordinately expensive, therefore excluding many amputees, who could otherwise benefit from it. We also wanted to orient our design as a PLS/PLP therapy, rather than just a distraction. Our team decided to conduct more research on the current types of VR technology to find a more cost-effective solution. Virtual reality tech ranged from products such as the Oculus Rift, a $800 VR headset and the Google Cardboard, a $15 VR headset. We went through over 15 products in the market, analyzing, comparing, contrasting between their costs, efficiency and their features until we decided to use the Google Cardboard. Gesture control technology was much easier to look at, as it is a new concept the only compatible product for our needs was the Myo, $200 gesture control armband. By thoroughly analyzing the technology available we were able to get a deeper understanding of how we should design our solution.

Experimental Design

***(4) Develop a design statement. Be sure to describe what exactly your device should be able to do. Do not describe HOW it’s going to do what it needs to do.***

Our final design should be able to recognize multiple gestures from amputee’s with different amputations (see below) and create a virtual limb with correlating movements to the amputee’s gestures through a cost effective design. The virtual environment should create the illusion that the amputated, and remaining limb, are both moving. This process will reduce the amputee’s opioid use and Phantom Limb Sensations/Pain. The specifications are as follow

1. Recognize skeletal muscle gestures from an amputee with

Upper Limb Amputations:
Metacarpal Amputation
Wrist Disarticulation
Transradial Amputation
Elbow Disarticulation
Transhumeral Amputation
Lower Limb Amputations:
Partial Foot Amputation
Ankle Disarticulation
Transtibial Amputations
2. Easily wearable
3. Easily removable
4. Adjustable
5. Comfortable
6. Accessible at home or a hospital

***(5) Determine the criteria for a successful solution and identify constraints for your design. Discuss what the device must have in order to accomplish its job and the restrictions of the device (i.e. the size, the cost, the weight, etc.).***

Criteria:

1. The device must be cost-effective.
Many current forms of non-pharmacological/pharmacological treatments for phantom limb pain are expensive, making it exclusive for use by only those that can afford it. By

making our device cost-effective, we can make it available to virtually every amputee that needs it.

2. The device must be able to recognize gestures made by the amputee.
The VR app on the Google Cardboard headset should be able to identify the signals the remaining portion of the amputee's limb, using the Myo Gesture Control Armband. The VR app must then be able to translate them into gestures on the virtual arm, seen in the Cardboard.

3. The device must be easy to use by the amputee.
For utilization in a hospital, home and amputees of all ages, the device, and its setup must be straightforward and easy to use.

Constraints:

4. The prototype must be complete in six weeks.
The deadline for the mission challenge limits the time to build, test, and evaluate the prototype.

5. The cost of the device must not exceed $250.
The cost of our prototype cannot exceed $250 according to the official rules of eCybermission.

***(6) Identify the relevant variables you will use to test your prototype or model and explain how you will measure your variables.***

The variables we were testing in our design is the percent of accuracy in the gesture control sensor synching with the VR app. We will test our design on transradial amputees, and measure the percent of gestures correctly picked up. We can measure this by analyzing the data from the eight EMG Pods on the Myo Gesture Control Armband.

Build Prototype or Model

***(7) Develop a design and list the materials you used in your design. Include technologies you used (e.g., scientific equipment, internet resources, computer programs, multimedia, etc.).***

To get the needed results, we are using a variety of materials and technologies to develop our design efficiently.

1. Google Cardboard: We run our VR application on the Google Cardboard and use it to connect with the Myo Armband.

2. Myo: Using the Myo SDK on unity, the Myo Gesture Control Armband can connect to Unity. The VR app can then replicate the gestures from the Myo Armband onto the screen. With the Myo's eight EMG Pods we can test the percent of accuracy of gestures being correctly picked up.

3. Development Tools \ SDK:
-Unity 3D Studio: Software we used for compiling the VR application and creating the virtual scene. We are using an older version (5.4.4) because the Myo SDK had issues with the newer versions.
-Google VR SDK: This provides the software for compiling the project to be accessed on Google Cardboard.
-Myo Connect: Software to connect Myo device with the PC.
-Myo SDK: Like stated above, the Myo SDK allows Unity to read the Myo Armband's gestures.
-Myo Unity Pluggin for Android

4. Smart Phone: We are using a Samsung Galaxy s6 to view the VR application and to use for the Google Cardboard.

***(8) Explain how you built your prototype(s) or model(s). Include each of the steps in your process. Include all safety precautions used by your team as step one.***

1. Checked for safety of website before downloading any software
Parent verification before downloading software
Verified latest anti-virus software before downloading any component from the Internet
Check for copyright restriction and understand open source usage policy
Approved IRB form before any testing
2. Drew out a design flow chart
3. Downloaded Myo Connect
4. Downloaded Unity SDK (5.4.4)
5. Downloaded Myo SDK
6. Downloaded Google Cardboard SDK for Unity
7. Downloaded Sample Code
8. Created a sample Unity game
9. Created our Unity Environment and Player
10. Placed our Unity Camera and Play Area
11. Created our Unity objects and other elements
12. Added Assets: Myo SDK, Google Cardboard SDK
13. Pushed to Android and launched application on Phone
14. Tested
15. Refined Unity Project and re-tested

Test Prototype or Model

***(9) Present the data you collected and observed in your testing. The use of data tables, charts and/or graphs is encouraged.***

To test the accuracy of our prototype, we recorded the percentage of the gestures correctly recognized. We were able to test our design on five subjects, with five trials per gesture (See attached files)

***(10) Analyze the data you collected and observed in your testing. Does your data support or refute your design statement? Do not answer with yes or no. Explain your answer using 'Our data supports/refutes the design statement because...'***

Our data supports our design statement because our final design was able to consistently recognize many gestures from the amputee's limb consistently and correlate the movements of the amputee's gestures, through a cost-effective design.

Our design was able to recognize each gesture and complete the corresponding game step accurately. The double tap gesture has recognized an average of 93% to open the game. The amputee could push objects away 60% of the time, but it was 73% accurate in pulling the objects. Lastly, the amputee could 'grip' objects using the fist gesture 80% of the time. An outlier was found in the Spread Fingers gesture, which was only 47% consistent.

***(11) Explain any sources of error and how these could have affected your results***

While we tried our hardest to make our prototype an accurate representation of our design, there are several sources of error to take into account that they could have affected our results:

1) Not tested on a range of amputees.
Our prototype can only be tested on amputees who have lost the lower extremity arm. Therefore the information we have collected only relates to a select group of amputees and is irrelevant for amputees with different conditions. Even if our prototype works ideal for one amputee, it could be unsuccessful for another.

2) Not fully able to test for results.
As it can take years, even a lifetime, for an amputee to overcome PLP/PLS our prototype was never tested for effectiveness in overcoming these problems. It relies more on the psychological hypothesis of the professionals and amputees we have spoken to, as well as what we read. Within our constraints, we cannot prove our prototype helps amputees overcome PLP/PLS, but in theory, it should.

3) Data is qualitative
Phantom Limb Pain and Phantom Limb Sensation are both more emotional than physical. It is impossible to track the level of pain or discomfort precisely an amputee will experience over time nor can you precisely measure the pain or discomfort an amputee experiences. We analyzed our results based on the percent of gestures accurately sensed by the Myo, but this may not directly correlate with the Phantom Limb Pain/Sensations.

4) Myo's accuracy
During our first trials, we began to find an inaccuracy in the collected EMG data. To identify the error, we had the Myo device in a static condition (the amputee's arm is at the stationary position). Because the Myo did not move, there should have been no changes in the recorded EMG data; However, we found many fluctuations in the values, showing we were processing errors in our data collection. We found more accurate values for the Accelerometer, and Gyro results, but we would need to retest the scenario for better results. In addition to this the armband size played a significant role in accuracy, a smaller arm would not be able to recognize gestures as easily as a bigger one. For example test subject 3 had the smallest arm and the lowest accuracy of 71% while the largest hand size test subject 1 had the highest accuracy of 85%.

Drawing Conclusions

***(12) Interpret and evaluate your results and write a conclusion statement that includes the following: Describe what you would do if you wanted to retest or further test your design. Evaluate the usefulness of your prototype or model. What changes would you make to your prototype or model for the future, if any?***

To further test our design we would retest on a larger sample group of amputees with different amputations, that would test our prototype's efficiency more accurately. Retesting on a larger group of amputees with a variety of amputations can also give us more feedback on how well the design of the prototype works, which will help us make improvements. We would also conduct testing over a longer period. As this is a therapy the patient's PLP/PLS will require several sessions using the design, not just one.

Because PLP/PLS is not a physical phenomenon, to measure the long-term effects of our VR therapy and an amputee's Phantom Limb Sensation/Pain is currently beyond our prototype's capabilities. However, our prototype performs very accurately in the underlying concepts of our design. Our prototype can successfully collect data from Myo's EMG pods, which is significant because it means that our program can receive the signals from Myo and translate it into movements in the Unity program. The EMG data is extremely consistent with gestures such as wave out and double tap. This proves that the prototype can accurately respond to the gestures that the amputee will make to interact with the virtual environment. Our prototype completes its criteria effectively; we just need to put it into practice.

Although our prototype was successful in creating a virtual limb for the amputee as well as a gamified therapy, it is not yet complete. First, we want to improve the virtual setting. The more realistic the surrounding, the better the therapy. We want also to explore the option of making the virtual setting into a place that the patient feels more comfortable. For example, we could create the virtual setting of one patient into their bedroom, a place that they will most likely feel more comfortable and relaxed. This will also allow the patient to heal faster because they are more open, rather than being in a tense hospital environment. Secondly, as the gestures required practice from the patients, practicing the movements before testing might make our prototype more efficient and easier to use.

Uploaded Files:

- [ **View** ] **Expert Discussions** (By: 321666, 02/22/2017, .pdf)
  *Our meetings with Karen, the director of The American Amputee Foundation of Oregon with a Transtibial Amputation and Tom at Advanced Arm Dynamics, who lost his lower left arm.*
- [ **View** ] **Problem Statement** (By: 321666, 02/22/2017, .pdf)
  *Problem statement section of the mission folder - The problem, Resources, and Our Learning*
- [ **View** ] **Experimental Design** (By: 321666, 02/22/2017, .pdf)
  *Experimental Design section of the mission folder - Design Statement, Success Criteria, and Variables*
- [ **View** ] **Build Prototype** (By: 321665, 02/22/2017, .pdf)
  *Build Prototype section of the mission folder - Bill of Material and Procedure*
- [ **View** ] **Test Prototype** (By: 321665, 02/22/2017, .pdf)
  *Test Prototype of the mission folder with Data Collection, Analysis, and Source of Error*
- [ **View** ] **Drawing Conclusions** (By: 321665, 02/22/2017, .pdf)
  *Drawing conclusions of the mission folder with Evaluations*

## Community Benefit

***(1) How could your design help solve your problem and benefit your community? Describe next steps for further research/design and how you have or how you could implement your solution in the future.***

Our design provides a cost effective therapy for Phantom Limb Sensation (PLS) and Phantom Limb Pain (PLP); amputee's most preeminent challenges. With amputation rates on the rise, there are ever more patients desiring effective PLS/PLP therapy. Our design will lessen the PLP in an amputee by creating the image of a working limb in the gesture control synced VR app. By using low-cost technologies such as the Google Cardboard, we can keep our design cost efficient while still effectively solving the problem. It could benefit the community of over 22,828 amputees in Oregon, of which 80% face PLP (Source 1), by minimizing the number of amputees that experience phantom limb pain.

Our design will also reduce the costs of the overall treatments for amputees experiencing PLS/PLP, as current therapy prices exclude many amputees.

In the future, we want to enhance our solution by;

1. Add additional VR/gesture experiences for the user to try

The current gestures we are using will need to be expanded on to provide more freedom to the amputee. Adding more gestures will also enhance the authenticity of the VR simulation (Ex.Tying shoelaces, holding a glass, and so forth). Without the real limb, the amputee's gestures might not be the same as a person with the limb. So we researched how our design could allow amputees to set up their personalized gestures in which they are more comfortable in, as well as decipherable by the Myo. We found that by using the 'Create Profile' tab on the Myo Armband Manager, the user can personalize the Fist, Finger Spread, Rest, Wave In, and Wave Out. Using this our design will work more efficiently for the amputee.

We also found an open source code available that also provided the EMG data corresponding to the Myo's movements. This app allowed the user to record the EMG data for any arm gesture. Incorporating a similar design could eliminate the need for amputee's to learn gestures that require the image of their missing limb, which can be confusing and challenging. Rather, the amputee can make their gestures, which they are comfortable in, and have the virtual limb mimic their personalized movements.

2. Make the design compatible for people with various amputations

Our prototype can only be tested on amputees who have lost the lower extremity arm. In the future, our design should be adaptable for patients with any amputation;

Upper Limb Amputations
(Metacarpal Amputation[1], Wrist Disarticulation[2], Transradial Amputation[3], Elbow Disarticulation[4], Transhumeral Amputation[5])

and Lower Limb Amputations
(Partial Foot Amputation[6], Ankle Disarticulation[7], Transtibial Amputations[8]).

3. Make our design adaptable for patients before receiving prosthetics. We want to bring in the next step of amputation, prosthesis, into the picture. Currently, "prosthetic fitting begins two to six months after surgery" (Source 12). Our design can introduce the patient to an identical VR prosthetic (via our VR app) before receiving the real prosthetic, so when the prosthetic is made and fitted, it will take less time to adjust. In the future we could implement our solution by running a test on a much larger group of amputees, getting data from nearby hospitals and partnering up with Advanced Arm Dynamics and Amputee Coalition to get professional help in making our design a reality.

[1]Hand is removed, except wrist
[ 2] Hand and wrist are removed
[3]An amputee whose radius and ulna (bones of lower arm) are cut
[4]Forearm at elbow is amputated on
[ 5]Arm above elbow is removed
[6]One or more toes are removed
[ 7]Foot at the ankle is amputated on
[8]Leg below the knee is amputated on

Uploaded Files:

- [ **View** ] **Benefit to Community** (By: 321666, 02/22/2017, .pdf)
  *Our mission folder content for Community Benefit section with images.*

---

## Mission Verification

***(1) Does your Mission Folder project involve vertebrate testing, defined as animals with backbones and spinal columns (which include humans)? If yes, team must complete and attach an IRB approval form.***

Yes

***(2) Did your team use a survey for any part of your project? If yes, team must complete and attach a survey approval form.***

Yes

***(3) You will need to include an abstract of 250 words or less. As part of the abstract you will need to describe your project and explain how you used STEM (Science, Technology, Engineering and Mathematics) to improve your community***

According to Amputee Coalition, there are 2.1 million people in the USA living with limb loss, and 185,000 people go through an amputation each year. One of the many challenges these amputees face is Phantom Limb Pain (PLP) or Phantom Limb Sensation (PLS). It is a painful sensation where an amputee continues to feel the pain of a missing limb, nearly 80 percent of the amputee population worldwide have experienced this kind of pain.

Currently, the main treatment available is Mirror therapy, but its level of success varies from person to person. Our team wanted to create an improved, enhanced therapy using recent technology. Our project will give the amputee community a cost-effective, more advanced solution to minimize their Phantom Limb Pain or Phantom Limb Sensations. We believe our design can impact the growing population of amputees facing these issues.

While creating our prototype we have used STEM abundantly in helping us design our Virtual Reality scenario on Unity, sync our Virtual Reality scenario with a Myo armband, learn how to work with Gesture Control, and test the accuracy of our design on Google Cardboard.

We also used STEM constantly while creating our mission folder, such as by designing infographics through Canva, Pictograph, Real Time Board, Google Forms and Google Drawings. Moreover, we were able to code our entire mission folder content in LaTeX through the professional document creator Overleaf. We also created an overleaf template for the future eCybermission participants.

Uploaded Files:

- [ **View** ] **IRB Approval Form** (By: 321665, 02/05/2017, .pdf)
  *This is the copy of our IRB approval by Principal, Science Teacher and RN. We are planning to use Myo Gesture Control Armband as the interface to our Google Cardboard project.*
- [ **View** ] **SurveyApproval** (By: 321665, 02/05/2017, .pdf)

*Survey to patients that have experienced phantom pain*

- [ **View** ] **Mission folder in Overleaf** (By: 321665, 02/21/2017, .pdf)

  *Our team wanted to keep a professional documentation of our eCYBERMISSION challenge, which is why we chose to code out our entire Mission Folder on Overleaf. It is an online LaTeX and Rich Text collaborative tool for writing, editing, and publishing scientific and other documents. Our entire mission folder for the project is available online at https://www.overleaf.com/read/kqdfdzmzdqmy*

- [ **View** ] **The Three Musketeeretts - Complete Mission Folder** (By: 321665, 02/22/2017, .pdf)

  *The complete mission folder contents, covering Mission Verification, Team Collaboration, Use of Engineering Design, and Community Benefits. In this document, we have included all of our attachments*

# 2. Plan

***Describe the plan your team used to complete your Mission Folder. Be sure to explain the role of each team member and how you shared and assigned responsibilities. Describe your team's process to ensure that assignments were completed on time and deadlines were met.***

## 2.1 Breakdown of Team Responsibilities

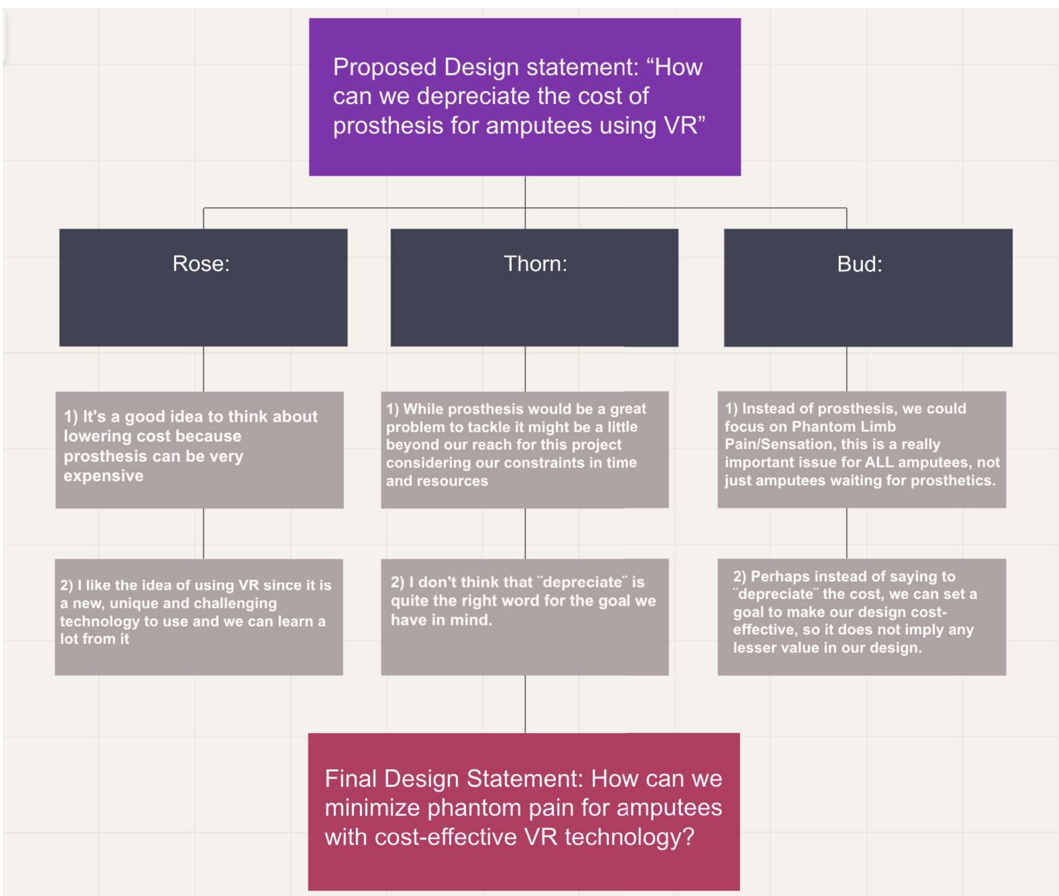
To efficiently complete our mission folder we decided to delegate specific roles for each member. However, it did not seem right for one person to write a whole section. Instead, we assigned a "Lead" for each of the three sections of the Mission Folder, who would distribute the tasks of her section and oversee its progress by checking up on weekly deadlines. Because each Musketeerette had a section to "Lead" we were able to smoothly follow our action plan as there was always a person distributing work and keeping everyone in check before moving on. We also assigned a "Reviewer" to critique and appraise each section.

We also assigned a "Reviewer" to critique and appraise each section.

- Musketeerette 1: Community Benefit Lead + 'Problem Statement' + 'Experimental Design' + Documented Bibliography + (Team Collaboration Reviewer)
- Musketeerette 2: Engineering Design Lead + 'Building Prototype' + 'Testing Prototype' + Completed IRB and Survey form + (Community Benefit Reviewer)
- Musketeerette 3: Team Collaboration Lead + 'Drawing Conclusions' + Mission Verification + Abstract + (Engineering Design Reviewer)

| | Team Collaboration | Engineering Design | Community Benefit | Mission Verification |
|---|---|---|---|---|
| *Writing Portion* | | | | |
| Nandhana | Owner | 'Drawing Conclusions' | | Abstract |
| Ragini | | Owner | | |
| Namitha | | 'Problem Statement' & 'Expiremental Design' | Owner | |
| *Reviewing Portion* | | | | |
| Nandhana | | Reviewed Doc | | |
| Ragini | | | Reviewed Doc | |
| Namitha | Reviewed Doc | | | |
| *Reasearch Portion* | | | | |
| Nandhana | -> | Current methods of treatment for PLP/PLS (in various resource formats | | |
| Ragini | -> | Uses of myo and Google Cardboard | | |
| Namitha | -> | Similar VR products currently available in the market | | |
| *Prototyping Portion* | | | | |
| Nandhana | -> | Unity Scenario Lead | | |
| Ragini | -> | Myo Sync Lead | | |
| Namitha | -> | Google VR Link Up Lead | | |
| *Outreach Portion* | | | | |
| Nandhana | -> | -> | Contacting professionals and experts | |
| Ragini | -> | -> | Documentation of Outreach | |
| Namitha | -> | -> | Updating list of questions for Expert Discussions/Mission Control | |

We used the Rose/Thorn/Bud technique to evaluate our work throughout the competition. One Musketeerette shared their work, then the other two Musketeeretts would say one positive thing/something to keep (Rose), one constructive thing/something to remove (Thorn), and one new step following the work the member shared (Bud). This method was a nice way to encourage one another, appreciate each member's work, and make our feedback more helpful and motivating, so there was less pressure in sharing our ideas.



For example, Musketeerette 2 thought of the primary problem statement “How can we depreciate the cost of a prosthesis [1] for amputees using Virtual Reality (VR) ?” When the other two musketeeretts evaluated this, they agreed that depreciating cost and using VR was a unique idea (Rose) but prosthesis [2] was a topic a little too big for this project (Thorn). From there we decided to improve the problem statement by trying to minimize phantom pain (Bud).

With each member’s set of tasks, our team always assisted and encouraged each other to keep ourselves on target and ease the pressure off our specific duties.

One specific example was when Musketeerette 1 was working on the Bibliography. All of her research links formatted into MLA, but she needed help to make it more coherent. After reviewing it, Musketeerette 3 had the idea to add small descriptions of each link to make it easier to find information and helped Musketeer 1 add them in. Musketeerette 2 also found links she had used personally to add. Together, as a team, we were able to keep Musketeerette 1’s work on the right track efficiently, and we could continue with our schedule.

## 2.2 Team Plan

Our Plan:

- Week 1: Select a Topic
- Week 2: Find a Problem
- Week 3-7: Research + Criteria/Constraints
- Week 7-End: First Prototype + Testing + Complete Mission Folder

**Idea: VR [3] /Augmented Reality Glasses that:**

- Simulates a comfortable/familiar place to accelerate healing
- Getting used to Prosthetic legs
- Improving Physical Therapy

**Research:**

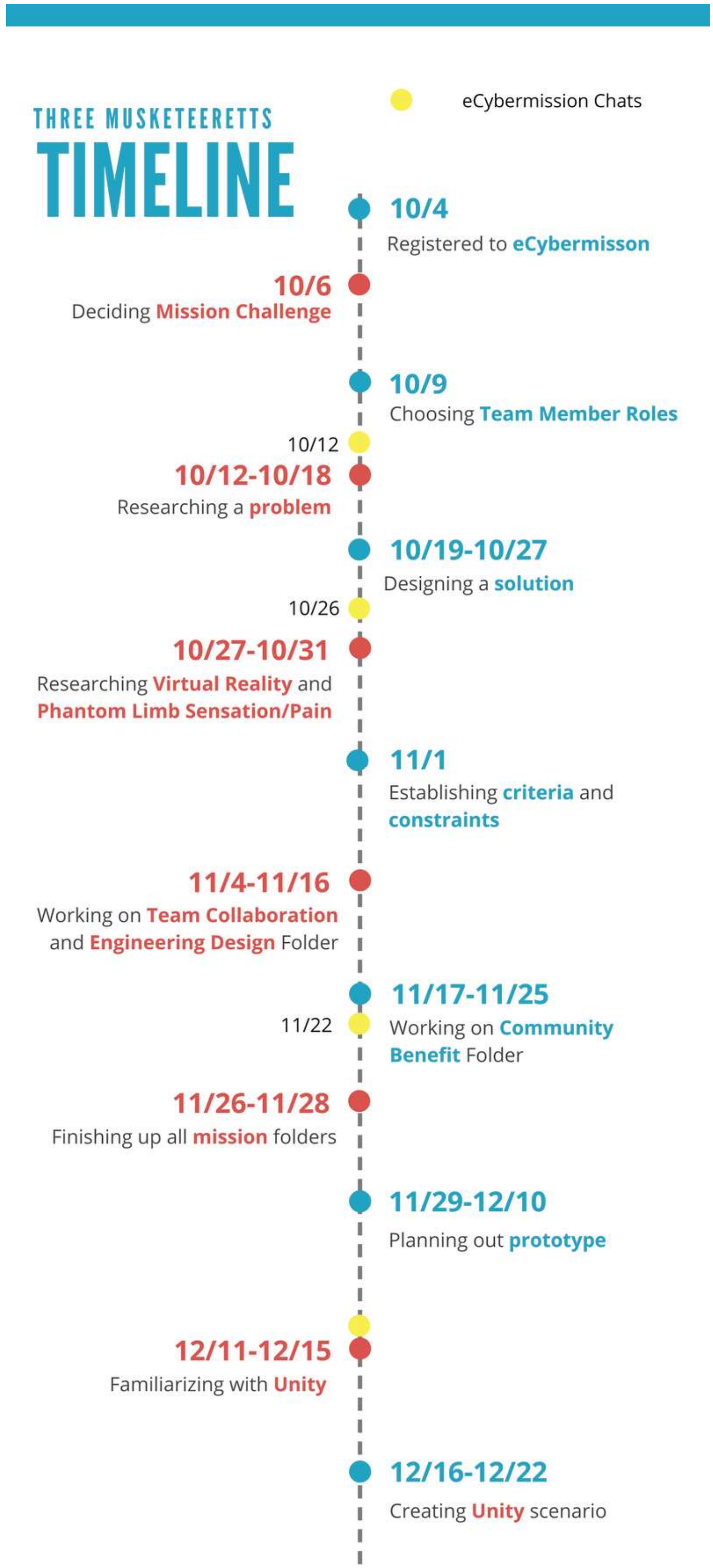
- Web Research (HOME)
- Talk to people that have gone through medical procedures
- Talk to patients in physical therapy/long term hospitalization
- Talk to nurses/physical therapists
- Talk to students: Psychology, Health Careers
- Talk to the teachers: Psychology, Health, Fitness Movement

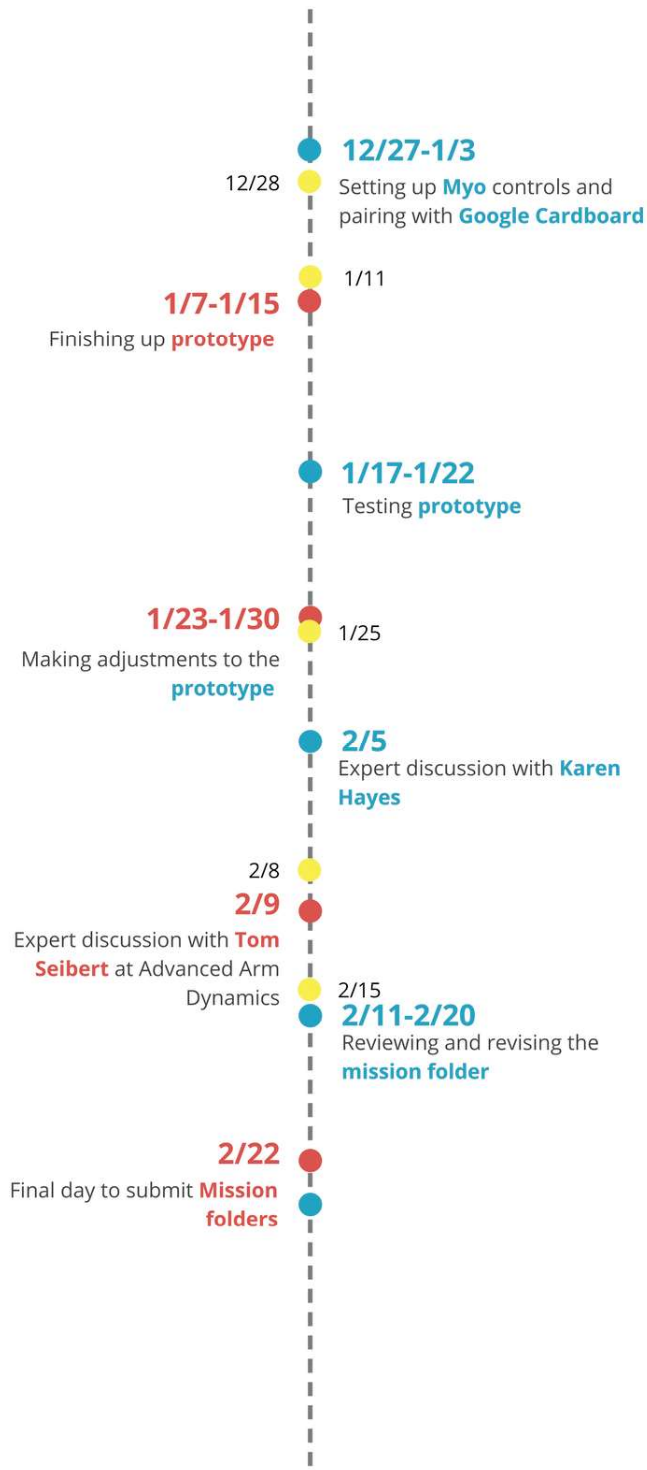
[1] An artificial body part
[2] An artificial body part, such as a leg, a heart, or a breast implant.
[3] Virtual Reality

| Date | Task |
|---|---|
| Set up our project | 1) Download Myo Connect |
| | 2) Download Unity SDK 5.4.4 |
| | 3) Download Myo SDK |
| | 4) Download Google Cardboard SDK for Unity |
| | |
| Familiarize with Unity | 1) Learn basics from tutorial video |
| | 2) **"Unity Learn" Test Game** |
| | - Roll A Ball Game |
| | |
| Create our Unity Scenario | 1) Import sample projects to learn from |
| | 2) **Enviroment and Player** |
| | - Setting up game + Moving Player |
| | 3) **Camera and Play Area-** |
| | - Moving Camera + Setting up a Play Area |
| | |
| Create our Unity Scenario | 1) **Collecting and Building Game** |
| | - Create Collectable Objects |
| | - Collecting the Pick Up Objects |
| | |
| Create our Unity Scenario | 1) **Build Game** |
| | - Add in hands + Other game elements |
| | |
| Myo Controls and Google Cardboard | 1) Add assets: Myo SDK |
| | 2) Add assets: Google Cardboard SDK |
| | |
| Build Final Project | 1) Push to Android |
| | 2) Launch Application on Phone |
| | |
| Test | 1) Run application with Google Cardboard |
| | 2) Sync Myo Armband |
| | 3) **Test with Myo + Google Cardboard on** |

## 2.3 Experiment Schedule

Our team followed this schedule (below) to complete our prototype in an organized and efficient manner.


eCybermission Chats
THREE MUSKETEERETTS
TIMELINE
10/4
Registered to eCybermisson
10/6
Deciding Mission Challenge
10/9
Choosing Team Member Roles
10/12
10/12-10/18
Researching a problem
10/19-10/27
Designing a solution
10/26
10/27-10/31
Researching Virtual Reality and Phantom Limb Sensation/Pain
11/1
Establishing criteria and constraints
11/4-11/16
Working on Team Collaboration and Engineering Design Folder
11/17-11/25
11/22
Working on Community Benefit Folder
11/26-11/28
Finishing up all mission folders
11/29-12/10
Planning out prototype
12/11-12/15
Familiarizing with Unity
12/16-12/22
Creating Unity scenario


12/27-1/3
12/28
Setting up Myo controls and pairing with Google Cardboard
1/11
1/7-1/15
Finishing up prototype
1/17-1/22
Testing prototype
1/23-1/30
1/25
Making adjustments to the prototype
2/5
Expert discussion with Karen Hayes
2/8
2/9
Expert discussion with Tom Seibert at Advanced Arm Dynamics
2/15
2/11-2/20
Reviewing and revising the mission folder
2/22
Final day to submit Mission folders

# 9. Expert Discussions

## 9.1 Meeting with Karen

Above: Meeting with Karen Hayes, the director of The American Amputee Foundation of Oregon with a Transtibial Amputation.

To learn more about the community of amputees we met up with the director of the American Amputee Foundation of Oregon, and an amputee herself. Karen shared with us her story. Sadly, eleven years ago she had been diagnosed with cancer, and the unfortunate surgery results ended with a Transtibial Amputation. Despite the amputation, Karen is an optimist who is passionate about assisting amputees. At the American Amputee Foundation of Oregon, they help amputees meet their physical and emotional challenges, provide monthly newspapers, promote public awareness in media, give peer counseling and help with financial aid for prosthetic limbs/assistive devices and services. We were genuinely inspired by both Karen's story and the work that the American Amputee Foundation of Oregon does for the community.

We shared our project with Karen and gave her a chance to try out the prototype. The three of us were euphoric to see her reaction, as it was our first time testing the prototype and we were eager to get as much feedback as possible. What Karen knows about amputation therapy and Phantom Limb Pain/Sensation is beyond what we could learn from a textbook. Here is a summary of some of the questions and answers we exchanged over the course of the meeting:

Have you experienced PLP/PLS?

Yes, I usually experience Phantom Limb Sensation as an "itch" on my missing limb, usually during the night.

When was the PLP/PLS at it's peak?

Right after the amputation it was most painful. It gradually decreased over time but it's been 11 years from my amputation and I still experience PLS.

Do you think our design would be more/less effective over mirror therapy?

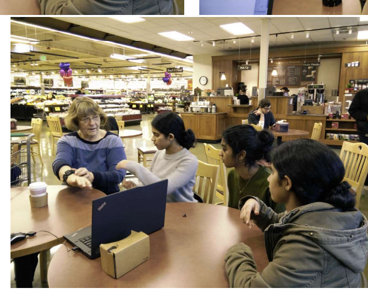
I've only tried mirror therapy once at a meeting, but it didn't make any sense to me. I don't think I'm the right person to compare between two ideas that I'm not too familiar with, but I will say that this concept has huge potential!

What do you think of our design, would it be helpful to you?

Trying out your prototype has been my first time trying out Virtual Reality, and I think what you've done is impressive. It is a unique mix between mirror therapy and guided imagery. And yes, over time I think if the design is more open to a wider range of amputees (I understand this is just a prototype) then I would want to try it out!

Below: Our team demonstrating our prototype to Karen and discussing the future of our solution.





## 9.2 Meeting with Tom

During our meeting with Karen, she recommended we speak to Tom at Advanced Arm Dynamics, who (as an amputee who had lost his lower left arm) could be of real help in testing our prototype out.

Tom Seibert was starting his senior year in high school when he lost his left hand after being injured while wakeboarding at the lake. As a young athlete, he graduated from the University of Utah with a degree in exercise science, and works part-time as a personal trainer, as well as working as the business development manager at Advanced Arm Dynamics.

We met up with Tom at the Advanced Arm Dynamics office. First, he showed us the different arm prosthetics he regularly used along with other prosthetics, each with their unique features or designs. Tom taught us a lot about the details and challenges behind amputations and how prosthetics can help. He also called in the clinic team at Advanced Arm Dynamics to join in for our design presentation. We explained our idea to them and set up the prototype so they could try it out themselves. We were nervous as to whether or not it would function along Tom's amputations and to our surprise it worked even better on him than on everyone else in the room! While we didn't have a formal Q&A session, we discussed our questions throughout the testing. Here is a summary of some of the questions and answers we exchanged over the course of the meeting:

How long does mirror therapy typically take?

Totally depends on the person; every case is different. For some people, it works quickly, for others it could take months.

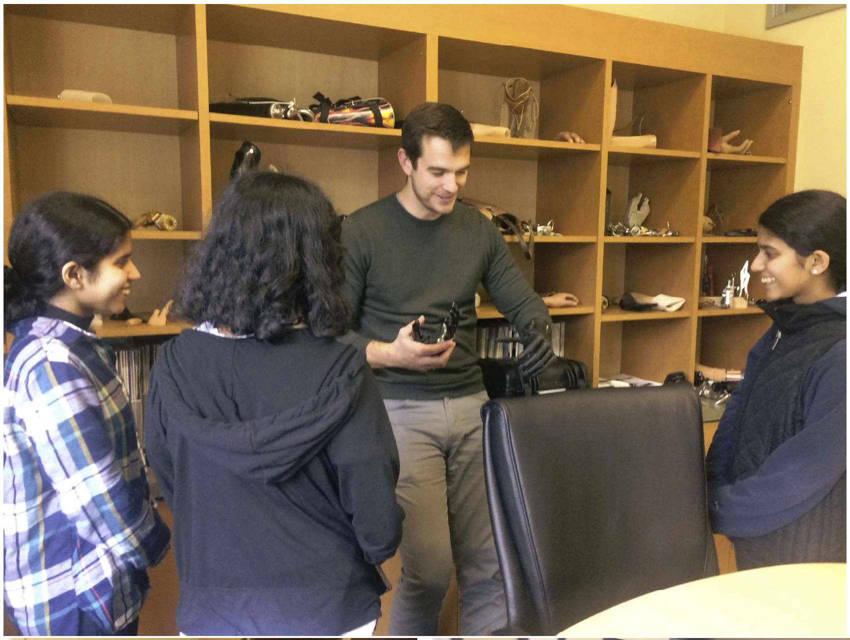
What benefits do you see in our design from the current mirror therapy?

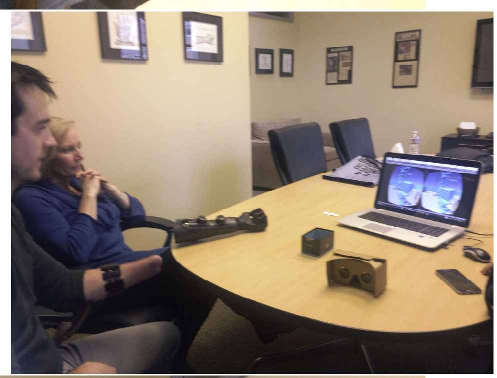
We find that many patients lack motivation to continue mirror therapy as it could take months or more depending on the person. What's great about your design is the virtual reality scenario is engaging for the patient so they can feel more of a drive to continue with the therapy.

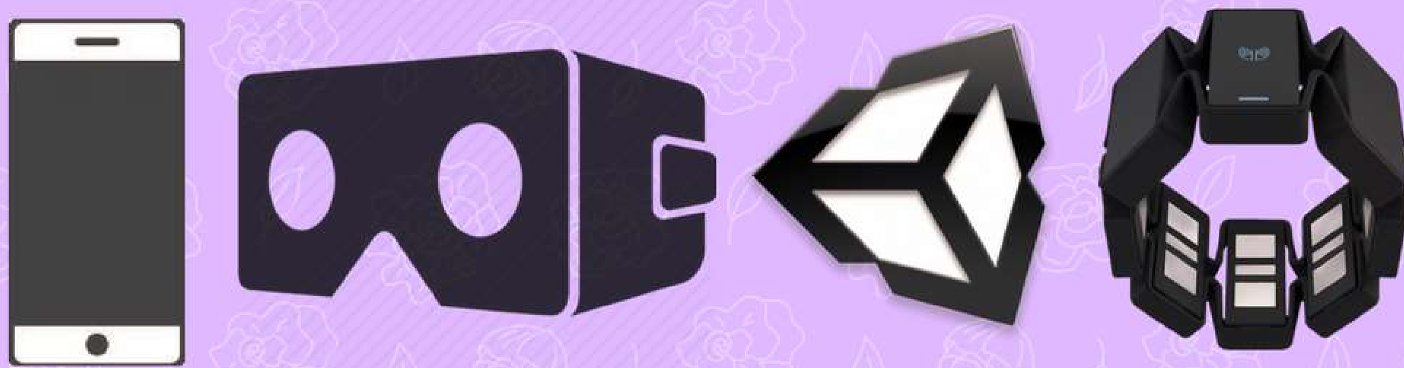
Would this design benefit amputees from your knowledge?

While this design might not be helpful in the area of prosthetics, it is perfect for training patients who have been recently amputated! You have a great idea going, and if further developed it could help with Phantom Limb Pain in amputees!

(Below) Our meeting with Tom Seibert and the Clinic Team at Advanced Arm Dynamics.





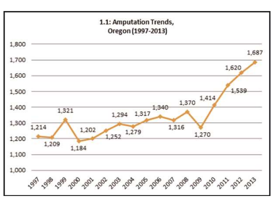


# 3. Problem Statement

## 3.1 The Problem

***What problem in your community did your team try to solve? Why is this problem important to your community?***

The growth in the technological and medical field has been quite significant this decade. However, even as humans are making significant breakthroughs in certain matters, new issues are quickly rising.




One obstacle on the rise, perhaps one of the most rapid, is amputations. It is hard to imagine that "Currently, 1.9 million people are living with limb loss in the United States, and an average of 507 people continue to lose a limb every day. This increase results in an estimated 185,000 amputations per year." (Source 1). Moreover, this is certainly not an issue that is planning to slow down anytime soon. The increases in diabetes[1], peripheral arterial diseases[2], vascular diseases[3], trauma and (believe it or not) lawn mower accidents has triggered a rise in amputations. What's even more frightening is that the number of amputations[4] per year "is expected to double by the year 2050". In our state of Oregon, there has been a 38.96% increase in amputations performed from 2000 to 2013 (Source 1). That is no minuscule number, and it is important not to forget that.

The number of amputees is escalating much faster than anyone has ever expected, with such a significant population of people suffering from the effects of amputation we wanted to make a solution that would change the way amputees face his or her challenges.

[1] A disease in which the body's ability to produce or respond to the hormone insulin results in abnormal metabolism of carbohydrates and higher levels of glucose in the blood and urine.

[2] A common circulatory problem, typically in which the legs don't receive enough blood flow to keep up with demand.

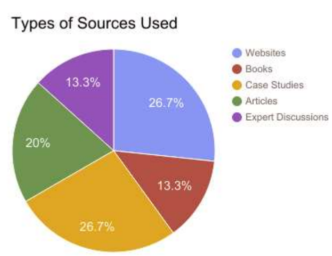
[3] A subgroup of cardiovascular diseases, it is a class of diseases of the blood vessels.

[4] The action of surgically cutting off a limb.

**Our Problem Statement:** How can we minimize Phantom Limb Sensation/Pain for amputees using VR technology, cost effectively?

## 3.2 Resources

***List at least 10 resources you used to complete your research (e.g., websites, professional journals, periodicals, subject matter experts). Use multiple types of resources and do not limit yourself to only websites.***




Before we began designing our solution, it was essential that we had a strong background of our topic. Our team divided our research into the types of sources we should collect; Websites, Books, Case Studies, Articles, and Expert Discussions. By using a variety of sources, we got a strong understanding of the problem we were trying to improve before improving it, and we were able to pick up much information we could have otherwise not noticed.

### Websites:

1. "Oregon Fact Sheet." Amputee Coalition . Amputee Coalition , Apr. 2016. Web. Dec. 2017. `http://www.amputee-coalition.org/resources/oregon-2`.
   This site covers facts about amputees in Oregon/United States of America, as well as daily and yearly limb loss trends in amputees. Data is also available for the types of amputations performed and demographics for the factors of gender, race, and age, on amputations. Lastly, it covers the current the current health care costs. This source is imperative for backing our design's importance/usefulness.

2. Firm, Pisanchyn Law. "Types of Amputations." Types of Amputations| Amputation Types | Pennsylvania Amputation Lawyers. Pisanchyn Law Firm, 08 Mar. 2013. Web. 15 Jan. 2017. `http://www.catastrophicallyinjured.com/pennsylvania-amputation-attorneys/amputation-types.html`
   We wanted to conduct research on the types of amputations before prototyping. This website shared the common types of amputations and their effects on the amputee. The broad range of amputations enforced us to design a prototype for a particular amputation before expanding.

3. "Managing Phantom Pain." Amputee Coalition. Amputee Coalition, n.d. Web. 15 Jan. 2017. http://www.amputee-coalition.org/limb-loss-resource-center/resources- for-pain-management/managing-phantom-pain
   To understand the concept of Phantom Limb Sensation and Phantom Limb Pain (as well as the difference), we used this site for an aggregate explanation. It covers a broad range of reasons for Phantom Limb Sensation/Pain, including non-amputation related conditions. Lastly, it describes current therapy and medications for PLS/PLP and their effectiveness. This resource had provided an essential background before we began designing a solution.

4. "Phantom Limb Pain: Mirror Therapy Treatment." MedicineNet. N.p., n.d. Web. 15 Jan. 2017. `http://www.medicinenet.com/script/main/art.asp?articlekey=88097`
To fully understand mirror therapy, a form nonpharmacological of treatment for Phantom Limb Sensation/Pain, we read about Jack Tsao's tests on amputees and a breaking down of why it works. Before finalizing our solution, we wanted to know the successfulness of the current therapies for PLS/PLP.

**Books**:

5. Ramachandran, V.S. The Tell-Tale Brain. N.p.: Norton, W. W. & Company, Inc., 2012. Print. This book provided us with a range of information. V.S Ramachandran explains his theories on the origin of Phantom Limb Sensation/Pain; The area in the brain deprived of sensory inputs becomes hungry for new sensations. We also learned about his methods in 'unlearning' phantom limb pain- an in-depth analysis of mirror therapy. This book was both an informative and fascinating read.

6. Murray, Craig, ed. Amputation, Prosthesis Use, and Phantom Limb Pain: An Interdisciplinary Perspective. London: Springer Science & Business Media, 2010. Print.

   The text offers a broad and innovative exploration of the entire process surrounding limb loss and eventual recovery. We were able to read in-depth on the adaptation to amputation and prosthetics, as well as post-amputation phantom limb sensation/pain recovery period.

**Case Studies:**

7. "Phantom Limb Pain." Phantom Limb Pain. Minnesota Department of Health, Aug. 2016. Web. Fall 2016.

   The Minnesota Department of Health created a study covering completed clinical trials, and observational studies on PLP, which we used before conducting our tests.

8. Nejatkermany, Mahtab Poor Zamany, Ehsan Modirian, Mohammadreza Soroush, Mehdi Masoumi, and Maryam Hossein. "Phantom Limb Sensation (PLS) and Phantom Limb Pain (PLP) among Young Landmine Amputees." Iranian Journal of Child Neurology. Shahid Beheshti University of Medical Sciences, 2016. Web. 27 Dec. 2016.

   This study provides the results and methods used for better understanding in Phantom Limb Sensation and Phantom Limb Pain. It also includes referable results/statistics on the PLS/PLP period.

9. Virtual Reality Prosthetics. N.p., n.d. Web. 27 Dec. 2016.

   To ensure our design was unique, we investigated similar projects- and their effectiveness. This link provides an example of a VR solution used for amputees before prosthesis; It includes videos on the community benefits and goals of the product. Our design does not share the same approach nor intentions, but it was important to confirm the differences.

10. "Virtual Reality for Phantom Limb Pain." Virtual Reality for Phantom Limb Pain - Tabular

View - ClinicalTrials.gov. N.p., n.d. Web. 27 Dec. 2016.

We wanted to find a complete study of Phantom Limb Sensation/Pain and discovered this proposed government plan, for studying amputees and VR. We aim to create a more cost-effective study than their proposed project. The goal of this project is to offer a distraction from the PLS/PLP. Our goal is to provide therapy for PLS/PLP.

**Articles:**

11. "Developing the World's Most Advanced Prosthetic Arm Using Model-Based Design." Developing the World's Most Advanced Prosthetic Arm Using Model-Based Design - MATLAB & Simulink. N.p., n.d. Web. 27 Dec. 2016.

    This article provides a description of a complete simulation of a virtual prosthetic arm run by Matlab and Simulink. This article includes the design process, i.e., creating the integration environment, interfacing with the nervous system. The aim of this project was to develop a virtual prosthetic arm (not used for therapy) that will move with the correct physics of an identical prosthetic arm. Though not directly relating to our solution, we still wanted to discover new technologies for amputees, and it helped us get ideas for our project.

12. Greenwald, Will. "The Best VR (Virtual Reality) Headsets of 2017." PCMAG. N.p., n.d. Web. 15 Jan. 2017.

    To keep our design cost- effective, we scrutinized the many types of VR headsets. This article distinguished the available technologies for displaying our VR app to the amputee and narrowed our choice. Following this reading, we decided on the Google Cardboard as it fit our needs as well as stayed on budget.

13. Ramachandran, V. S., and W. Hirstein. "The perception of phantom limbs. The D. O. Hebb lecture." Perception of phantom limbs. The D. O. Hebb lecture. | Brain | Oxford Academic. Oxford University Press, 01 Sept. 1998. Web. 15 Jan. 2017.

    This article explains how the brain perceives phantom limb pain and also different medical technology that shows cortical topography in the patient/amputee. It also covers more advanced operations and imaging procedures.

**Expert Discussions:**

14. Hayes, Karen, Ms. "Expert Discussion with Karen Hayes." Personal interview. 9 Feb. 2017.

    To learn more about the community of amputees we met up with the director of the American Amputee Foundation of Oregon, and an amputee herself. We shared our project with Karen, gave her a chance to try out the prototype and got our questions about amputees, and Phantom Limb Pain/Sensation answered.

15. Seibert, Tom, Mr. "Expert Discussion with Tom Seibert." Personal interview. 9 Feb. 2017.

    During our meeting with Karen, she recommended we speak to Tom at Advanced Arm Dynamics, who (as an amputee who had lost his lower left arm) could be of real help in testing our prototype out. We met up with Tom at the Advanced Arm Dynamics office where we presented our design to him and the whole clinic team!

## 3.3 Our Learning

***Describe what you learned in your research***

| Research Topic | Questions we asked to confirm it's relevance to our Mission Challenge |
|---|---|
| 1. Amputees | ➔ Will our solution be beneficial for this group of people?<br>➔ Are the issues this group of people face serious?<br>➔ Is the amputee population one that is growing? Will our solution still be useful for this group in the near future? |
| 2. Phantom Limb Pain | ➔ Will our solution improve the state of this issue or at least lessen the degree of it?<br>➔ Is this issue harmful, and are its effects on amputees authentically proven?<br>➔ Is this a common issue for amputees? |
| 3. Current Phantom Pain Treatments | ➔ What technology is being used to improve this issue currently?<br>➔ What are the problems with the technology being used currently to improve this issue?<br>➔ How would our solution fix or improve those problems? |
| 4. Virtual Reality | ➔ What would Virtual Reality do for our solution to make it more efficient and effective?<br>➔ Is this a new, unique technology?<br>➔ What are the types of VR tech available, and what features do they have? |

We began our research by thinking of the current problems we face in our community and the world. For each of these problems, we brainstormed possible solution then chose the most important ones to research further- including the relevance to our eCybermission.

To determine the importance of our problem in the community, now and in the future, we did extensive research on the amputee population, our state of Oregon in particular. We wanted to see the magnitude amputations had near us; the results left us with consternation. Source 1 told us that amputations performed in Oregon were at a high of 1,687, according to hospital discharge data[5]. It is an issue that is not only relevant in our state but also throughout the globe; as there are nearly 10 million people worldwide suffering from the effects of amputations.

[5]The point at which the patient leaves the hospital and either returns home or is transferred to another facility.

First, we began by studying the major challenges faced by amputees. As side effects of an amputation, amputees face many negative cognitive changes such as phantom limb sensation (PLS) and phantom limb pain (PLP). PLS/PLP can be described as "Pain that is experienced in a missing or amputated limb" (Source 6). To narrow down our research and problem topic, we chose to target minimization of PLP and PLS as they frequently occur in many amputees and can be very damaging to the amputee's mental and physical condition. A study about the frequency of PLP and PLS concluded that "Phantom limb sensation and pain" appear to be common even after years of amputation" (Source 4).

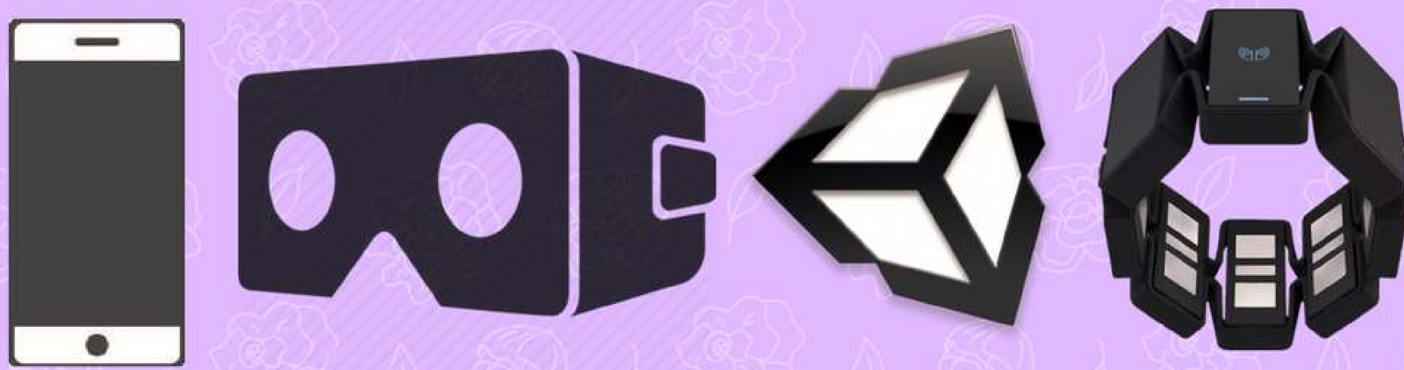
| Problem | What has already been done to fix this problem? | How can we improve their solution? How can we solve the problem? |
|---|---|---|
| Prosthesis process for amputees are expensive. | VR prosthesis project using Oculus and Myo to see if amputee is capable for using a prosthesis.<br><br>https://vrprosthetics.shu.ac.uk/project/ | We can lower the cost of the VR headset by using Google Cardboard or other cost-effective options. |
| Amputees need an effective Phantom Limb Sensation/Pain therapy | No attempts have been completed to solve this issue; However there is a proposed plan to use VR.<br>https://clinicaltrials.gov/ct2/show/record/NCT02784548 | Lower the cost of the VR, as well as provide a therapy oriented design, rather than a distraction oriented design. |

Next, we researched the current methods of pharmacological treatment for PLP. We first found the use of Opioids[6],a drug that relieves pain in the brain (Source 6). However, this treatment has proved to only have moderate success in reducing Phantom Limb Sensation/Pain and was only effective in reducing PLS/PLP short term. We found that non-pharmacological treatments were more beneficial in reducing PLS/PLP. For example, Mirror Visual Therapy is a process where an amputee places their corresponding non-amputated limb in a mirrored box, which gives the effect that they have reinstated their limb. This treatment has proven to be effective in reducing PLP, although there have been no formal trials conducted using this treatment. A similar procedure called guided imagery, asks for the amputee to use their mental imagery to create an image in which the amputee can feel their missing limb.

With a clearer idea of our problem, we thought of using Virtual Reality (VR) technology to better implement a combination of mirror visual therapy and guided imagery treatments for PLP. We found a similar study had been conducted using VR for amputees. The cost of this solution was inordinately expensive, therefore excluding many amputees, who could otherwise benefit from it. We also wanted to orient our design as a PLS/PLP therapy, rather than just a distraction. Our

[6] An opium-like compound that binds to one or more of the three opioid receptors of the body.

team decided to conduct more research on the current types of VR technology to find a more cost-effective solution. Virtual reality tech ranged from products such as the Oculus Rift, a $800 VR headset and the Google Cardboard, a $15 VR headset. We went through over 15 products in the market, analyzing, comparing, contrasting between their costs, efficiency and their features until we decided to use the Google Cardboard. Gesture control technology was much easier to look at, as it is a new concept the only compatible product for our needs was the Myo, $200 gesture control armband. By thoroughly analyzing the technology available we were able to get a deeper understanding of how we should design our solution.



# 4. Experimental Design

## 4.1 Design Statement

***Develop a design statement. Be sure to describe what exactly your device should be able to do. Do not describe HOW it's going to do what it needs to do.***

Our final design should be able to recognize multiple gestures from amputee's with different amputations (see below) and create a virtual limb with correlating movements to the amputee's gestures through a cost effective design. The virtual environment should create the illusion that the amputated, and remaining limb, are both moving. This process will reduce the amputee's opioid[1] use and Phantom Limb Sensations/Pain. The specifications are as follow

1. Recognize skeletal muscle gestures from an amputee with

   Upper Limb Amputations
   - Metacarpal Amputation
   - Wrist Disarticulation
   - Transradial Amputation
   - Elbow Disarticulation
   - Transhumeral Amputation

   Lower Limb Amputations:
   - Partial Foot Amputation
   - Ankle Disarticulation
   - Transtibial Amputations
2. Easily wearable
3. Easily removable
4. Adjustable
5. Comfortable
6. Accessible at home or at a hospital

[1] A drug used to relieve pain

| Problem Statement Properties | How? | What? | When? | Where? | Why? | Who? |
|---|---|---|---|---|---|---|
| Time | At least a month for creating the prototype (Unity SDK) and test (Using Google Cardboard) | Anytime, preferably day (for the test subjects). | As soon as SDK is ready and working with the Myo and Google Phone. | In the the Advanced Arm Mechanics Clinic or other Amputee Clinics. | We must have time to test and analyze our project. | Our team will plan our time. |
| Materials | We will download the Unity SDK, Myo SDK, and Google VR SDK. We also need a Myo armband and Google Cardboard. | We will need the Unity SDK, Myo SDK, and Google VR SDK. | As soon as we acquire all the materials. | Download from the correspon ding websites. The rest must be purchased. | To make a cost-reduced VR arm to reduce phantom limb sensation/pain. | We will get our team advisors to help get the materials. |
| Safety | Our advisor will be with us and we've completed our IRB form. | A completed IRB form. | As soon as the IRB form is complete. | A wide open area for patient. | So our test subjects are safe during the test. | A school authoritative, science teacher, doctor and team advisor. |
| Benefit to community | Allows more amputees to reduce their PLS/PLP. | A cheaper PLS/PLP therapy for amputees | During an amputee's phantom limb pain period. | In hospitals and any amputee's home. | It allows amputees facing PLS/PLP to heal with cost-effective therapy. | Amputees facing Phantom Limb Sensation/Pain. |
| Appropriateness. | It falls under the Technology | We can use the engineerin | When our prototype is ready. | Wherever the amputee is | So are solution is effective in reducing | Our team's design. |

## 4.2 Success Criteria

***Determine the criteria for a successful solution and identify constraints for your design. Discuss what the device must have in order to accomplish its job and the restrictions of the device (i.e. the size, the cost, the weight, etc.).***

**Criteria:**

1. The device must be cost-effective.

   Many current forms of non-pharmacological/pharmacological treatments for phantom limb pain are expensive, making it exclusive for use by only those that can afford it. By making our device cost-effective, we can make it available to virtually every amputee that needs it.

2. The device must be able to recognize gestures made by the amputee.

The VR app on the Google Cardboard headset should be able to identify the signals the remaining portion of the amputee's limb, using the Myo Gesture Control Armband. The VR app must then be able to translate them into gestures on the virtual arm, seen in the Cardboard.

3. The device must be easy to use by the amputee.
   For utilization in a hospital, home and amputees of all ages, the device, and its setup must be straightforward and easy to use.

**Constraints:**

1. The prototype must be complete in six weeks.

   The deadline for the mission challenge limits the time to build, test, and evaluate the prototype.

2. The cost of the device must not exceed $250.

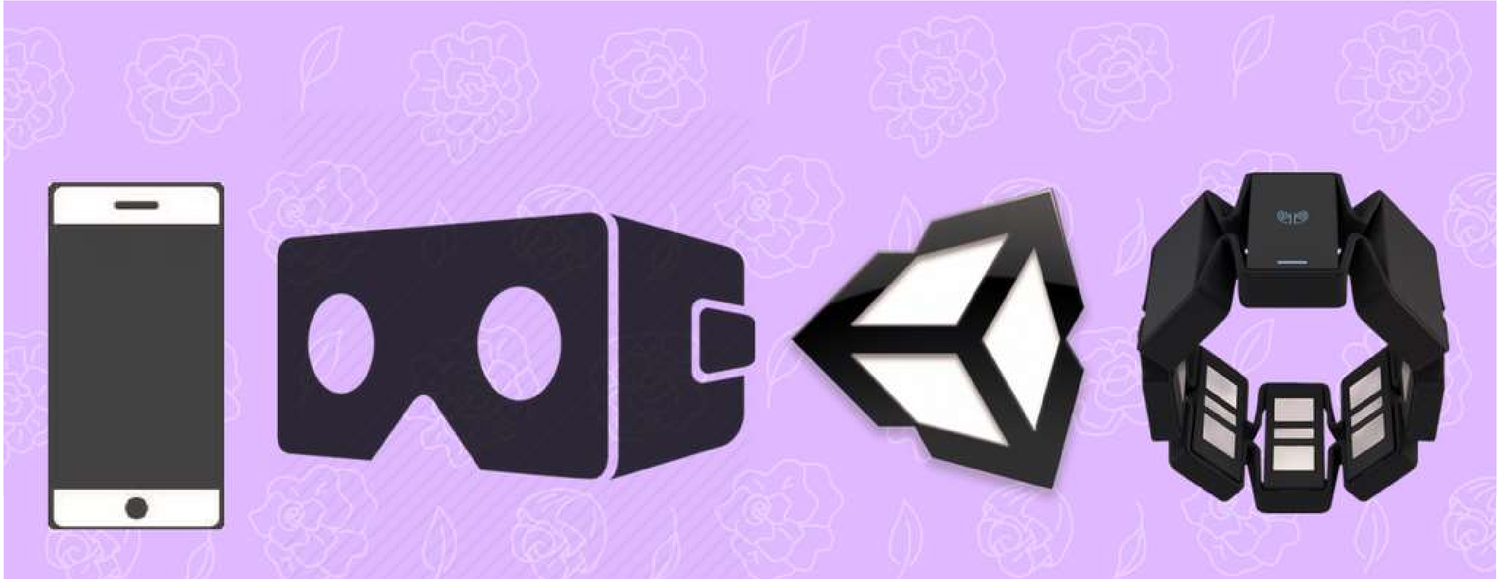
The cost of our prototype cannot exceed $250 according to the official rules of eCybermission.

## 4.3 Variables

***Identify the relevant variables you will use to test your prototype or model and explain how you will measure your variables.***

The variables we were testing in our design is the percent of accuracy in the gesture control sensor synching with the VR app. We will test our design on transradial amputees[2], and measure the percent of gestures correctly picked up. We can measure this by analyzing the data from the eight EMG Pods on the Myo Gesture Control Armband.

[2] An amputee who's radius and ulna (bones of lower arm) are cut.

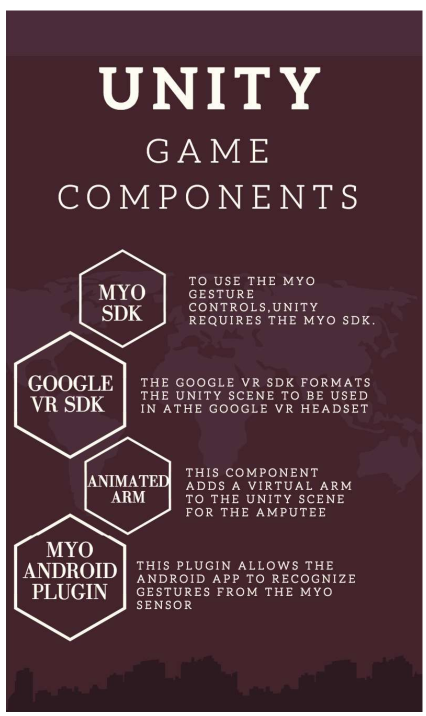


# 5. Build Prototype or Model

## 5.1 Bill of Materials

***Develop a design and list the materials you used in your design. Include technologies you used (e.g., scientific equipment, internet resources, computer programs, multimedia, etc.).***

To get the needed results, we are using a variety of materials and technologies to develop our design efficiently.

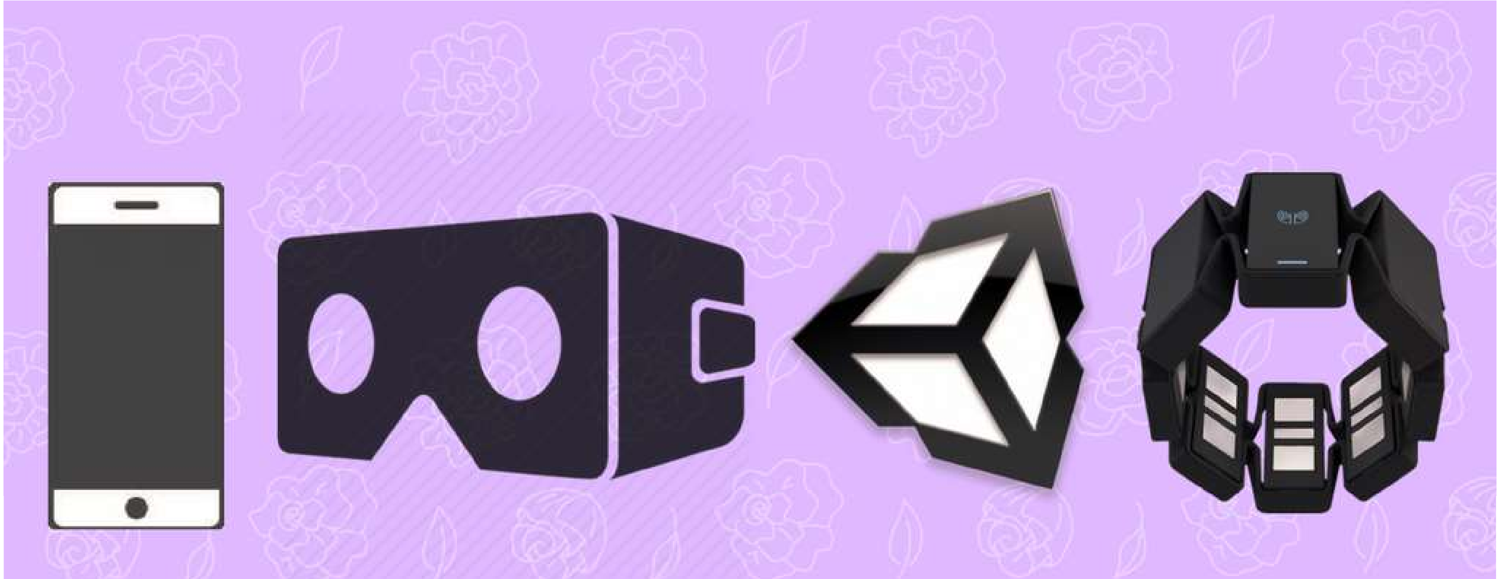


1. Google Cardboard:
   We run our VR application on the Google Cardboard and use it to connect with the Myo Armband.
2. Myo:
   Using the Myo SDK on unity, the Myo Gesture Control Armband can connect to Unity. The VR app can then replicate the gestures from the Myo Armband onto the screen. With the Myo's eight EMG Pods we can test the percent of accuracy of gestures being correctly picked up.
3. Development Tools & SDK:
   - Unity 3D Studio: Software we used for compiling the VR application and creating the virtual scene. We are using an older version (5.4.4) because the Myo SDK had issues with the newer versions.
   - Google VR SDK: This provides the software for compiling the project to be accessed on Google Cardboard.
   - Myo Connect: Software to connect Myo device with the PC.
   - Myo SDK: Like stated above, the Myo SDK allows Unity to read the Myo Armband's gestures.
   - Myo Unity Pluggin for Android
4. Smart Phone: We are using a Samsung Galaxy s6 to view the VR application and to use for the Google Cardboard.

## 5.2 Procedure

***Explain how you built your prototype(s) or model(s). Include each of the steps in your process. Include all safety precautions used by your team as step one.***

1. Safety Precautions
   - Checked for safety of website before downloading any software
   - Parent verification before downloading software
   - Verified latest anti-virus software before downloading any component from the Internet
   - Check for copyright restriction and understand open source usage policy
2. Drew out a design flow chart
3. Downloaded Myo Connect
4. Downloaded Unity SDK (5.4.4)
5. Downloaded Myo SDK
6. Downloaded Google Cardboard SDK for Unity
7. Downloaded Unity Sample Game
8. Created a sample Unity game
9. Created our Unity Environment and Player
10. Placed our Unity Camera and Play Area
11. Created our Unity objects and other elements
12. Added Assets: Myo SDK, Google Cardboard SDK
13. Pushed to Android and launched application on Phone
14. Tested
15. Refined Unity Project and re-tested



# 6. Test Prototype or Model

## 6.1 Data Collection

***Present the data you collected and observed in your testing. The use of data tables, charts and/or graphs is encouraged.***

To test the accuracy of our prototype, we recorded the percentage of the gestures correctly recognized. We were able to test our design on three subjects, with five trials per gesture.

| **Test Subject 1:** | | | | | | |
|---|---|---|---|---|---|---|
| **Gesture Type** | **Trial 1** | **Trial 2** | **Trial 3** | **Trial 4** | **Trial 5** | |
| Wave Left | 1 | 0 | 1 | 1 | 1 | 80.00% |
| Wave Right | 1 | 1 | 1 | 1 | 1 | 100.00% |
| Double Tap | 1 | 1 | 1 | 1 | 1 | 100.00% |
| Fist | 1 | 0 | 1 | 1 | 1 | 80.00% |
| Spread Fingers | 0 | 0 | 1 | 1 | 0 | 40.00% |
| Rotate | 1 | 1 | 1 | 1 | 1 | 100.00% |
| Pan | 1 | 1 | 1 | 1 | 1 | 100.00% |

Figure 6.1: Table shows the data collected from our first test subject with calculated value for accuracy

While some gestures were very accurately recognized, like Fist, others were not at all, ex. Wave Right. With the third subject, the gesture Spread Fingers was never recognized while Double Tap was recognized every time.

| Test Subject 2: | | | | | | |
|---|---|---|---|---|---|---|
| Gesture Type | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | |
| Wave Left | 0 | 1 | 1 | 1 | 0 | 60.00% |
| Wave Right | 0 | 1 | 0 | 0 | 1 | 40.00% |
| Double Tap | 1 | 1 | 0 | 1 | 1 | 80.00% |
| Fist | 1 | 1 | 1 | 1 | 0 | 80.00% |
| Spread Fingers | 1 | 1 | 1 | 1 | 1 | 100.00% |
| Rotate | 0 | 0 | 1 | 1 | 1 | 60.00% |
| Pan | 1 | 1 | 1 | 1 | 1 | 100.00% |

Figure 6.2: Table shows the data collected from our second test subject with calculated value for accuracy

| Test Subject 3: | | | | | | |
|---|---|---|---|---|---|---|
| Gesture Type | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | |
| Wave Left | 1 | 0 | 1 | 1 | 1 | 80.00% |
| Wave Right | 0 | 0 | 0 | 1 | 1 | 40.00% |
| Double Tap | 1 | 1 | 1 | 1 | 1 | 100.00% |
| Fist | 0 | 1 | 1 | 1 | 1 | 80.00% |
| Spread Fingers | 0 | 0 | 0 | 0 | 0 | 0.00% |
| Rotate | 1 | 1 | 1 | 1 | 1 | 100.00% |
| Pan | 1 | 1 | 1 | 1 | 1 | 100.00% |

Figure 6.3: Table shows the data collected from our third test subject

The next step to collect the user response on the game interaction. The following steps are used for game interaction.

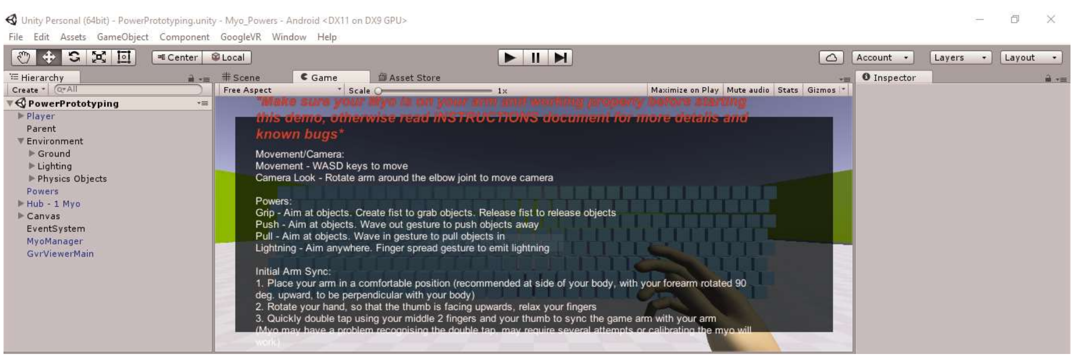



Figure 6.4: (Above) To begin game use the double tap gesture. The rest of the game instructions are also found on this page.

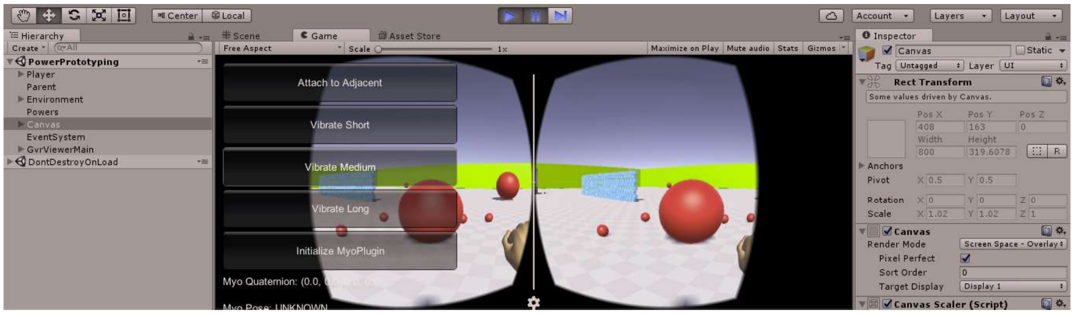



Figure 6.5: The Fist gesture allows the amputee to grip ball/balls.

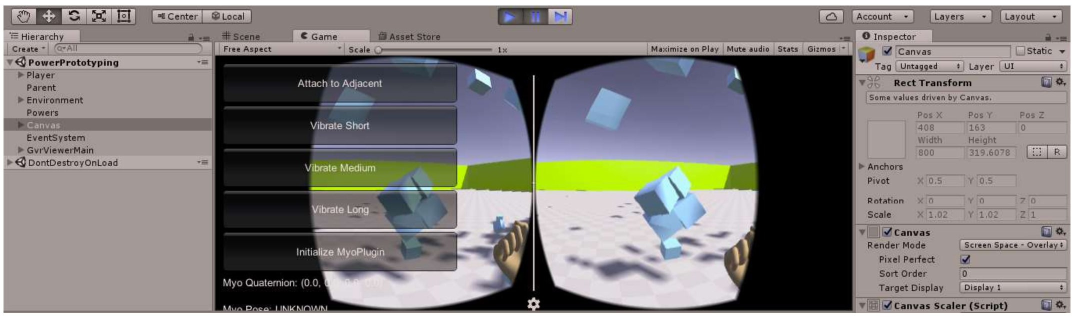



Figure 6.6: The fist gesture can also grip blocks (above) and rods.

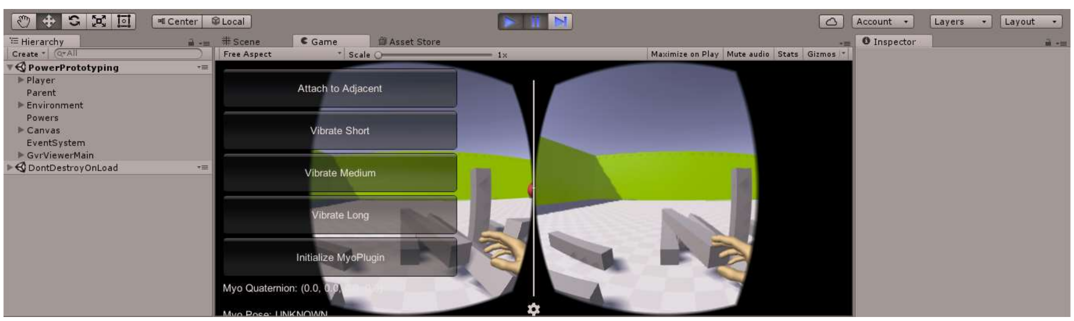



Figure 6.7: To push objects away from the screen, the amputee can use the Wave Out gesture.

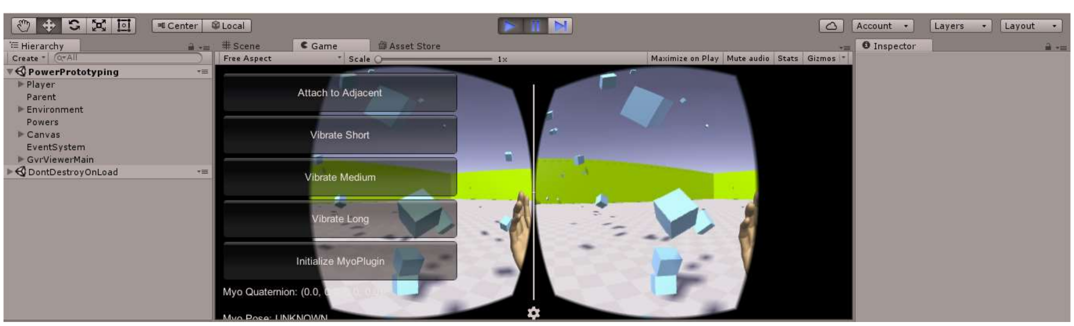



Figure 6.8: Similarly, the Wave In gesture brings objects towards the screen.

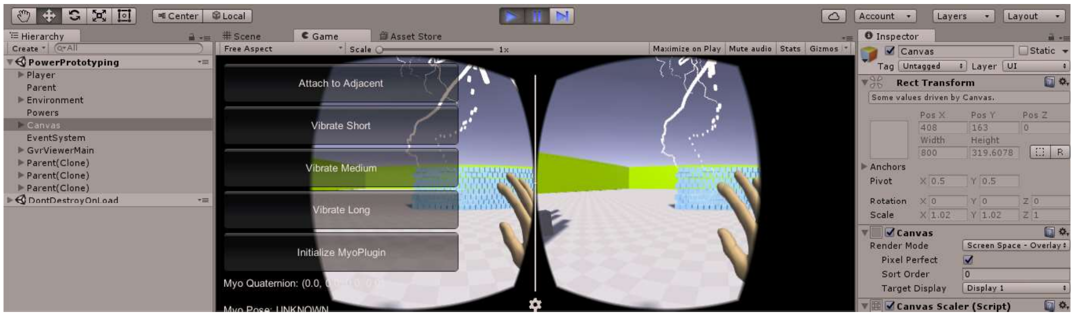



Figure 6.9: Lastly, the player can emit lightning through the Fingers Spread gesture

## 6.2 Analysis

***Analyze the data you collected and observed in your testing. Does your data support or refute your design statement? Do not answer with yes or no. Explain your answer using 'Our data supports/refutes the design statement because...'***

Our data supports our design statement because our final design was able to consistently recognize various gestures from the amputee's limb consistently and correlate the movements of the amputee's gestures, through a cost-effective design.

Our design was able to recognize each gesture and complete the corresponding game step accurately. The double tap gesture was recognized an average of 93% to open the game. The amputee could push objects away 60% of the time, but it was 73% accurate in pulling the objects. Lastly, the amputee could 'grip' objects using the fist gesture 80% of the time. An outlier was found in the Spread Fingers gesture, which was only 47% consistent.

| Gesture | Corrosponding Game Step | Average Accuracy |
|---|---|---|
| Double Tap | Open Game | 93% |
| Fist | Grip | 80% |
| Open Left | Pull | 73% |
| Open Right | Push | 60% |
| Spread Fingers | Lightning | 47% |

## 6.3 Sources of Error

***Explain any sources of error and how these could have affected your results***

While we tried our hardest to make our prototype an accurate representation of our design, there are several sources of error to take into account that they could have affected our results:

1. Not tested on a range of amputees.

Our prototype can only be tested on amputees who have lost the lower extremity arm. Therefore the information we have collected only relates to a select group of amputees and is irrelevant for amputees with different conditions. Even if our prototype works ideal for one amputee, it could be unsuccessful for another.

2. Not fully able to test for results.

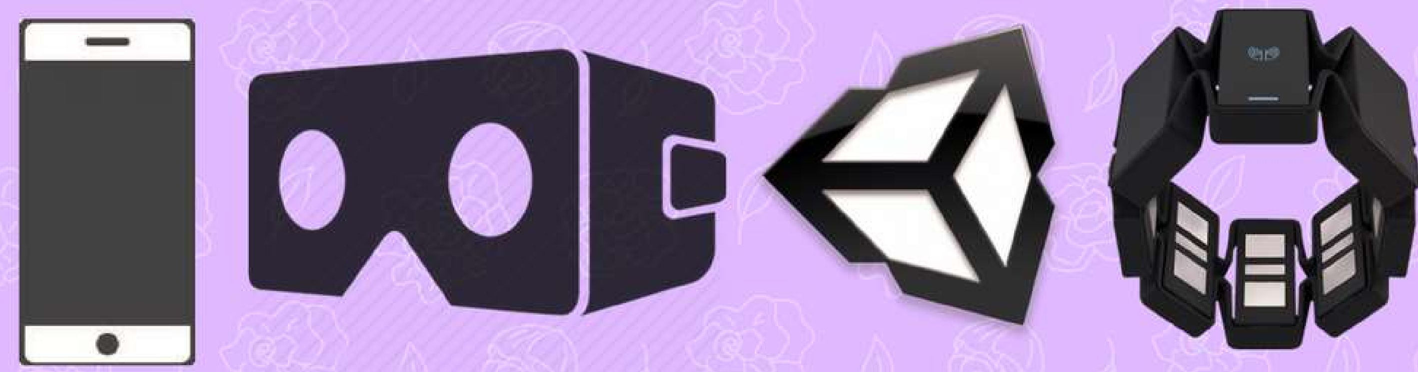
   As it can take years, even a lifetime, for an amputee to overcome PLP/PLS our prototype was never tested for effectiveness in overcoming these problems. It relies more on the psychological hypothesis of the professionals and amputees we have spoken to, as well as what we read. Within our constraints, we cannot prove our prototype helps amputees overcome PLP/PLS, but in theory, it should.

3. Data is qualitative

   Phantom Limb Pain and Phantom Limb Sensation are both more emotional than physical. It is impossible to track the level of pain or discomfort precisely an amputee will experience over time nor can the pain or discomfort an amputee experiences be precisely measured. We analyzed our results based on the percent of gestures accurately sensed by the Myo, but this may not directly correlate with the Phantom Limb Pain/Sensations.

4. Myo's accuracy

   During our first trials, we began to find an inaccuracy in the collected EMG data. To identify the error, we had the Myo device in a static condition (the amputee's arm is at the stationary position). Because the Myo did not move, there should have been no changes in the recorded EMG data; However, we found many fluctuations in the values, showing we were processing errors in our data collection. We found more accurate values for the Accelerometer, and Gyro results, but we would need to retest the scenario for better results. In addition to this, the armband size played a significant role in accuracy; a smaller arm would not be able to recognize gestures as easily as a bigger one. For example test subject 3 had the smallest arm and the lowest accuracy of 71% while the largest hand size test subject 1 had the highest accuracy of 85%.



# 7. Drawing Conclusions

## 7.1 Evaluation

***Interpret and evaluate your results and write a conclusion statement that includes the following: Describe what you would do if you wanted to retest or further test your design. Evaluate the usefulness of your prototype or model. What changes would you make to your prototype or model for the future, if any?***

To further test our design we would retest on a larger sample group of amputees with different amputations, that would test our prototype's efficiency more accurately. Retesting on a larger group of amputees with a variety of amputations can also give us more feedback on how well the design of the prototype works, which will help us make improvements. We would also conduct testing over a longer period. As this is a therapy the patient's PLP/PLS will require several sessions using the design, not just one.

Because PLP/PLS is not a physical phenomenon, to measure the long-term effects of our VR therapy and an amputee's Phantom Limb Sensation/Pain is currently beyond our prototype's capabilities. However, our prototype performs very accurately in the underlying concepts of our design. Our prototype can successfully collect data from Myo's EMG pods, which is significant because it means that our program can receive the signals from Myo and translate it into movements in the Unity program. The EMG data is extremely consistent with gestures such as wave out and double tap. This proves that the prototype can accurately respond to the gestures that the amputee will make to interact with the virtual environment. Our prototype completes its criteria effectively; we just need to put it into practice.

Although our prototype was successful in creating a virtual limb for the amputee as well as a gamified therapy, it is not yet complete. First, we want to improve the virtual setting. The more realistic the surrounding, the better the therapy. We also want to explore the option of making the virtual setting into a place that the patient feels more comfortable than our current scenario. For example, we could create the virtual setting of one patient into their bedroom, a place that they will most likely feel more comfortable and relaxed. This will also allow the patient to heal faster because they are more open, rather than being in a tense hospital environment. Secondly, as the gestures required practice from the patients, practicing the movements before testing might make our prototype more efficient and easier to use.

# 8. Benefit to the Community

***How could your design help solve your problem and benefit your community? Describe next steps for further research/design and how you have or how you could implement your solution in the future.***

Our design provides a cost effective therapy for Phantom Limb Sensation (PLS) and Phantom Limb Pain (PLP); amputee's most preeminent challenges. With amputation rates on the rise, there are ever more patients desiring effective PLS/PLP therapy. Our design will lessen the PLP in an amputee by creating the image of a working limb in the gesture control synced VR app. By using low-cost technologies such as the Google Cardboard, we can keep our design cost efficient while still effectively solving the problem.

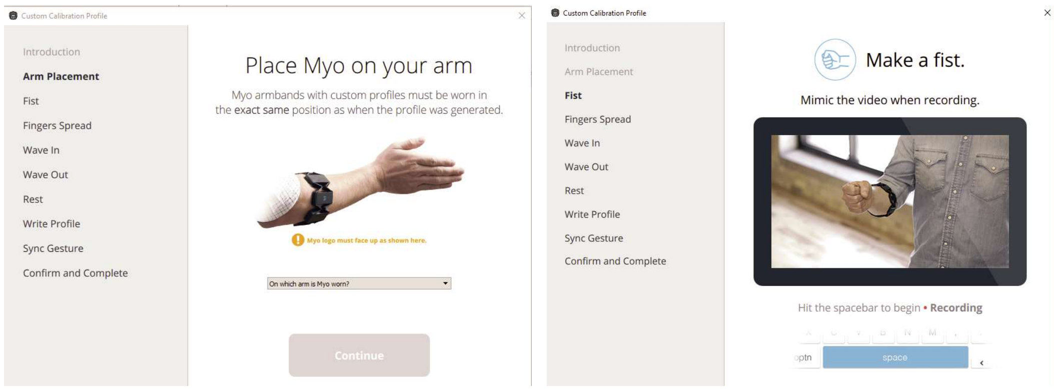
It could benefit the community of over 22,828 amputees in Oregon, of which 80% face PLP (Source 1), by minimizing the number of amputees that experience phantom limb pain. Our design will also reduce the costs of the overall treatments for amputees experiencing PLS/PLP, as current therapy prices exclude many amputees.

In the future, we want to enhance our solution by;

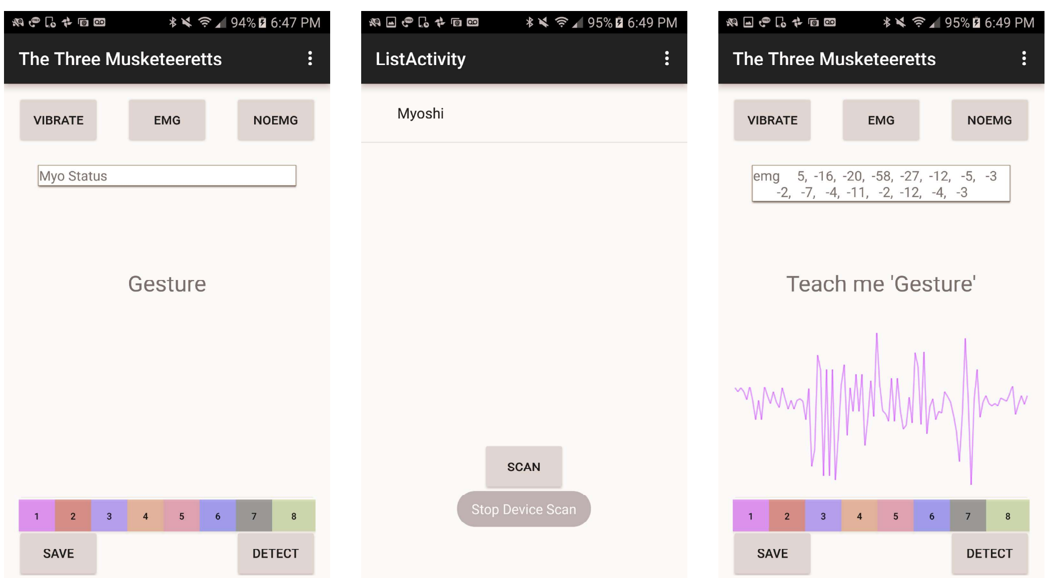
1. Add additional VR/gesture experiences for the user to try

   The current gestures we are using will need to be expanded on to provide more freedom to the amputee. Adding more gestures will also enhance the authenticity of the VR simulation (Ex.Tying shoelaces, holding a glass, and so forth).

   Without the real limb, the amputee's gestures might not be the same as a person with the limb. So we researched how our design could allow amputees to set up their personalized gestures in which they are more comfortable in, as well as decipherable by the Myo. We found that by using the 'Create Profile' tab on the Myo Armband Manager, the user can personalize the Fist, Finger Spread, Rest, Wave In, and Wave Out. Using this our design will work more efficiently for the amputee.




We also found an open source code available that also provided the EMG data corresponding to the Myo's movements. This app allowed the user to record the EMG data for any arm gesture. Incorporating a similar design could eliminate the need for amputee's to learn gestures that require the image of their missing limb, which can be confusing and challenging. Rather, the amputee can make their own gestures, which they are comfortable in, and have the virtual limb mimic their personalized movements.



2. Make the design compatible for people with various amputations

Our prototype can only be tested on amputees who have lost the lower extremity arm. In the future, our design should be adaptable for patients with any amputation; Upper Limb Amputations (Metacarpal Amputation[1], Wrist Disarticulation[2], Transradial Amputation[3], Elbow Disarticulation[4], Transhumeral Amputation[5]) and Lower Limb Amputations (Partial Foot Amputation[6], Ankle Disarticulation[7], Transtibial Amputations[8]).

3. Make our design adaptable for patients before receiving prosthetics

We want to bring in the next step of amputation, prosthesis, into the picture. Currently, "prosthetic fitting begins two to six months after surgery" (Source 12). Our design can introduce the patient to an identical VR prosthetic (via our VR app) before receiving the real prosthetic, so when the prosthetic is made and fitted, it will take less time to adjust.

In the future we could implement our solution by running a test on a much larger group of amputees, getting data from nearby hospitals and partnering up with Advanced Arm Dynamics and Amputee Coalition to get professional help in making our design a reality.

[1] Hand is removed, with the exception of wrist
[2] Hand and wrist are removed
[3] An amputee whose radius and ulna (bones of lower arm) are cut
[4] Forearm at elbow is amputated on
[5] Arm above elbow is removed
[6] One or more toes are removed
[7] Foot at the ankle is amputated on
[8] Leg below the knee is amputated on


OUR SOLUTION
THE THREE MUSKETEERETTS
ANDROID AND IOS
UNITY APP
PHONE PRICE NOT INCLUDED
GOOGLE CARDBOARD
$15
MYO ARMBAND
$200
unity
PERSONAL EDITION (FREE)
OVERALL COST: $215

# ABOUT US

We are freshmen in high school from Portland, Oregon. All of us have been interested in STEM at a young age and have participated in many robotics competitions over the years.

# THE PROBLEM

According to Amputee Coalition, there are 2.1 million people in the USA living with limb loss, and 185,000 people go through an amputation each year. One of the many challenges these amputees face is Phantom Limb Pain (PLP) or Phantom Limb Sensation (PLS). It is a painful sensation where an amputee continues to feel the pain of a missing limb, nearly 80 percent of the amputee population worldwide have experienced this kind of pain.

# THE SOLUTION

Currently, the main treatment available is Mirror therapy, but its level of success varies from person to person. Our team wanted to create an improved, enhanced therapy using recent technology. Our project will give the amputee community a cost-effective, more advanced solution to minimize their Phantom Limb Pain or Phantom Limb Sensations. We believe our design can truly impact the growing population of amputees facing these issues.

# THE DESIGN

The design, using Google Cardboard, and Myo, a gesture control technology, should be able to recognize multiple gestures from amputee's with different amputations and create a virtual limb with correlating movements to the amputee's  through a cost effective design. The virtual environment should create the illusion that the amputated, and remaining limb, are both moving. This process will reduce the amputee's Phantom Limb Sensations/Pain.

AEOP ARMY EDUCATIONAL OUTREACH PROGRAM | eCYBERMISSION ACCEPT THE CHALLENGE | U.S. ARMY

# INSTITUTIONAL REVIEW BOARD

## APPROVAL FORM

**Student(s) User Name(s):** 321665, 321666, 348234

**Grade:** 9th grade **Team Advisor:** Nixon Xavier

**Team Name:** The Three Musketeers

**Brief Description of Project:** Our project for the eCYBERMISSION is a cost effective solution that will minimize phantom pain for amputees using Virtual Reality and Gesture control technology.

**Team Advisor:** Please sign here if the project proposed is a viable eCYBERMISSION Project in which neither animals nor humans will be harmed.

**Team Advisor Approval Signature:** Nixon Xavier

### IRB Waiver of Written Informed Consent for Human or Animal Participation

The IRB may waive the requirement for documentation of written informed consent/assent/parental permission if the research involves **only minimal risk *and* anonymous data collection *and* if it is one of the following:** (NOTE: This statement only applies to providing the written certification mentioned in 1a or 2a above).

- Research involving normal educational practices.
- Research on individual or group behavior or characteristics of individuals where the researcher does not manipulate the subjects' behavior and the study does not involve more than minimal risk.
- Surveys, questionnaires, or activities that are determined by the IRB to involve perception, cognition, or game theory and do NOT involve gathering personal information, invasion of privacy or potential for emotional distress.
- Studies involving physical activity where the IRB determines that no more than minimal risk (Daily Activity) exists and where the probability and magnitude of harm or discomfort anticipated in the research are not greater than those ordinarily encountered in DAILY LIFE or during performance of routine physical activities.

**If there is any uncertainty regarding the appropriateness of waiving written informed consent/assent/parental permission, it is strongly recommended that documentation of written informed consent/assent/parental permission be obtained.**

| HUMAN or ANIMAL SUBJECTS |
|---|
| **Permission Slips needed? (see above to determine)** ____ **Yes** ✓ **No**<br>**(Scan and attach slips to Mission Folder)** |
| **Check-up of Human or Animal Subjects required by Doctor, school nurse or Veterinarian? (see above to determine)** ____ **Yes** ✓ **No**<br>**If yes, Doctor's, Nurse's or Veterinarian's (before and after experimentation) current evaluation report must be attached to Mission Folder.** |

***APPROVALS –***

Principal / Administrator Signature: [signature] — Date Reviewed: 1/5/17

Doctor or Medical Professional Signature: [signature] — Date Reviewed: 1/10/17

Science Fair Coordinator or other Science Teacher Signature: [signature] — Date Reviewed: 1/5/17

AEOP ARMY EDUCATIONAL OUTREACH PROGRAM | eCYBERMISSION ACCEPT THE CHALLENGE | U.S.ARMY

### *eCYBERMISSION Survey Approval Form*

eCYBERMISSION team name: The Three Musketeers

Team Advisor name: Nixon Xavier

Team Advisor email: nixonxavier@gmail.com

Team Advisor phone: 503-997-6110

Student usernames: 321665, 321666, 348234

School name: Westview High School

School address: 4200 NW 185th Ave, Portland, OR 97229

**Describe the survey your team will conduct:** The survey our team will conduct will conduct data on when phantom pain occurs (in terms of post-amputation), after how long does it go away, and when was the pain at it's peak.

**Describe the participants you plan to distribute your survey to:** We plan to distribute our survey to patients that have experienced phantom pain in the past or are experiencing it currently.

**Project approved by school administration?**

☑ Yes ☐ No

**Approved by:**

**Title:** Principal

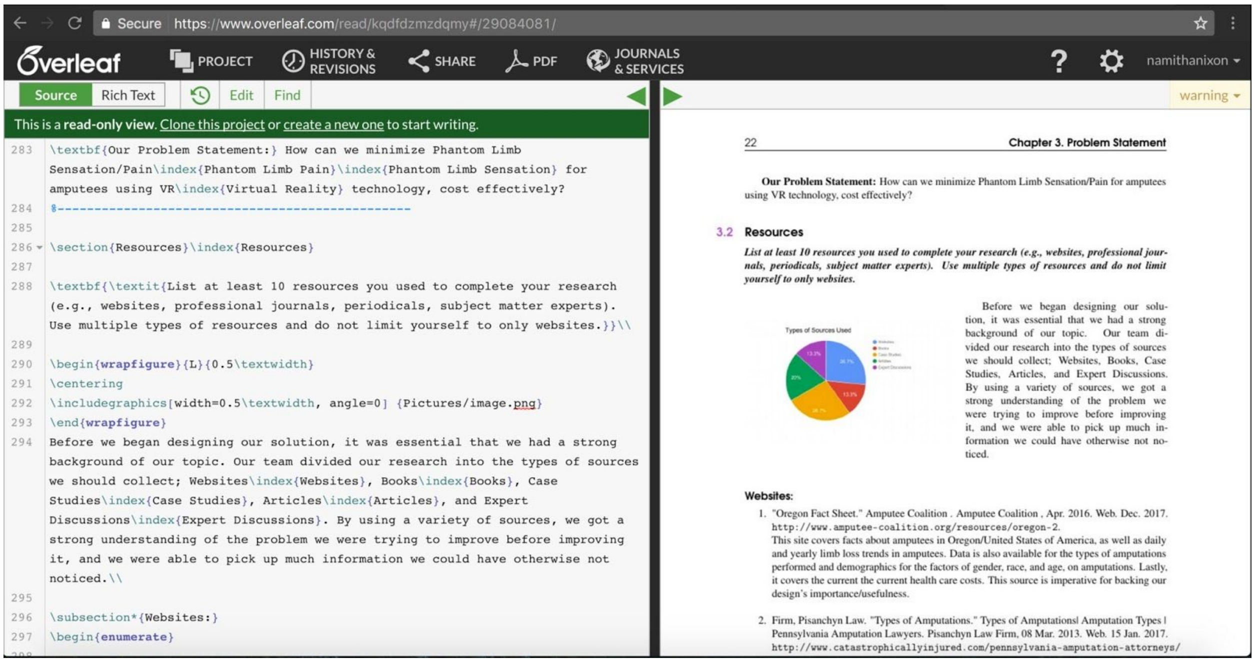
**Date approved:** 1/5/17

**Signature, School Administrator:** [signature]

*Please save form and upload to your team's Mission Folder BEFORE surveys are administered.

Our team wanted to keep a professional documentation of our eCYBERMISSION challenge, which is why we chose to code out our entire Mission Folder on Overleaf. It is an online LaTeX and Rich Text collaborative tool for writing, editing, and publishing scientific and other documents.

Here is a sample of how Overleaf works:




Our entire mission folder for the project is available online at [https://www.overleaf.com/read/kqdfdzmzdqmy](https://www.overleaf.com/read/kqdfdzmzdqmy)

eCYBERMISSION
ACCEPT THE CHALLENGE

U.S.ARMY

# A Cost Effective Solution to Minimize Phantom Limb Sensation

Using Virtual Reality and Gesture Controls

by: The Three Musketeeretts

PUBLISHED BY THE THREE MUSKETEERETTS

WWW.STEM4GIRLS.ORG/THETHREEMUSKETEERETTS

Thanks to Overleaf for providing us with the platform and all the support to create this document. Special thanks to Dr. Hammersley and Dr. Lian Tze for the guidance and coaching on using this wonderful tool. The Legrand Orange Book LaTeX Template is downloaded from `http://www.LaTeXTemplates.com`. Thank you to Mathias Legrand.



*First printing, February 2017*

Thanks to Our Sponsor

https://www.overleaf.com

We are affiliated to

https://www.stem4girls.org

Thanks to our Team Advisor and parents. And a special thanks to all members at Advanced Arm Dynamics.

http://armdynamics.com/

# Contents


| I | Mission Verification | |
|---|---|---|
| 1 | Abstract | 9 |

| II | Team Collaboration | |
|---|---|---|
| 2 | Plan | 13 |
| 2.1 | Breakdown of Team Responsibilities | 13 |
| 2.2 | Team Plan | 15 |
| 2.3 | Experiment Schedule | 16 |

| III | Use of Engineering Design | |
|---|---|---|
| 3 | Problem Statement | 21 |
| 3.1 | The Problem | 21 |
| 3.2 | Resources | 22 |
| 3.3 | Our Learning | 25 |
| 4 | Experimental Design | 29 |
| 4.1 | Design Statement | 29 |
| 4.2 | Success Criteria | 30 |
| 4.3 | Variables | 31 |

5 Build Prototype or Model . . . . . 33
5.1 Bill of Materials 33
5.2 Procedure 34

6 Test Prototype or Model . . . . . 35
6.1 Data Collection 35
6.2 Analysis 38
6.3 Sources of Error 38

7 Drawing Conclusions . . . . . 41
7.1 Evaluation 41

IV Community Benefit

8 Benefit to the Community . . . . . 45

V Additional Details

9 Expert Discussions . . . . . 53
9.1 Meeting with Karen 53
9.2 Meeting with Tom 55

Index . . . . . 57

# Mission Verification

1 Abstract . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 9

# 1. Abstract

***You will need to include an abstract of 250 words or less. As part of the abstract you will need to describe your project and explain how you used STEM (Science, Technology, Engineering and Mathematics) to improve your community***

According to Amputee Coalition, there are 2.1 million people in the USA living with limb loss, and 185,000 people go through an amputation each year. One of the many challenges these amputees face is Phantom Limb Pain (PLP) or Phantom Limb Sensation (PLS). It is a painful sensation where an amputee continues to feel the pain of a missing limb, nearly 80 percent of the amputee population worldwide have experienced this kind of pain.

Currently, the main treatment available is Mirror therapy, but its level of success varies from person to person. Our team wanted to create an improved, enhanced therapy using recent technology. Our project will give the amputee community a cost-effective, more advanced solution to minimize their Phantom Limb Pain or Phantom Limb Sensations. We believe our design can truly impact the growing population of amputees facing these issues.

While creating our prototype we have used STEM abundantly in helping us design our Virtual Reality scenario on Unity, sync our Virtual Reality scenario with a Myo armband, learn how to work with Gesture Control, and test the accuracy of our design on Google Cardboard.

We also used STEM constantly while creating our mission folder, such as by designing infographics through Canva, Pictograph, Real Time Board, Google Forms and Google Drawings. Moreover, we were able to code our entire mission folder content in LaTeX through the professional document creator Overleaf. We also created an overleaf template for the future eCybermission participants.

# II Team Collaboration

2 Plan . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 13
2.1 Breakdown of Team Responsibilities
2.2 Team Plan
2.3 Experiment Schedule

# 2. Plan

***Describe the plan your team used to complete your Mission Folder. Be sure to explain the role of each team member and how you shared and assigned responsibilities. Describe your team's process to ensure that assignments were completed on time and deadlines were met.***

## 2.1 Breakdown of Team Responsibilities

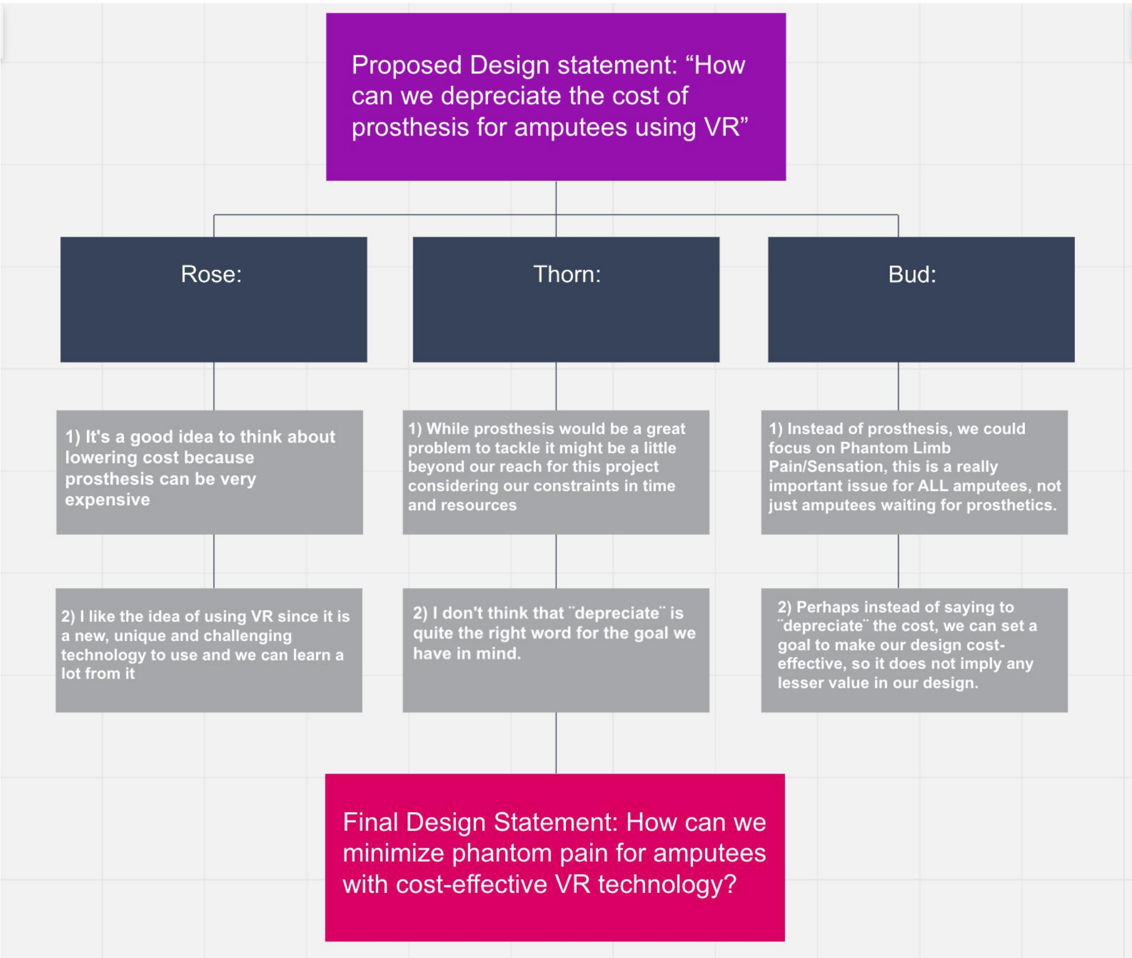
To efficiently complete our mission folder we decided to delegate specific roles for each member. However, it did not seem right for one person to write a whole section. Instead, we assigned a "Lead" for each of the three sections of the Mission Folder, who would distribute the tasks of her section and oversee its progress by checking up on weekly deadlines. Because each Musketeerette had a section to "Lead" we were able to smoothly follow our action plan as there was always a person distributing work and keeping everyone in check before moving on. We also assigned a "Reviewer" to critique and appraise each section.

We also assigned a "Reviewer" to critique and appraise each section.

- Musketeerette 1: Community Benefit Lead + 'Problem Statement' + 'Experimental Design' + Documented Bibliography + (Team Collaboration Reviewer)
- Musketeerette 2: Engineering Design Lead + 'Building Prototype' + 'Testing Prototype' + Completed IRB and Survey form + (Community Benefit Reviewer)
- Musketeerette 3: Team Collaboration Lead + 'Drawing Conclusions' + Mission Verification + Abstract + (Engineering Design Reviewer)

| | Team Collaboration | Engineering Design | Community Benefit | Mission Verification |
|---|---|---|---|---|
| *Writing Portion* | | | | |
| Nandhana | Owner | 'Drawing Conclusions' | | Abstract |
| Ragini | | Owner | | |
| Namitha | | 'Problem Statement' & 'Exprimental Design' | Owner | |
| *Reviewing Portion* | | | | |
| Nandhana | | Reviewed Doc | | |
| Ragini | | | Reviewed Doc | |
| Namitha | Reviewed Doc | | | |
| *Reasearch Portion* | | | | |
| Nandhana | -> | Current methods of treatment for PLP/PLS (in various resource formats | | |
| Ragini | -> | Uses of myo and Google Cardboard | | |
| Namitha | -> | Similar VR products currently available in the market | | |
| *Prototyping Portion* | | | | |
| Nandhana | -> | Unity Scenario Lead | | |
| Ragini | -> | Myo Sync Lead | | |
| Namitha | -> | Google VR Link Up Lead | | |
| *Outreach Portion* | | | | |
| Nandhana | -> | -> | Contacting professionals and experts | |
| Ragini | -> | -> | Documentation of Outreach | |
| Namitha | -> | -> | Updating list of questions for Expert Discussions/Mission Control | |

We used the Rose/Thorn/Bud technique to evaluate our work throughout the competition. One Musketeerette shared their work, then the other two Musketeeretts would say one positive thing/something to keep (Rose), one constructive thing/something to remove (Thorn), and one new step following the work the member shared (Bud). This method was a nice way to encourage one another, appreciate each member's work, and make our feedback more helpful and motivating, so there was less pressure in sharing our ideas.



For example, Musketeerette 2 thought of the primary problem statement “How can we depreciate the cost of a prosthesis [1] for amputees using Virtual Reality (VR) ?” When the other two musketeeretts evaluated this, they agreed that depreciating cost and using VR was a unique idea (Rose) but prosthesis was a topic a little too big for this project (Thorn). From there we decided to improve the problem statement by trying to minimize phantom pain (Bud).

With each member’s set of tasks, our team always assisted and encouraged each other to keep ourselves on target and ease the pressure off our specific duties.

One specific example was when Musketeerette 1 was working on the Bibliography. All of her research links formatted into MLA, but she needed help to make it more coherent. After reviewing it, Musketeerette 3 had the idea to add small descriptions of each link to make it easier to find information and helped Musketeer 1 add them in. Musketeerette 2 also found links she had used personally to add. Together, as a team, we were able to keep Musketeerette 1’s work on the right track efficiently, and we could continue with our schedule.

## 2.2 Team Plan

Our Plan:

- Week 1: Select a Topic
- Week 2: Find a Problem
- Week 3-7: Research + Criteria/Constraints
- Week 7-End: First Prototype + Testing + Complete Mission Folder

**Idea: Virtual Reality /Augmented Reality Glasses that:**

- Simulates a comfortable/familiar place to accelerate healing
- Getting used to Prosthetic legs
- Improving Physical Therapy

**Research:**

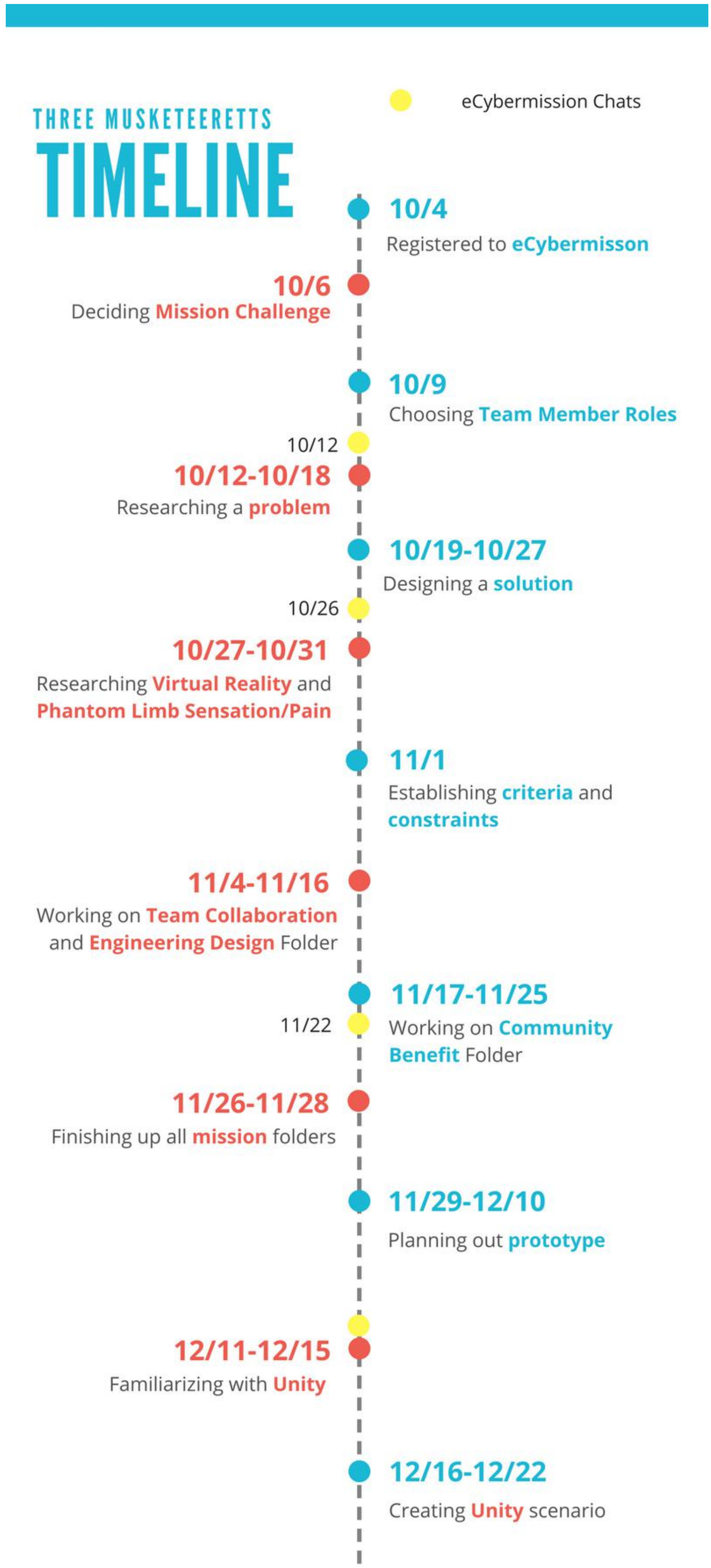
- Web Research (HOME)
- Talk to people that have gone through medical procedures
- Talk to patients in physical therapy/long term hospitalization
- Talk to nurses/physical therapists
- Talk to students: Psychology, Health Careers
- Talk to the teachers: Psychology, Health, Fitness Movement

[1] An artificial body part, such as a leg, a heart, or a breast implant.

| Date | Task |
|---|---|
| Set up our project | 1) Download Myo Connect |
| | 2) Download Unity SDK 5.4.4 |
| | 3) Download Myo SDK |
| | 4) Download Google Cardboard SDK for Unity |
| | |
| Familiarize with Unity | 1) Learn basics from tutorial video |
| | 2) **"Unity Learn" Test Game** |
| | - Roll A Ball Game |
| | |
| Create our Unity Scenario | 1) Import sample projects to learn from |
| | 2) **Enviroment and Player** |
| | - Setting up game + Moving Player |
| | 3) **Camera and Play Area-** |
| | - Moving Camera + Setting up a Play Area |
| | |
| Create our Unity Scenario | 1) **Collecting and Building Game** |
| | - Create Collectable Objects |
| | - Collecting the Pick Up Objects |
| | |
| Create our Unity Scenario | 1) **Build Game** |
| | - Add in hands + Other game elements |
| | |
| Myo Controls and Google Cardboard | 1) Add assets: Myo SDK |
| | 2) Add assets: Google Cardboard SDK |
| | |
| Build Final Project | 1) Push to Android |
| | 2) Launch Application on Phone |
| | |
| Test | 1) Run application with Google Cardboard |
| | 2) Sync Myo Armband |
| | 3) **Test with Myo + Google Cardboard on** |

## 2.3 Experiment Schedule

Our team followed this schedule (below) to complete our prototype in an organized and efficient manner.


eCybermission Chats
THREE MUSKETEERETTS
TIMELINE
10/4
Registered to eCybermisson
10/6
Deciding Mission Challenge
10/9
Choosing Team Member Roles
10/12
10/12-10/18
Researching a problem
10/19-10/27
Designing a solution
10/26
10/27-10/31
Researching Virtual Reality and Phantom Limb Sensation/Pain
11/1
Establishing criteria and constraints
11/4-11/16
Working on Team Collaboration and Engineering Design Folder
11/17-11/25
Working on Community Benefit Folder
11/22
11/26-11/28
Finishing up all mission folders
11/29-12/10
Planning out prototype
12/11-12/15
Familiarizing with Unity
12/16-12/22
Creating Unity scenario


12/27-1/3
Setting up Myo controls and pairing with Google Cardboard
12/28
1/11
1/7-1/15
Finishing up prototype
1/17-1/22
Testing prototype
1/23-1/30
Making adjustments to the prototype
1/25
2/5
Expert discussion with Karen Hayes
2/8
2/9
Expert discussion with Tom Seibert at Advanced Arm Dynamics
2/15
2/11-2/20
Reviewing and revising the mission folder
2/22
Final day to submit Mission folders

# Use of Engineering Design

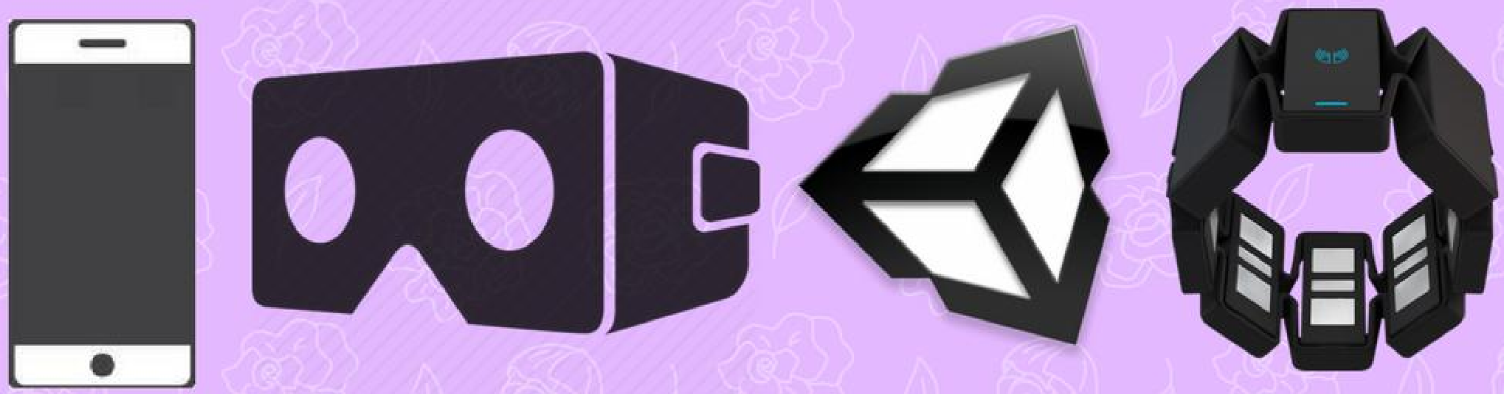

3 Problem Statement . . . . . . . . . . . . . . . . . . . 21
3.1 The Problem
3.2 Resources
3.3 Our Learning

4 Experimental Design . . . . . . . . . . . . . . . . . . 29
4.1 Design Statement
4.2 Success Criteria
4.3 Variables

5 Build Prototype or Model . . . . . . . . . . . . . . 33
5.1 Bill of Materials
5.2 Procedure

6 Test Prototype or Model . . . . . . . . . . . . . . . 35
6.1 Data Collection
6.2 Analysis
6.3 Sources of Error

7 Drawing Conclusions . . . . . . . . . . . . . . . . . 41
7.1 Evaluation

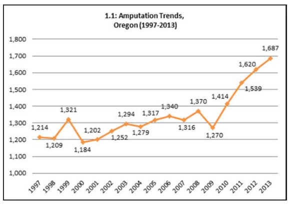


# 3. Problem Statement

## 3.1 The Problem

***What problem in your community did your team try to solve? Why is this problem important to your community?***

The growth in the technological and medical field has been quite significant this decade. However, even as humans are making significant breakthroughs in certain matters, new issues are quickly rising.




One obstacle on the rise, perhaps one of the most rapid, is amputations. It is hard to imagine that "Currently, 1.9 million people are living with limb loss in the United States, and an average of 507 people continue to lose a limb every day. This increase results in an estimated 185,000 amputations per year." (Source 1). Moreover, this is certainly not an issue that is planning to slow down anytime soon. The increases in diabetes[1], peripheral arterial diseases[2], vascular diseases[3], trauma and (believe it or not) lawn mower accidents has triggered a rise in amputations. What's even more frightening is that the number of amputations[4] per year "is expected to double by the year 2050". In our state of Oregon, there has been a 38.96% increase in amputations performed from 2000 to 2013 (Source 1). That is no minuscule number, and it is important not to forget that.

The number of amputees is escalating much faster than anyone has ever expected, with such a significant population of people suffering from the effects of amputation we wanted to make a solution that would change the way amputees face his or her challenges.

[1]A disease in which the body's ability to produce or respond to the hormone insulin results in abnormal metabolism of carbohydrates and higher levels of glucose in the blood and urine.

[2]A common circulatory problem, typically in which the legs don't receive enough blood flow to keep up with demand.

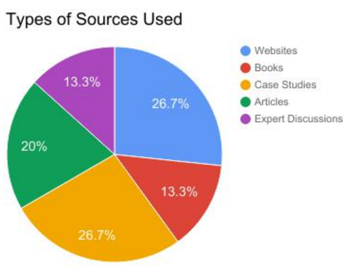
[3]A subgroup of cardiovascular diseases, it is a class of diseases of the blood vessels.

[4]The action of surgically cutting off a limb.

**Our Problem Statement:** How can we minimize Phantom Limb Sensation/Pain for amputees using VR technology, cost effectively?

## 3.2 Resources

***List at least 10 resources you used to complete your research (e.g., websites, professional journals, periodicals, subject matter experts). Use multiple types of resources and do not limit yourself to only websites.***




Before we began designing our solution, it was essential that we had a strong background of our topic. Our team divided our research into the types of sources we should collect; Websites, Books, Case Studies, Articles, and Expert Discussions. By using a variety of sources, we got a strong understanding of the problem we were trying to improve before improving it, and we were able to pick up much information we could have otherwise not noticed.

### Websites:

1. "Oregon Fact Sheet." Amputee Coalition . Amputee Coalition , Apr. 2016. Web. Dec. 2017. `http://www.amputee-coalition.org/resources/oregon-2`.
   This site covers facts about amputees in Oregon/United States of America, as well as daily and yearly limb loss trends in amputees. Data is also available for the types of amputations performed and demographics for the factors of gender, race, and age, on amputations. Lastly, it covers the current the current health care costs. This source is imperative for backing our design's importance/usefulness.

2. Firm, Pisanchyn Law. "Types of Amputations." Types of Amputations| Amputation Types | Pennsylvania Amputation Lawyers. Pisanchyn Law Firm, 08 Mar. 2013. Web. 15 Jan. 2017. `http://www.catastrophicallyinjured.com/pennsylvania-amputation-attorneys/amputation-types.html`
   We wanted to conduct research on the types of amputations before prototyping. This website shared the common types of amputations and their effects on the amputee. The broad range of amputations enforced us to design a prototype for a particular amputation before expanding.

3. "Managing Phantom Pain." Amputee Coalition. Amputee Coalition, n.d. Web. 15 Jan. 2017. http://www.amputee-coalition.org/limb-loss-resource-center/resources- for-pain-management/managing-phantom-pain
   To understand the concept of Phantom Limb Sensation and Phantom Limb Pain (as well as the difference), we used this site for an aggregate explanation. It covers a broad range of reasons for Phantom Limb Sensation/Pain, including non-amputation related conditions. Lastly, it describes current therapy and medications for PLS/PLP and their effectiveness. This resource had provided an essential background before we began designing a solution.

4. "Phantom Limb Pain: Mirror Therapy Treatment." MedicineNet. N.p., n.d. Web. 15 Jan. 2017. `http://www.medicinenet.com/script/main/art.asp?articlekey=88097`
To fully understand mirror therapy, a form nonpharmacological of treatment for Phantom Limb Sensation/Pain, we read about Jack Tsao's tests on amputees and a breaking down of why it works. Before finalizing our solution, we wanted to know the successfulness of the current therapies for PLS/PLP.

**Books**:

5. Ramachandran, V.S. The Tell-Tale Brain. N.p.: Norton, W. W. & Company, Inc., 2012. Print.
This book provided us with a range of information. V.S Ramachandran explains his theories on the origin of Phantom Limb Sensation/Pain; The area in the brain deprived of sensory inputs becomes hungry for new sensations. We also learned about his methods in 'unlearning' phantom limb pain- an in-depth analysis of mirror therapy. This book was both an informative and fascinating read.

6. Murray, Craig, ed. Amputation, Prosthesis Use, and Phantom Limb Pain: An Interdisciplinary Perspective. London: Springer Science & Business Media, 2010. Print.

   The text offers a broad and innovative exploration of the entire process surrounding limb loss and eventual recovery. We were able to read in-depth on the adaptation to amputation and prosthetics, as well as post-amputation phantom limb sensation/pain recovery period.

**Case Studies:**

7. "Phantom Limb Pain." Phantom Limb Pain. Minnesota Department of Health, Aug. 2016. Web. Fall 2016.

   The Minnesota Department of Health created a study covering completed clinical trials, and observational studies on PLP, which we used before conducting our tests.

8. Nejatkermany, Mahtab Poor Zamany, Ehsan Modirian, Mohammadreza Soroush, Mehdi Masoumi, and Maryam Hossein. "Phantom Limb Sensation (PLS) and Phantom Limb Pain (PLP) among Young Landmine Amputees." Iranian Journal of Child Neurology. Shahid Beheshti University of Medical Sciences, 2016. Web. 27 Dec. 2016.

   This study provides the results and methods used for better understanding in Phantom Limb Sensation and Phantom Limb Pain. It also includes referable results/statistics on the PLS/PLP period.

9. Virtual Reality Prosthetics. N.p., n.d. Web. 27 Dec. 2016.

   To ensure our design was unique, we investigated similar projects- and their effectiveness. This link provides an example of a VR solution used for amputees before prosthesis; It includes videos on the community benefits and goals of the product. Our design does not share the same approach nor intentions, but it was important to confirm the differences.

10. "Virtual Reality for Phantom Limb Pain." Virtual Reality for Phantom Limb Pain - Tabular

View - ClinicalTrials.gov. N.p., n.d. Web. 27 Dec. 2016.

We wanted to find a complete study of Phantom Limb Sensation/Pain and discovered this proposed government plan, for studying amputees and VR. We aim to create a more cost-effective study than their proposed project. The goal of this project is to offer a distraction from the PLS/PLP. Our goal is to provide therapy for PLS/PLP.

**Articles:**

11. "Developing the World's Most Advanced Prosthetic Arm Using Model-Based Design." Developing the World's Most Advanced Prosthetic Arm Using Model-Based Design - MATLAB & Simulink. N.p., n.d. Web. 27 Dec. 2016.

This article provides a description of a complete simulation of a virtual prosthetic arm run by Matlab and Simulink. This article includes the design process, i.e., creating the integration environment, interfacing with the nervous system. The aim of this project was to develop a virtual prosthetic arm (not used for therapy) that will move with the correct physics of an identical prosthetic arm. Though not directly relating to our solution, we still wanted to discover new technologies for amputees, and it helped us get ideas for our project.

12. Greenwald, Will. "The Best VR (Virtual Reality) Headsets of 2017." PCMAG. N.p., n.d. Web. 15 Jan. 2017.

To keep our design cost- effective, we scrutinized the many types of VR headsets. This article distinguished the available technologies for displaying our VR app to the amputee and narrowed our choice. Following this reading, we decided on the Google Cardboard as it fit our needs as well as stayed on budget.

13. Ramachandran, V. S., and W. Hirstein. "The perception of phantom limbs. The D. O. Hebb lecture." Perception of phantom limbs. The D. O. Hebb lecture. | Brain | Oxford Academic. Oxford University Press, 01 Sept. 1998. Web. 15 Jan. 2017.

This article explains how the brain perceives phantom limb pain and also different medical technology that shows cortical topography in the patient/amputee. It also covers more advanced operations and imaging procedures.

**Expert Discussions:**

14. Hayes, Karen, Ms. "Expert Discussion with Karen Hayes." Personal interview. 9 Feb. 2017.

To learn more about the community of amputees we met up with the director of the American Amputee Foundation of Oregon, and an amputee herself. We shared our project with Karen, gave her a chance to try out the prototype and got our questions about amputees, and Phantom Limb Pain/Sensation answered.

15. Seibert, Tom, Mr. "Expert Discussion with Tom Seibert." Personal interview. 9 Feb. 2017.

During our meeting with Karen, she recommended we speak to Tom at Advanced Arm Dynamics, who (as an amputee who had lost his lower left arm) could be of real help in testing our prototype out. We met up with Tom at the Advanced Arm Dynamics office where we presented our design to him and the whole clinic team!

## 3.3 Our Learning

***Describe what you learned in your research***

| Research Topic | Questions we asked to confirm it's relevance to our Mission Challenge |
|---|---|
| 1. Amputees | ➔ Will our solution be beneficial for this group of people?<br>➔ Are the issues this group of people face serious?<br>➔ Is the amputee population one that is growing? Will our solution still be useful for this group in the near future? |
| 2. Phantom Limb Pain | ➔ Will our solution improve the state of this issue or at least lessen the degree of it?<br>➔ Is this issue harmful, and are its effects on amputees authentically proven?<br>➔ Is this a common issue for amputees? |
| 3. Current Phantom Pain Treatments | ➔ What technology is being used to improve this issue currently?<br>➔ What are the problems with the technology being used currently to improve this issue?<br>➔ How would our solution fix or improve those problems? |
| 4. Virtual Reality | ➔ What would Virtual Reality do for our solution to make it more efficient and effective?<br>➔ Is this a new, unique technology?<br>➔ What are the types of VR tech available, and what features do they have? |

We began our research by thinking of the current problems we face in our community and the world. For each of these problems, we brainstormed possible solution then chose the most important ones to research further- including the relevance to our eCybermission.

To determine the importance of our problem in the community, now and in the future, we did extensive research on the amputee population, our state of Oregon in particular. We wanted to see the magnitude amputations had near us; the results left us with consternation. Source 1 told us that amputations performed in Oregon were at a high of 1,687, according to hospital discharge data[5]. It is an issue that is not only relevant in our state but also throughout the globe; as there are nearly 10 million people worldwide suffering from the effects of amputations.

[5]The point at which the patient leaves the hospital and either returns home or is transferred to another facility.

First, we began by studying the major challenges faced by amputees. As side effects of an amputation, amputees face many negative cognitive changes such as phantom limb sensation (PLS) and phantom limb pain (PLP). PLS/PLP can be described as “Pain that is experienced in a missing or amputated limb” (Source 6). To narrow down our research and problem topic, we chose to target minimization of PLP and PLS as they frequently occur in many amputees and can be very damaging to the amputee’s mental and physical condition. A study about the frequency of PLP and PLS concluded that “Phantom limb sensation and pain" appear to be common even after years of amputation” (Source 4).

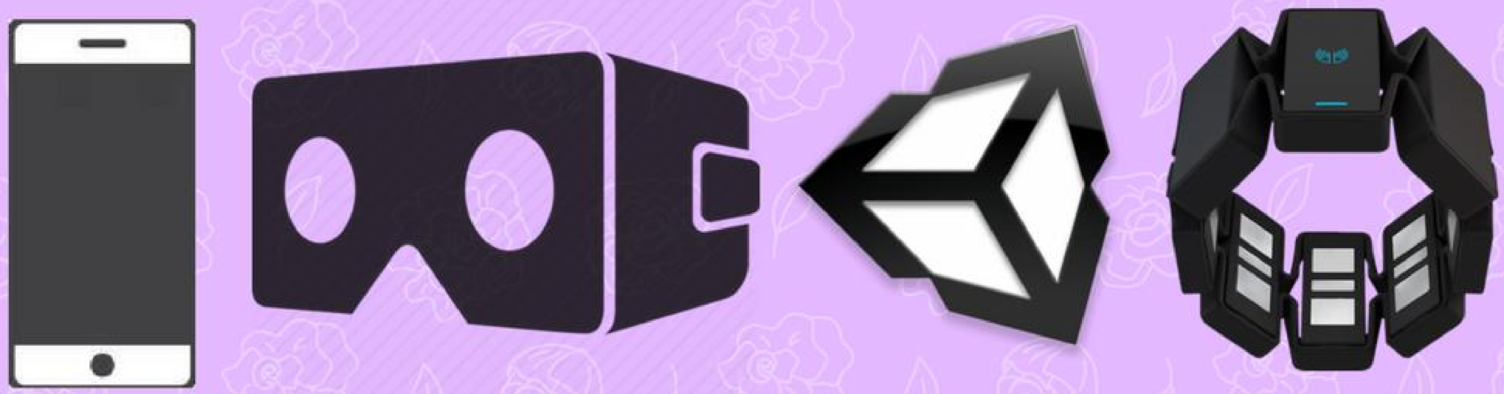
| Problem | What has already been done to fix this problem? | How can we improve their solution? How can we solve the problem? |
|---|---|---|
| Prosthesis process for amputees are expensive. | VR prosthesis project using Oculus and Myo to see if amputee is capable for using a prosthesis. https://vrprosthetics.shu.ac.uk/project/ | We can lower the cost of the VR headset by using Google Cardboard or other cost-effective options. |
| Amputees need an effective Phantom Limb Sensation/Pain therapy | No attempts have been completed to solve this issue; However there is a proposed plan to use VR. https://clinicaltrials.gov/ct2/show/record/NCT02784548 | Lower the cost of the VR, as well as provide a therapy oriented design, rather than a distraction oriented design. |

Next, we researched the current methods of pharmacological treatment for PLP. We first found the use of Opioids[6],a drug that relieves pain in the brain (Source 6). However, this treatment has proved to only have moderate success in reducing Phantom Limb Sensation/Pain and was only effective in reducing PLS/PLP short term. We found that non-pharmacological treatments were more beneficial in reducing PLS/PLP. For example, Mirror Visual Therapy is a process where an amputee places their corresponding non-amputated limb in a mirrored box, which gives the effect that they have reinstated their limb. This treatment has proven to be effective in reducing PLP, although there have been no formal trials conducted using this treatment. A similar procedure called guided imagery, asks for the amputee to use their mental imagery to create an image in which the amputee can feel their missing limb.

With a clearer idea of our problem, we thought of using Virtual Reality (VR) technology to better implement a combination of mirror visual therapy and guided imagery treatments for PLP. We found a similar study had been conducted using VR for amputees. The cost of this solution was inordinately expensive, therefore excluding many amputees, who could otherwise benefit from it. We also wanted to orient our design as a PLS/PLP therapy, rather than just a distraction. Our

[6]An opium-like compound that binds to one or more of the three opioid receptors of the body.

team decided to conduct more research on the current types of VR technology to find a more cost-effective solution. Virtual reality tech ranged from products such as the Oculus Rift, a $800 VR headset and the Google Cardboard, a $15 VR headset. We went through over 15 products in the market, analyzing, comparing, contrasting between their costs, efficiency and their features until we decided to use the Google Cardboard. Gesture control technology was much easier to look at, as it is a new concept the only compatible product for our needs was the Myo, $200 gesture control armband. By thoroughly analyzing the technology available we were able to get a deeper understanding of how we should design our solution.



# 4. Experimental Design

## 4.1 Design Statement

***Develop a design statement. Be sure to describe what exactly your device should be able to do. Do not describe HOW it's going to do what it needs to do.***

Our final design should be able to recognize multiple gestures from amputee's with different amputations (see below) and create a virtual limb with correlating movements to the amputee's gestures through a cost effective design. The virtual environment should create the illusion that the amputated, and remaining limb, are both moving. This process will reduce the amputee's opioid[1] use and Phantom Limb Sensations/Pain. The specifications are as follow

1. Recognize skeletal muscle gestures from an amputee with

   Upper Limb Amputations
   - Metacarpal Amputation
   - Wrist Disarticulation
   - Transradial Amputation
   - Elbow Disarticulation
   - Transhumeral Amputation

   Lower Limb Amputations:
   - Partial Foot Amputation
   - Ankle Disarticulation
   - Transtibial Amputations
2. Easily wearable
3. Easily removable
4. Adjustable
5. Comfortable
6. Accessible at home or at a hospital

[1] A drug used to relieve pain

| Problem Statement Properties | How? | What? | When? | Where? | Why? | Who? |
|---|---|---|---|---|---|---|
| Time | At least a month for creating the prototype (Unity SDK) and test (Using Google Cardboard) | Anytime, preferably day (for the test subjects). | As soon as SDK is ready and working with the Myo and Google Phone. | In the the Advanced Arm Mechanics Clinic or other Amputee Clinics. | We must have time to test and analyze our project. | Our team will plan our time. |
| Materials | We will download the Unity SDK, Myo SDK, and Google VR SDK. We also need a Myo armband and Google Cardboard. | We will need the Unity SDK, Myo SDK, and Google VR SDK. | As soon as we acquire all the materials. | Download from the correspon ding websites. The rest must be purchased. | To make a cost-reduced VR arm to reduce phantom limb sensation/pain. | We will get our team advisors to help get the materials. |
| Safety | Our advisor will be with us and we've completed our IRB form. | A completed IRB form. | As soon as the IRB form is complete. | A wide open area for patient. | So our test subjects are safe during the test. | A school authoritative, science teacher, doctor and team advisor. |
| Benefit to community | Allows more amputees to reduce their PLS/PLP. | A cheaper PLS/PLP therapy for amputees | During an amputee's phantom limb pain period. | In hospitals and any amputee's home. | It allows amputees facing PLS/PLP to heal with cost-effective therapy. | Amputees facing Phantom Limb Sensation/Pain. |
| Appropriateness. | It falls under the Technology | We can use the engineerin | When our prototype is ready. | Wherever the amputee is | So are solution is effective in reducing | Our team's design. |

## 4.2 Success Criteria

***Determine the criteria for a successful solution and identify constraints for your design. Discuss what the device must have in order to accomplish its job and the restrictions of the device (i.e. the size, the cost, the weight, etc.).***

**Criteria:**

1. The device must be cost-effective.

   Many current forms of non-pharmacological/pharmacological treatments for phantom limb pain are expensive, making it exclusive for use by only those that can afford it. By making our device cost-effective, we can make it available to virtually every amputee that needs it.

2. The device must be able to recognize gestures made by the amputee.

The VR app on the Google Cardboard headset should be able to identify the signals the remaining portion of the amputee's limb, using the Myo Gesture Control Armband. The VR app must then be able to translate them into gestures on the virtual arm, seen in the Cardboard.

3. The device must be easy to use by the amputee.
   For utilization in a hospital, home and amputees of all ages, the device, and its setup must be straightforward and easy to use.

**Constraints:**

1. The prototype must be complete in six weeks.

   The deadline for the mission challenge limits the time to build, test, and evaluate the prototype.

2. The cost of the device must not exceed $250.

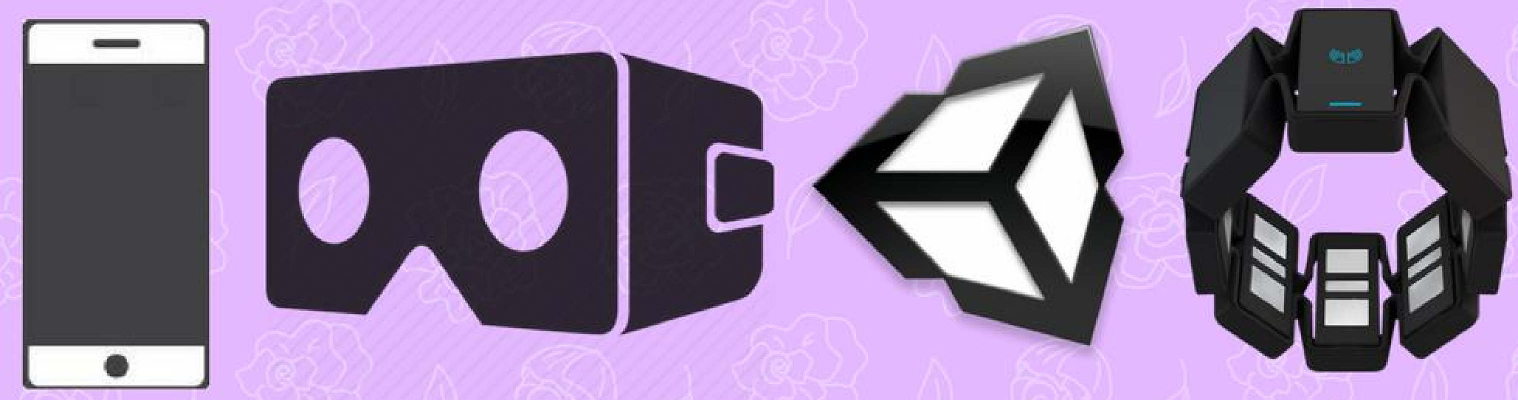
The cost of our prototype cannot exceed $250 according to the official rules of eCybermission.

## 4.3 Variables

***Identify the relevant variables you will use to test your prototype or model and explain how you will measure your variables.***

The variables we were testing in our design is the percent of accuracy in the gesture control sensor synching with the VR app. We will test our design on transradial amputees[2], and measure the percent of gestures correctly picked up. We can measure this by analyzing the data from the eight EMG Pods on the Myo Gesture Control Armband.

[2] An amputee who's radius and ulna (bones of lower arm) are cut.

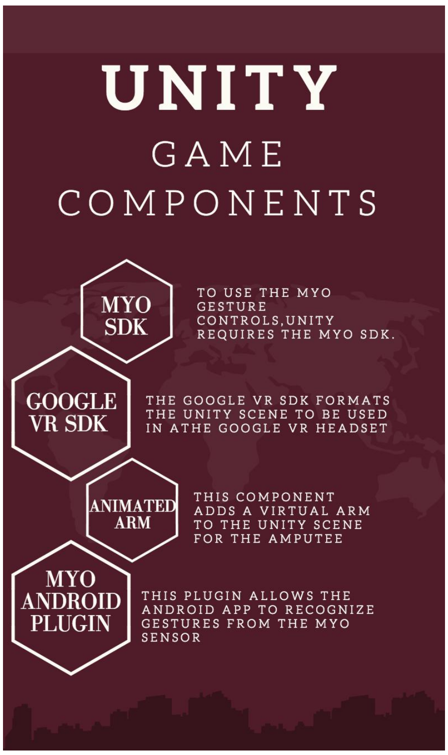


# 5. Build Prototype or Model

## 5.1 Bill of Materials

***Develop a design and list the materials you used in your design. Include technologies you used (e.g., scientific equipment, internet resources, computer programs, multimedia, etc.).***

To get the needed results, we are using a variety of materials and technologies to develop our design efficiently.

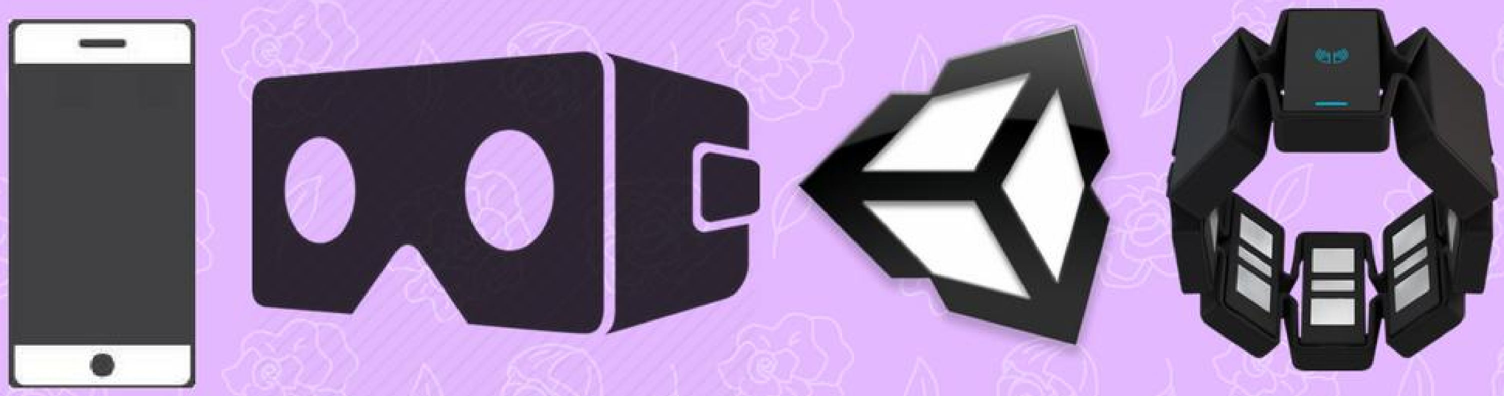


1. Google Cardboard:
   We run our VR application on the Google Cardboard and use it to connect with the Myo Armband.
2. Myo:
   Using the Myo SDK on unity, the Myo Gesture Control Armband can connect to Unity. The VR app can then replicate the gestures from the Myo Armband onto the screen. With the Myo's eight EMG Pods we can test the percent of accuracy of gestures being correctly picked up.
3. Development Tools & SDK:
   - Unity 3D Studio: Software we used for compiling the VR application and creating the virtual scene. We are using an older version (5.4.4) because the Myo SDK had issues with the newer versions.
   - Google VR SDK: This provides the software for compiling the project to be accessed on Google Cardboard.
   - Myo Connect: Software to connect Myo device with the PC.
   - Myo SDK: Like stated above, the Myo SDK allows Unity to read the Myo Armband's gestures.
   - Myo Unity Pluggin for Android
4. Smart Phone: We are using a Samsung Galaxy s6 to view the VR application and to use for the Google Cardboard.

## 5.2 Procedure

***Explain how you built your prototype(s) or model(s). Include each of the steps in your process. Include all safety precautions used by your team as step one.***

1. Safety Precautions
   - Checked for safety of website before downloading any software
   - Parent verification before downloading software
   - Verified latest anti-virus software before downloading any component from the Internet
   - Check for copyright restriction and understand open source usage policy
2. Drew out a design flow chart
3. Downloaded Myo Connect
4. Downloaded Unity SDK (5.4.4)
5. Downloaded Myo SDK
6. Downloaded Google Cardboard SDK for Unity
7. Downloaded Unity Sample Game
8. Created a sample Unity game
9. Created our Unity Environment and Player
10. Placed our Unity Camera and Play Area
11. Created our Unity objects and other elements
12. Added Assets: Myo SDK, Google Cardboard SDK
13. Pushed to Android and launched application on Phone
14. Tested
15. Refined Unity Project and re-tested



# 6. Test Prototype or Model

## 6.1 Data Collection

***Present the data you collected and observed in your testing. The use of data tables, charts and/or graphs is encouraged.***

To test the accuracy of our prototype, we recorded the percentage of the gestures correctly recognized. We were able to test our design on three subjects, with five trials per gesture.

| **Test Subject 1:** | | | | | | |
|---|---|---|---|---|---|---|
| **Gesture Type** | **Trial 1** | **Trial 2** | **Trial 3** | **Trial 4** | **Trial 5** | |
| Wave Left | 1 | 0 | 1 | 1 | 1 | 80.00% |
| Wave Right | 1 | 1 | 1 | 1 | 1 | 100.00% |
| Double Tap | 1 | 1 | 1 | 1 | 1 | 100.00% |
| Fist | 1 | 0 | 1 | 1 | 1 | 80.00% |
| Spread Fingers | 0 | 0 | 1 | 1 | 0 | 40.00% |
| Rotate | 1 | 1 | 1 | 1 | 1 | 100.00% |
| Pan | 1 | 1 | 1 | 1 | 1 | 100.00% |

Figure 6.1: Table shows the data collected from our first test subject with calculated value for accuracy

While some gestures were very accurately recognized, like Fist, others were not at all, ex. Wave Right. With the third subject, the gesture Spread Fingers was never recognized while Double Tap was recognized every time.

| Test Subject 2: | | | | | | |
|---|---|---|---|---|---|---|
| Gesture Type | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | |
| Wave Left | 0 | 1 | 1 | 1 | 0 | 60.00% |
| Wave Right | 0 | 1 | 0 | 0 | 1 | 40.00% |
| Double Tap | 1 | 1 | 0 | 1 | 1 | 80.00% |
| Fist | 1 | 1 | 1 | 1 | 0 | 80.00% |
| Spread Fingers | 1 | 1 | 1 | 1 | 1 | 100.00% |
| Rotate | 0 | 0 | 1 | 1 | 1 | 60.00% |
| Pan | 1 | 1 | 1 | 1 | 1 | 100.00% |

Figure 6.2: Table shows the data collected from our second test subject with calculated value for accuracy

| Test Subject 3: | | | | | | |
|---|---|---|---|---|---|---|
| Gesture Type | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | |
| Wave Left | 1 | 0 | 1 | 1 | 1 | 80.00% |
| Wave Right | 0 | 0 | 0 | 1 | 1 | 40.00% |
| Double Tap | 1 | 1 | 1 | 1 | 1 | 100.00% |
| Fist | 0 | 1 | 1 | 1 | 1 | 80.00% |
| Spread Fingers | 0 | 0 | 0 | 0 | 0 | 0.00% |
| Rotate | 1 | 1 | 1 | 1 | 1 | 100.00% |
| Pan | 1 | 1 | 1 | 1 | 1 | 100.00% |

Figure 6.3: Table shows the data collected from our third test subject

The next step to collect the user response on the game interaction. The following steps are used for game interaction.

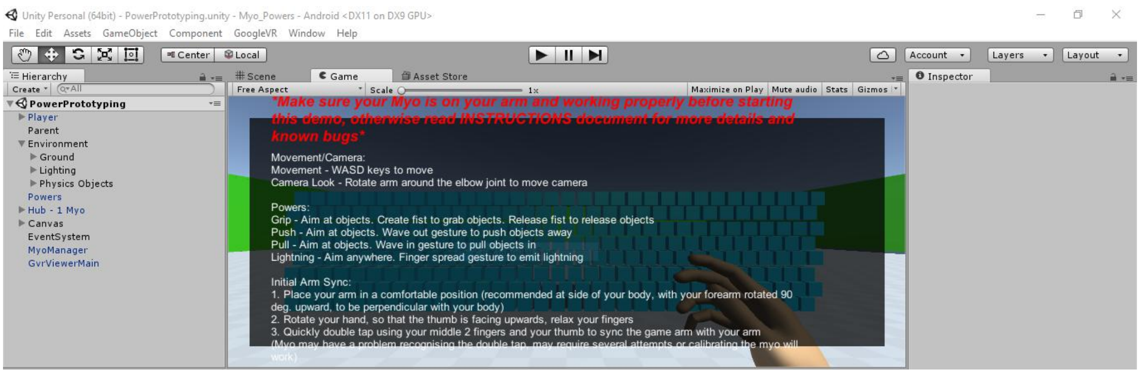



Figure 6.4: (Above) To begin game use the double tap gesture. The rest of the game instructions are also found on this page.

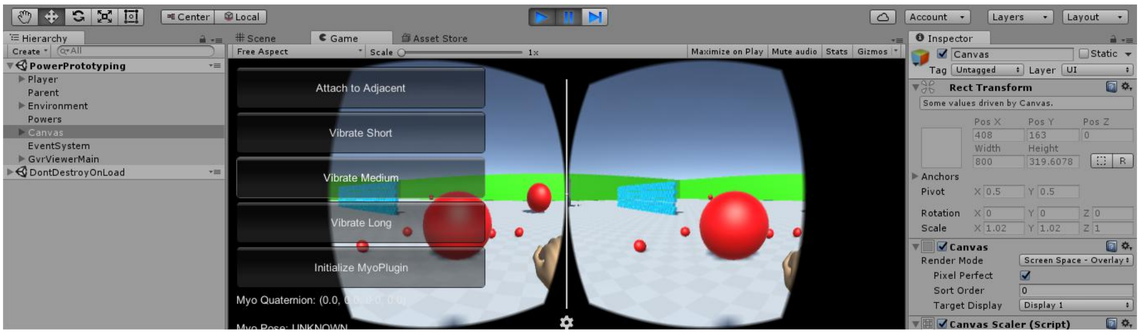



Figure 6.5: The Fist gesture allows the amputee to grip ball/balls.

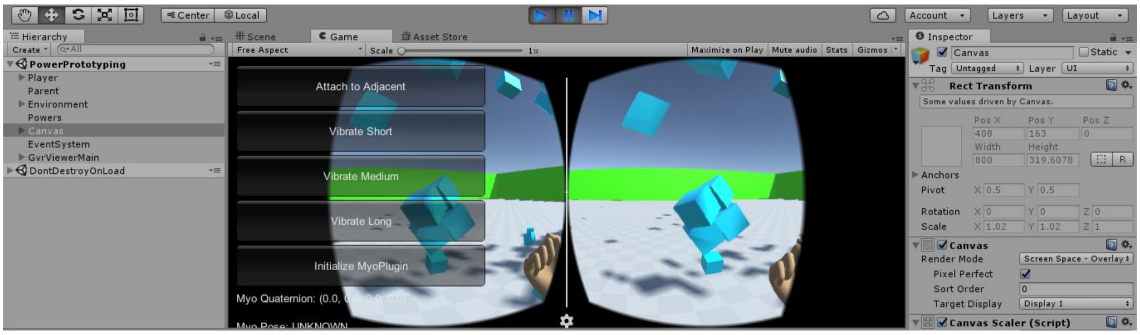



Figure 6.6: The fist gesture can also grip blocks (above) and rods.

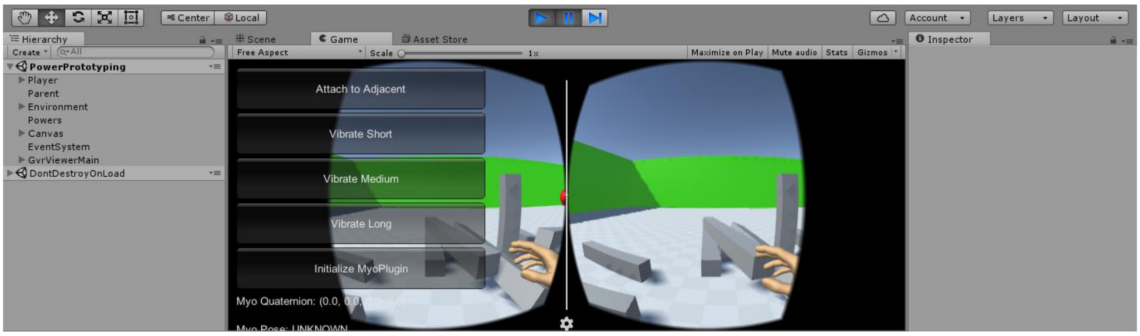



Figure 6.7: To push objects away from the screen, the amputee can use the Wave Out gesture.

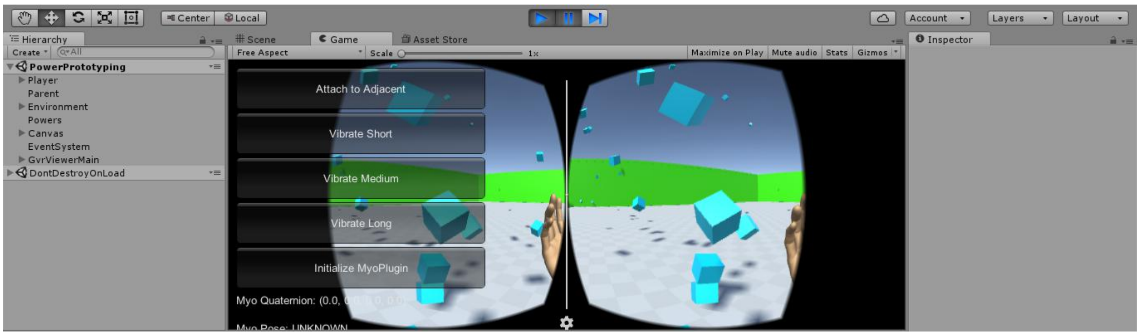



Figure 6.8: Similarly, the Wave In gesture brings objects towards the screen.

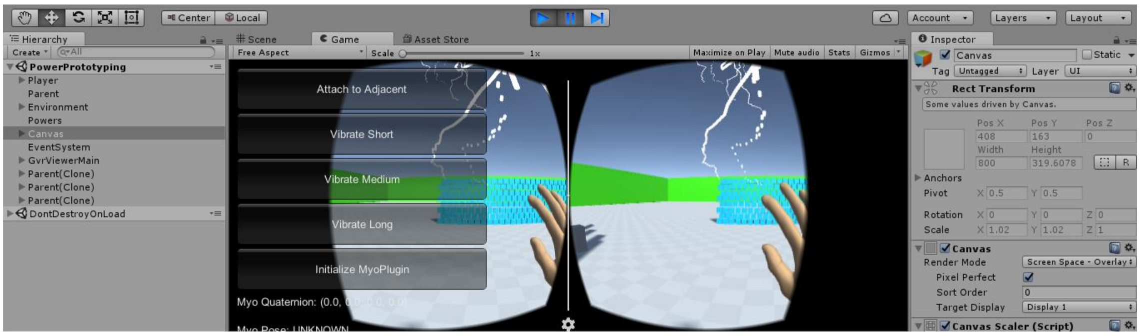



Figure 6.9: Lastly, the player can emit lightning through the Fingers Spread gesture

## 6.2 Analysis

***Analyze the data you collected and observed in your testing. Does your data support or refute your design statement? Do not answer with yes or no. Explain your answer using 'Our data supports/refutes the design statement because...'***

Our data supports our design statement because our final design was able to consistently recognize various gestures from the amputee's limb consistently and correlate the movements of the amputee's gestures, through a cost-effective design.

Our design was able to recognize each gesture and complete the corresponding game step accurately. The double tap gesture was recognized an average of 93% to open the game. The amputee could push objects away 60% of the time, but it was 73% accurate in pulling the objects. Lastly, the amputee could 'grip' objects using the fist gesture 80% of the time. An outlier was found in the Spread Fingers gesture, which was only 47% consistent.

| Gesture | Corrosponding Game Step | Average Accuracy |
|---|---|---|
| Double Tap | Open Game | 93% |
| Fist | Grip | 80% |
| Open Left | Pull | 73% |
| Open Right | Push | 60% |
| Spread Fingers | Lightning | 47% |

## 6.3 Sources of Error

***Explain any sources of error and how these could have affected your results***

While we tried our hardest to make our prototype an accurate representation of our design, there are several sources of error to take into account that they could have affected our results:

1. Not tested on a range of amputees.

Our prototype can only be tested on amputees who have lost the lower extremity arm. Therefore the information we have collected only relates to a select group of amputees and is irrelevant for amputees with different conditions. Even if our prototype works ideal for one amputee, it could be unsuccessful for another.

2. Not fully able to test for results.

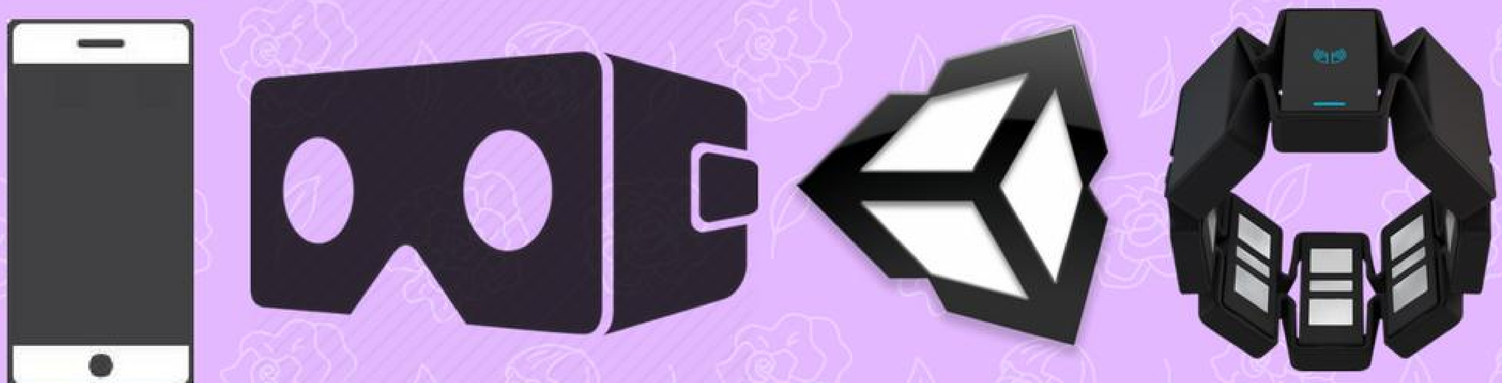
   As it can take years, even a lifetime, for an amputee to overcome PLP/PLS our prototype was never tested for effectiveness in overcoming these problems. It relies more on the psychological hypothesis of the professionals and amputees we have spoken to, as well as what we read. Within our constraints, we cannot prove our prototype helps amputees overcome PLP/PLS, but in theory, it should.

3. Data is qualitative

   Phantom Limb Pain and Phantom Limb Sensation are both more emotional than physical. It is impossible to track the level of pain or discomfort precisely an amputee will experience over time nor can the pain or discomfort an amputee experiences be precisely measured. We analyzed our results based on the percent of gestures accurately sensed by the Myo, but this may not directly correlate with the Phantom Limb Pain/Sensations.

4. Myo's accuracy

   During our first trials, we began to find an inaccuracy in the collected EMG data. To identify the error, we had the Myo device in a static condition (the amputee's arm is at the stationary position). Because the Myo did not move, there should have been no changes in the recorded EMG data; However, we found many fluctuations in the values, showing we were processing errors in our data collection. We found more accurate values for the Accelerometer, and Gyro results, but we would need to retest the scenario for better results. In addition to this, the armband size played a significant role in accuracy; a smaller arm would not be able to recognize gestures as easily as a bigger one. For example test subject 3 had the smallest arm and the lowest accuracy of 71% while the largest hand size test subject 1 had the highest accuracy of 85%.



# 7. Drawing Conclusions

## 7.1 Evaluation

***Interpret and evaluate your results and write a conclusion statement that includes the following: Describe what you would do if you wanted to retest or further test your design. Evaluate the usefulness of your prototype or model. What changes would you make to your prototype or model for the future, if any?***

To further test our design we would retest on a larger sample group of amputees with different amputations, that would test our prototype's efficiency more accurately. Retesting on a larger group of amputees with a variety of amputations can also give us more feedback on how well the design of the prototype works, which will help us make improvements. We would also conduct testing over a longer period. As this is a therapy the patient's PLP/PLS will require several sessions using the design, not just one.

Because PLP/PLS is not a physical phenomenon, to measure the long-term effects of our VR therapy and an amputee's Phantom Limb Sensation/Pain is currently beyond our prototype's capabilities. However, our prototype performs very accurately in the underlying concepts of our design. Our prototype can successfully collect data from Myo's EMG pods, which is significant because it means that our program can receive the signals from Myo and translate it into movements in the Unity program. The EMG data is extremely consistent with gestures such as wave out and double tap. This proves that the prototype can accurately respond to the gestures that the amputee will make to interact with the virtual environment. Our prototype completes its criteria effectively; we just need to put it into practice.

Although our prototype was successful in creating a virtual limb for the amputee as well as a gamified therapy, it is not yet complete. First, we want to improve the virtual setting. The more realistic the surrounding, the better the therapy. We also want to explore the option of making the virtual setting into a place that the patient feels more comfortable than our current scenario. For example, we could create the virtual setting of one patient into their bedroom, a place that they will most likely feel more comfortable and relaxed. This will also allow the patient to heal faster because they are more open, rather than being in a tense hospital environment. Secondly, as the gestures required practice from the patients, practicing the movements before testing might make our prototype more efficient and easier to use.

IV

# Community Benefit

8 Benefit to the Community . . . . . . . . . . . . . 45

# 8. Benefit to the Community

***How could your design help solve your problem and benefit your community? Describe next steps for further research/design and how you have or how you could implement your solution in the future.***

Our design provides a cost effective therapy for Phantom Limb Sensation (PLS) and Phantom Limb Pain (PLP); amputee's most preeminent challenges. With amputation rates on the rise, there are ever more patients desiring effective PLS/PLP therapy. Our design will lessen the PLP in an amputee by creating the image of a working limb in the gesture control synced VR app. By using low-cost technologies such as the Google Cardboard, we can keep our design cost efficient while still effectively solving the problem.

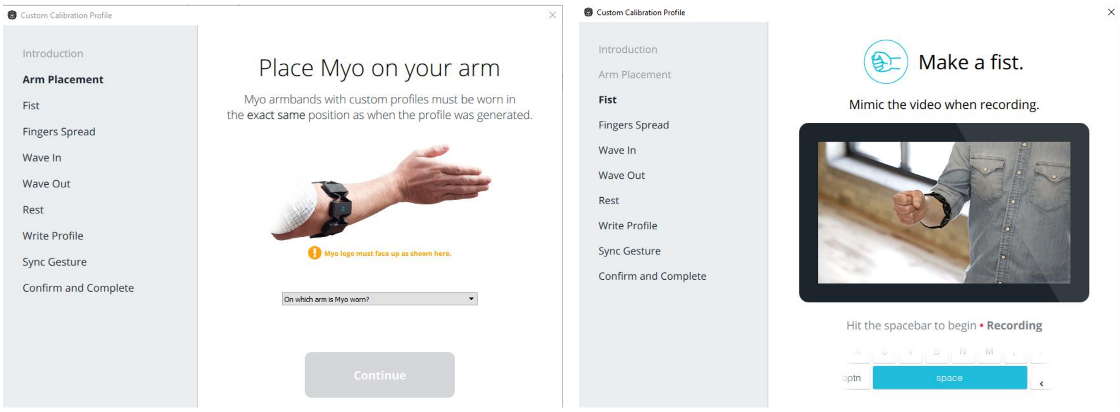
It could benefit the community of over 22,828 amputees in Oregon, of which 80% face PLP (Source 1), by minimizing the number of amputees that experience phantom limb pain. Our design will also reduce the costs of the overall treatments for amputees experiencing PLS/PLP, as current therapy prices exclude many amputees.

In the future, we want to enhance our solution by;

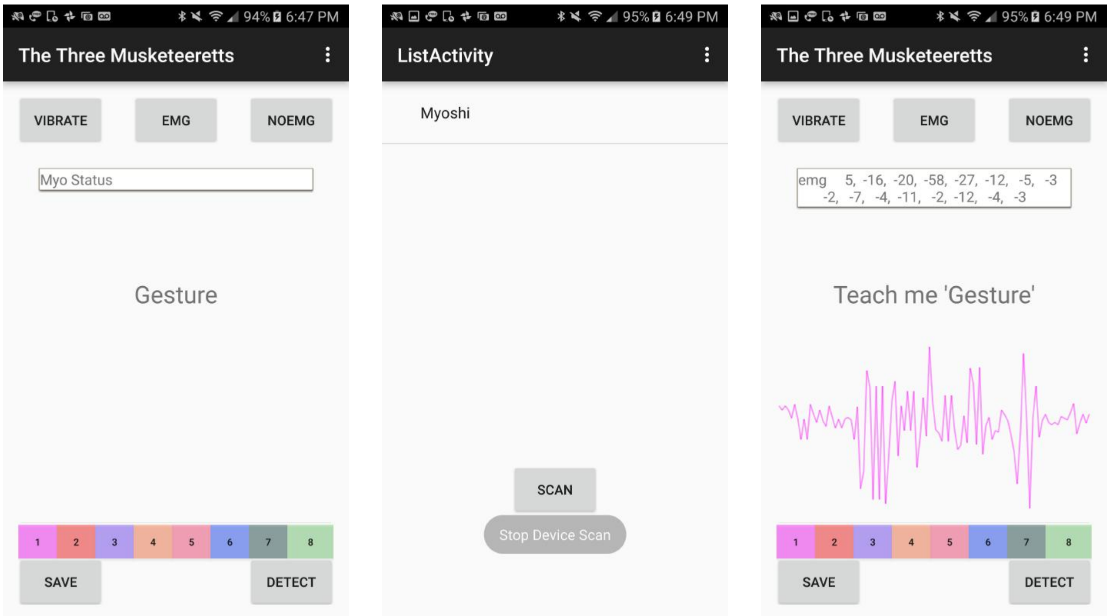
1. Add additional VR/gesture experiences for the user to try

   The current gestures we are using will need to be expanded on to provide more freedom to the amputee. Adding more gestures will also enhance the authenticity of the VR simulation (Ex.Tying shoelaces, holding a glass, and so forth).

   Without the real limb, the amputee's gestures might not be the same as a person with the limb. So we researched how our design could allow amputees to set up their personalized gestures in which they are more comfortable in, as well as decipherable by the Myo. We found that by using the 'Create Profile' tab on the Myo Armband Manager, the user can personalize the Fist, Finger Spread, Rest, Wave In, and Wave Out. Using this our design will work more efficiently for the amputee.




We also found an open source code available that also provided the EMG data corresponding to the Myo's movements. This app allowed the user to record the EMG data for any arm gesture. Incorporating a similar design could eliminate the need for amputee's to learn gestures that require the image of their missing limb, which can be confusing and challenging. Rather, the amputee can make their own gestures, which they are comfortable in, and have the virtual limb mimic their personalized movements.



2. Make the design compatible for people with various amputations

Our prototype can only be tested on amputees who have lost the lower extremity arm. In the future, our design should be adaptable for patients with any amputation; Upper Limb Amputations (Metacarpal Amputation[1], Wrist Disarticulation[2], Transradial Amputation[3], Elbow Disarticulation[4], Transhumeral Amputation[5]) and Lower Limb Amputations (Partial Foot Amputation[6], Ankle Disarticulation[7], Transtibial Amputations[8]).

3. Make our design adaptable for patients before receiving prosthetics

We want to bring in the next step of amputation, prosthesis, into the picture. Currently, "prosthetic fitting begins two to six months after surgery" (Source 12). Our design can introduce the patient to an identical VR prosthetic (via our VR app) before receiving the real prosthetic, so when the prosthetic is made and fitted, it will take less time to adjust.

In the future we could implement our solution by running a test on a much larger group of amputees, getting data from nearby hospitals and partnering up with Advanced Arm Dynamics and Amputee Coalition to get professional help in making our design a reality.

[1] Hand is removed, with the exception of wrist
[2] Hand and wrist are removed
[3] An amputee whose radius and ulna (bones of lower arm) are cut
[4] Forearm at elbow is amputated on
[5] Arm above elbow is removed
[6] One or more toes are removed
[7] Foot at the ankle is amputated on
[8] Leg below the knee is amputated on


OUR SOLUTION
THE THREE MUSKETEERETTS
UNITY APP
ANDROID AND IOS
PHONE PRICE NOT INCLUDED
GOOGLE CARDBOARD
$15
MYO ARMBAND
$200
unity
PERSONAL EDITION (FREE)
OVERALL COST: $215

# ABOUT US

We are freshmen in high school from Portland, Oregon. All of us have been interested in STEM at a young age and have participated in many robotics competitions over the years.

# THE PROBLEM

According to Amputee Coalition, there are 2.1 million people in the USA living with limb loss, and 185,000 people go through an amputation each year. One of the many challenges these amputees face is Phantom Limb Pain (PLP) or Phantom Limb Sensation (PLS). It is a painful sensation where an amputee continues to feel the pain of a missing limb, nearly 80 percent of the amputee population worldwide have experienced this kind of pain.

# THE SOLUTION

Currently, the main treatment available is Mirror therapy, but its level of success varies from person to person. Our team wanted to create an improved, enhanced therapy using recent technology. Our project will give the amputee community a cost-effective, more advanced solution to minimize their Phantom Limb Pain or Phantom Limb Sensations. We believe our design can truly impact the growing population of amputees facing these issues.

# THE DESIGN

The design, using Google Cardboard, and Myo, a gesture control technology, should be able to recognize multiple gestures from amputee's with different amputations and create a virtual limb with correlating movements to the amputee's  through a cost effective design. The virtual environment should create the illusion that the amputated, and remaining limb, are both moving. This process will reduce the amputee's Phantom Limb Sensations/Pain.

V

# Additional Details


9 Expert Discussions . . . . . . . . . . . . . . . . . . . . 53
9.1 Meeting with Karen
9.2 Meeting with Tom

Index . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 57

# 9. Expert Discussions

## 9.1 Meeting with Karen

Above: Meeting with Karen Hayes, the director of The American Amputee Foundation of Oregon with a Transtibial Amputation.

To learn more about the community of amputees we met up with the director of the American Amputee Foundation of Oregon, and an amputee herself. Karen shared with us her story. Sadly, eleven years ago she had been diagnosed with cancer, and the unfortunate surgery results ended with a Transtibial Amputation. Despite the amputation, Karen is an optimist who is passionate about assisting amputees. At the American Amputee Foundation of Oregon, they help amputees meet their physical and emotional challenges, provide monthly newspapers, promote public awareness in media, give peer counseling and help with financial aid for prosthetic limbs/assistive devices and services. We were genuinely inspired by both Karen's story and the work that the American Amputee Foundation of Oregon does for the community.

We shared our project with Karen and gave her a chance to try out the prototype. The three of us were euphoric to see her reaction, as it was our first time testing the prototype and we were eager to get as much feedback as possible. What Karen knows about amputation therapy and Phantom Limb Pain/Sensation is beyond what we could learn from a textbook. Here is a summary of some of the questions and answers we exchanged over the course of the meeting:

Have you experienced PLP/PLS?

Yes, I usually experience Phantom Limb Sensation as an "itch" on my missing limb, usually during the night.

When was the PLP/PLS at it's peak?

Right after the amputation it was most painful. It gradually decreased over time but it's been 11 years from my amputation and I still experience PLS.

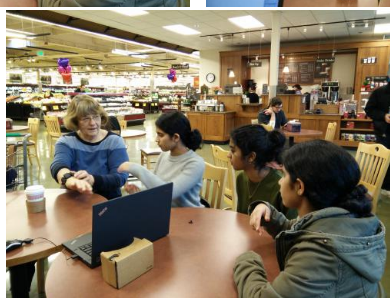
Do you think our design would be more/less effective over mirror therapy?

I've only tried mirror therapy once at a meeting, but it didn't make any sense to me. I don't think I'm the right person to compare between two ideas that I'm not too familiar with, but I will say that this concept has huge potential!

What do you think of our design, would it be helpful to you?

Trying out your prototype has been my first time trying out Virtual Reality, and I think what you've done is impressive. It is a unique mix between mirror therapy and guided imagery. And yes, over time I think if the design is more open to a wider range of amputees (I understand this is just a prototype) then I would want to try it out!

Below: Our team demonstrating our prototype to Karen and discussing the future of our solution.



## 9.2 Meeting with Tom

During our meeting with Karen, she recommended we speak to Tom at Advanced Arm Dynamics, who (as an amputee who had lost his lower left arm) could be of real help in testing our prototype out.

Tom Seibert was starting his senior year in high school when he lost his left hand after being injured while wakeboarding at the lake. As a young athlete, he graduated from the University of Utah with a degree in exercise science, and works part-time as a personal trainer, as well as working as the business development manager at Advanced Arm Dynamics.

We met up with Tom at the Advanced Arm Dynamics office. First, he showed us the different arm prosthetics he regularly used along with other prosthetics, each with their unique features or designs. Tom taught us a lot about the details and challenges behind amputations and how prosthetics can help. He also called in the clinic team at Advanced Arm Dynamics to join in for our design presentation. We explained our idea to them and set up the prototype so they could try it out themselves. We were nervous as to whether or not it would function along Tom's amputations and to our surprise it worked even better on him than on everyone else in the room! While we didn't have a formal Q&A session, we discussed our questions throughout the testing. Here is a summary of some of the questions and answers we exchanged over the course of the meeting:

How long does mirror therapy typically take?

Totally depends on the person; every case is different. For some people, it works quickly, for others it could take months.

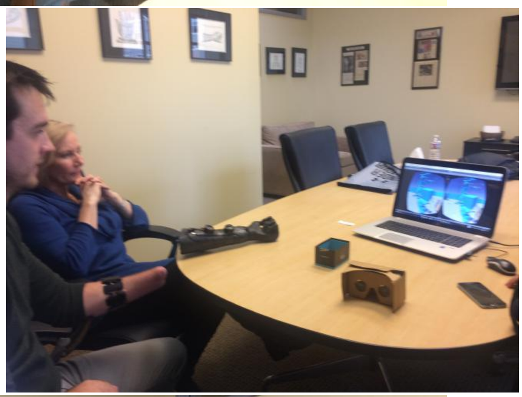
What benefits do you see in our design from the current mirror therapy?

We find that many patients lack motivation to continue mirror therapy as it could take months or more depending on the person. What's great about your design is the virtual reality scenario is engaging for the patient so they can feel more of a drive to continue with the therapy.

Would this design benefit amputees from your knowledge?

While this design might not be helpful in the area of prosthetics, it is perfect for training patients who have been recently amputated! You have a great idea going, and if further developed it could help with Phantom Limb Pain in amputees!

(Below) Our meeting with Tom Seibert and the Clinic Team at Advanced Arm Dynamics.



# Index


Amputation, 21, 26, 29
Amputations, 21
Amputee, 26
Amputees, 26
Analysis, 38
Articles, 22
Augmented Reality, 15

Bill of Materials, 33
Books, 22

Case Studies, 22

Design Statement, 29

eCybermission, 31
Evaluation, 41
Experiment Schedule, 16
Expert Discussions, 22

gestures, 29
Google Cardboard, 27, 34, 45
Guided Imagery, 26

Karen, 53

Learning, 25
Lower Limb Amputations, 29

Mirror Therapy, 26

non-pharmacological, 30

Opioid, 26, 29

peripheral arterial diseases, 21
Phantom Limb Pain, 22, 26, 45
Phantom Limb Sensation, 22, 26, 45
pharmacological, 30
Problem, 21
Procedure, 34
Prosthesis, 15
Prosthetic, 47
Prosthetics, 15

Resources, 22
Rose/Bud/Thorn, 15
Rose/Thorn/Bud, 14

Sources of Error, 38
Success Criteria, 30

Team Plan, 15
Team responsibilities, 13
Therapy, 26
Tom, 55
Transradial amputees, 31, 53

Upper Limb Amputations, 29
utilization, 31

Variables, 31
vascular diseases, 21
Virtual Reality, 15, 22, 26

Websites, 22

# Thank You

The Three Musketeeretts