ENGINEERING

McMaster University

Design Project 3 – Sense of Independence

IBEHS 1P10 – Health Solutions Design Projects

Tutorial 05

Team 36

ABBY BENYAIR (benyaira)

ALEXANDER DIAB-LIU (diabliua)

EMELINE BESPALOV (bespaloe)

MIHNEA BALAN (balanm2)

Submitted: March 6, 2022

Table of Contents

Academic Integrity Statement

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Abby Benyair 400388282

X Abby Benyair

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Mihnea Balan 400378197

X Mihnea Balan

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Emeline Bespalov 400396802

X

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Alexander Diab-Liu 400370788

X

Executive Summary

Neuromuscular disorders are among the most common medical disorders worldwide, affecting over 14,000,000 people [1]. One of the most indicative symptoms of neuromuscular disorders is tremors in the hand or arm, which can make many daily activities more challenging and even dangerous. [2]. Neuromuscular disorders that deteriorate nerves, such as multiple sclerosis, can involve agonizing muscle spasms that worsen as the condition progresses [3].

Patients with neuromuscular disorders must adjust to physical limitations as well as deal with other psychological factors that are indirectly caused by their condition. Studies have shown a positive correlation between patients suffering from neuromuscular disorders and depressive symptoms [4]. In addition, epilepsy patients often experience a decrease in their quality of life after diagnosis [5]. Also, the decrease in mobility seen in elderly neuromuscular disorder patients has been shown to cause strain on their families [6]. Essentially, the main problems associated with neuromuscular disorders are pain, symptom management, and quality of life.

Our team designed a wearable personal monitoring device to help individuals achieve more transparency and autonomy regarding their disorder and medical treatment. Our customer demographic would be individuals in the early stages of neuromuscular disorder symptom development, characterized by arm and hand tremors/spasms. Studies have found that the average onset age for neuromuscular disorders such as multiple sclerosis is early 30s, meaning most users of our device are expected to be well into adulthood [7].

The finalized design consists of a glove-sleeve combination with embedded electrodes connected to two EMG muscle sensors on the surface – one on the forearm and one on the bicep. To help individuals assess the severity of their tremors/spasms without an overly intrusive alert, we placed coloured LEDs on top of the battery box on the back of the arm, with high, cautionary, or mild muscle activity turning on a red, yellow, or green LED, respectively. This data is also stored for later reference. In addition, the device has a therapeutic function in the form of heating wiring sewn throughout the sleeve and glove. When more severe or quickly escalating tremors/spasms are detected, this would activate the heating elements, warming the sleeve to help ease muscle activity [8].

This product is unique in its versatility, combining key features of symptom tracking and symptom management for a variety of neuromuscular disorders. It has a user-friendly design, and its predictive function can help prevent potentially life-threatening accidents. This product would not only be marketed directly to consumers, but we would also direct it towards medical practitioners who work closely with neuromuscular disorder patients. Since doctors are the ones who will be referring patients to specific wearable devices, it is important they understand the improvements in patient autonomy and lifestyle that this device would facilitate.

Overall, our wearable device will help individuals with neuromuscular disorders gain more insight into their symptoms and disease progression, while also offering relief from abnormal muscle activity, thereby improving quality of life.

Main Body

Summary of Design Objectives

Milestone 1 Need Statement

- Design a wearable device for individuals suffering from neuromuscular disorders such as epilepsy, Parkinson's, and multiple sclerosis. The device should detect symptoms and monitor disease progression, while collecting and storing information that can help direct their treatment. The device must gather data from a sensor and output relevant suggestions to the user that will improve their lifestyle. The device should help the user achieve more transparency, clarity, and autonomy regarding their disorder and medical care, thereby improving their quality of life.

Milestone 1 Design Criteria

- **Objectives**: The device should be user-friendly and easy to operate, lightweight, and applicable to multiple neuromuscular disorders regardless of their severity. It should also incorporate user input to help tailor device outputs (i.e., alerts, warnings, etc.) as feedback to the user.
- **Constraints**: The device must be portable and not too bulky, as well as easily wearable (i.e., easy to put on and remove). It must also include only one type of sensor compatible with a Raspberry Pi 4, and the coding behind the sensor's function must be within the capabilities of the same Raspberry Pi.
- **Functions**: The device will record data received from the sensor mentioned above, as well as store this data in a dedicated file for later use (i.e., to be reviewed by the user or during a doctor's appointment and added to the user's patient profile). It will also pass information back to the user through output devices based on readings from the sensor, especially in the case that a severe neuromuscular episode is predicted.

Refinements / Updates to Design Objectives

- The device should be able to address the user's disease more directly by allowing customization of threshold values used to determine the appropriate output(s) to the user, as not all neuromuscular conditions / diseases may exhibit the same range of sensor readings.
- The sensor data and the resulting output device feedback should be recorded in multiple text files rather than just one dedicated file. This would allow a personalized data timeline to be established (i.e., compiling the data in a new file each day to track progression over an extended period).

Background & Research Summary

The concept for our design consists of a compression sleeve/glove with the various outputs embedded within the sleeve. The two EMG sensors would be contained within the sleeve, with electrodes attached in order to detect muscle spasms/tremors. In addition, wires would be contained within the sleeve and would heat up as a therapeutic response to high levels of EMG activity. The level of detected EMG activity would be displayed using three LEDs, helping to give a visual depiction of the severity to the user. Realistically, the input and output devices cannot be physically attached to our design due to limitations of resources and capabilities, but the concepts still execute successfully. In our prototype, the heating wires are represented by a buzzer.

The two EMG sensors are placed on the arm, one on the bicep and one on the forearm. The sensors can read muscular activity through the electrodes, due to the depolarization of your muscles when moved/contracted, which causes changes in electrical activity [9]. Electrodes are typically made from silver chloride, since they are nearly nonpolarizable, meaning the electrode-skin impedance is a resistance and not a capacitance [10]. Each sensor has three electrodes, one of which is the 'ground' and is placed away from muscular areas in order to be used as a comparison.

Connected to the Raspberry Pi 4 and breadboard through GPIO pins, the data from the sensors can be scaled down using the functions within the given sensor library. We broke these values into three levels of severity in order to trigger the output devices. When the values are of cautionary magnitude (yellow LED is on), our predictive heating function turns on, which would turn on the heating wires as a therapeutic response before the values reach extreme EMG activity (preventative measure). In our prototype, this is represented by the buzzer turning on. In addition, normal values would display the green LED and no buzzer vibration, whereas high values would display the red LED and would cause the buzzer to vibrate. All of this data is sent to a text file, in order for the user to track the progression of their condition.

The compression sleeve/glove would be made of a nylon-elastane blend in order to give the design stretchy and insulating characteristics. Nylon is an electrical insulator, which is favourable because we do not want the EMG signal to be disrupted by a conductive material, since the sensors would be contained within the sleeve [11]. In addition, nylon acts as an insulator of heat which is favourable since we are using heat as a therapeutic response. The nylon and elastane are very stretchy materials often used in athletic clothing, which is ideal in the case of a compression sleeve [12]. Lastly, the heating wires themselves would be composed of carbon fiber insulated heating wires because they are durable, lightweight, and flexible, making them favourable for an area like the arm [13]. The wires are also low-voltage, making them a safe option [13].

Market Analysis

1. PDMonitor System

Created by PD Neurotechnology, this system is meant to aid with monitoring movement disorders such as Parkinson's disease. It helps the user keep track of their symptoms and provides a record of the disorder's progression [14]. The PDMonitor also has a dedicated app to improve communication between the user and their physician, based on the information provided by the device. This is a similar concept to one of our ideas for future development of our device, where an app would allow our user to customize functionality.

Unlike our device, the PDMonitor is not limited to one type of sensor and utilizes five different monitoring devices to record the user's symptoms. However, these sensors are tailored to 'collect kinematic data' rather than relying on EMG activity [14]. Furthermore, the files containing patient data are stored in the Raspberry Pi connected to the device instead of having a Cloud-based system.

The PDMonitor has also been used in studies assessing the accuracy of monitoring Parkinson's symptoms using a wearable device, especially during the pandemic. Several case studies were analyzed where the PDMonitor was used in lieu of frequent doctor's appointments, and it was found that data recorded by the device successfully aided physicians in assessing what courses of treatment were required [15].

2. Embrace2 Seizure Monitoring

The Empatica Embrace2 bracelet is currently marketed as the only FDA-approved wearable for seizure disorders (i.e., epilepsy) [16]. While our design is fully user-oriented, this bracelet also allows the user to set up a link with the personal devices of caregivers. This is especially useful in the case of users with particularly extreme seizure disorders or children using the device.

This device determines possible seizure-related activity by sensing electrical impulses, which is the same concept as our design. However, it uses EDA (electrodermal) sensors rather than EMG sensors, and it also uses other criteria to determine if a seizure is occurring such as readings from motion and temperature sensors.

In terms of consumer reviews, the Embrace2 bracelet is not without its drawbacks. For example, the device may register certain rapid movements such as erasing writing from paper, and it may also have issues registering all types of seizures [17]. On top of this, the bracelet requires a prescription to be sold and includes a monthly fee, which may turn away potential customers.

Concluding Remarks

Overall, our design has space in the market for neuromuscular disease monitoring because there is no concept as versatile as ours. As seen above, each device is tailored for a specific condition and is less applicable to other disorders. Our device is all-inclusive, as evidenced by our choice of sensor. For almost all neuromuscular conditions characterized by tremors and spasms, the constant is abnormal electro-muscular activity, so our design incorporates several EMG sensors with variable ‘threshold values’. In addition, our design includes a heating function to ease muscle activity as a form of symptom management (see Description of Design).

Description of Design

This wearable device is designed to aid individuals suffering from neuromuscular disorders such as Parkinson’s and multiple sclerosis to achieve more transparency, clarity, and autonomy regarding their disorder and medical care, thereby improving their quality of life.

Our design consists of a glove and compressive sleeve (attached separately for easy assembly), with electrical heating elements installed throughout it, transmitted through wires (as seen in Figure 1-2). The design’s main purpose is to react to ongoing or incoming hand tremors. This was achieved through two EMG MyoWare muscle sensors and their corresponding electrodes, which detects the filtered electric potential of the muscle and outputs a value in volts. To best capture the electric muscle potential of the entire arm, the two EMG sensors have been placed on the forearm and bicep (Figure 3). These sensors are used to identify when the user is experiencing a tremor/spasm and has been equipped to record the time and severity of said spasm as well as lessen the symptoms through a heating function. The device is coded to be able to display the severity of the tremor/spasm in real time through green, yellow, and red LEDs, and this information is then stored into files for future medical reference either by the user or their physician. This LED colour scale is located on the back of the upper arm on top of the rechargeable battery pack which powers the device, so it would be easy to check, while not being in the way of everyday activities.

Next, since there have been studies showing that heat eases hand tremors in Parkinson’s, the entire glove/sleeve will heat up to alleviate the severity/pain of the arm spasm [8]. The medium-fidelity prototype of the device has a vibration motor as a stand-in for the heating due of a lack of materials. The heating function also has a predictive feature. This feature can predict when a tremor will occur in the future based on the slope of the muscle sensor readings, causing the device to heat up accordingly. In terms of storage, the device can be stored inside of a housing unit that can be mounted to different heights of shelves/tables using a clamp (Figure

4). The Raspberry Pi 4, breadboard, and T-cobbler are stored in a compartment at the top that is covered by a lid, while the sleeve/glove itself can be hung on two pegs at the front for easy access.

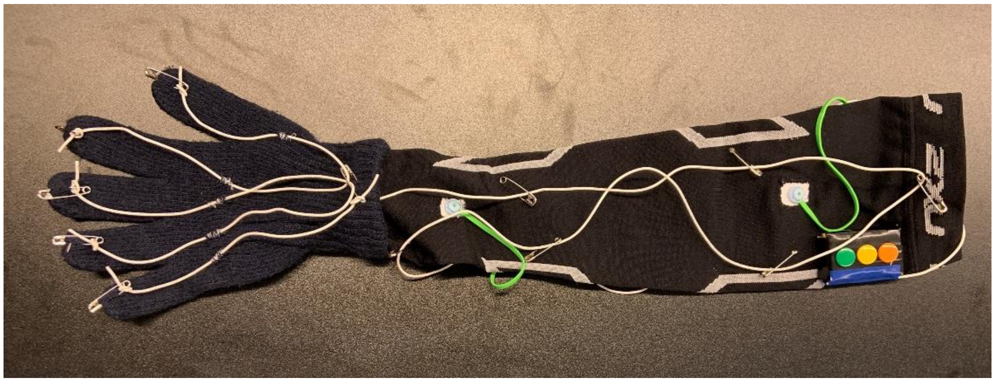


Figure 1: The medium-fidelity prototype (palm up), with heating wires and LEDs on top of the battery pack, located at the bottom right.

Figure 2: The medium-fidelity prototype (palm down), with heating wires and muscle sensors.

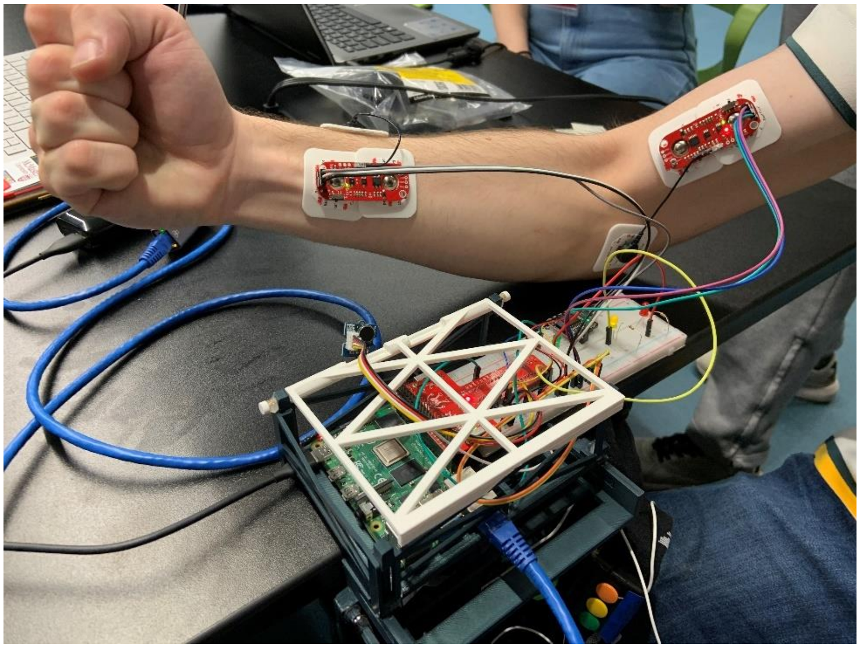


Figure 3: The Raspberry Pi 4, breadboard, T-cobbler, EMG sensors, and electrodes used to record the data.

Figure 4: Raspberry Pi housing, the clamp is adjusted and customized to the thickness of the given surface.

Design Critique, Discussion & Recommendations

A key strength of our device is that it incorporates a therapeutic response in addition to monitoring and recording data about symptoms. Additionally, the therapeutic heating is not limited to one disease in terms of its applicability – the functionality of our device is broad enough that a variety of individuals and neuromuscular disorders can benefit from it. This means that our device can help individuals better manage their muscle tremors/spasms, and thus carry out daily tasks more efficiently. However, the device is currently unable to locate the muscle activity signal, nor localize the heating. Because tremors/spasms do not always occur throughout the entire arm, it would be useful to be able to determine where (i.e., from which sensor) the data was gathered so that the heating elements could be activated in that area specifically. This could be carried out through coding that is able to distinguish between multiple muscle sensors, thus allowing clusters of heating wiring that to be activated independently.

Another strength of our current design is that all of its electrical components are powered by a battery attached to the sleeve, making it portable. This means that a user could wear it around the house without having to keep it plugged into a wall socket. However, there are inherent limitations of using a battery pack to supply energy to the heating elements and LEDs. Because heating elements require substantial energy to operate, the batteries would need to be recharged frequently, which is inconvenient. Therefore, supplementing the design with reusable, mechanically-activated chemical heating packs would reduce demands on the battery, thus giving it a longer lifespan.

In addition, it would be beneficial to be able to control the temperature for the heating response. This would be helpful if, for example, a user preferred a higher heating for more severe tremors/spasms and lower heating for mild ones. This could be achieved through an app that interfaces with the device’s computer program, allowing the user to adjust the temperature settings based on their preferences.

Also, it is important to consider that our sleeve/glove design currently involves all the hardware - the heating wiring, muscle sensors, LEDs, and battery - being directly sewn into the sleeve. This is useful in many ways because it makes putting on the sleeve easier, and there is only a single component that users need to keep track of. However, this could be an issue since users would likely want to be able to wash the sleeve without damaging the hardware. This issue could be resolved by having the hardware attached to a separate, inside layer that can be removed from between two surrounding sleeve layers. This would mean that the outside ‘shell’ of the sleeve could be washed, and the inner hardware sleeve re-inserted afterwards. This could also possibly limit wear and tear of the device, as the outer layers would be exposed to the arm and outside world and could subsequently be easily replaced without replacing any of the expensive hardware inside.

Citations

[1] Ucl, “About neuromuscular diseases,” Queen Square Centre for Neuromuscular Diseases, 17-Oct-2019. [Online]. Available: https://www.ucl.ac.uk/centre-for-neuromuscular-diseases/about-neuromuscular-diseases. [Accessed: 06-Mar-2022].

[2] “Parkinson's disease,” Mayo Clinic, 14-Jan-2022. [Online]. Available: https://www.mayoclinic.org/diseases-conditions/parkinsons-disease/symptoms-causes/syc-20376055. [Accessed: 16-Jan-2022].

[3] A. B. O’Connor, S. R. Schwid, D. N. Herrmann, J. D. Markman, and R. H. Dworkin, “Pain associated with multiple sclerosis: Systematic review and proposed classification,” PAIN®, 24-Oct-2007. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0304395907004605. [Accessed: 18-Jan-2022].

[4] J. M. VanSwearingen, J. F. Cohn, and A. Bajaj-Luthra, “Specific impairment of smiling increases the severity of depressive symptoms in patients with facial neuromuscular disorders - aesthetic plastic surgery,” SpringerLink, 01-Mar-2014. [Online]. Available: https://link.springer.com/article/10.1007%2Fs002669900312. [Accessed: 18-Jan-2022].

[5] “Living with epilepsy,” EFEPA, 23-Jul-2019. [Online]. Available: https://www.efepa.org/living-with-epilepsy/#:~:text=People%20with%20epilepsy%20often%20experience,%2C%20relationships%2C%20and%20social%20interactions. [Accessed: 17-Jan-2022].

[6] J. H. Carter, B. J. Stewart, P. G. Archbold, I. Inoue, J. Jaglin, M. Lannon, E. Rost-Ruffner, M. Tennis, M. P. McDermott, D. Amyot, R. Barter, L. Cornelius, C. Demong, J. Dobson, J. Duff, J. Erickson, N. Gardiner, L. Gauger, P. Gray, B. Kanigan, B. Kiryluk, P. Lewis, K. Mistura, T. Malapira, M. Pay, C. Sheldon, L. Winfield, K. Wolfington-Shallow, and K. Zoog, “Living with a person who has Parkinson’s disease: The spouse's perspective by stage of disease,” International Parkinson and Movement Disorder Society, 04-Nov-2004. [Online]. Available: https://movementdisorders.onlinelibrary.wiley.com/doi/abs/10.1002/mds.870130108. [Accessed: 18-Jan-2022].

[7] Stoppler MC. Multiple Sclerosis Symptoms, Causes, Treatment, Diagnosis, and Life Expectancy [Internet]. Davis CP, editor. eMedicineHealth. eMedicineHealth; 2019 [cited 2022Mar6]. Available from: https://www.emedicinehealth.com/multiple_sclerosis/article_em.htm

[8] Cooper C, Evidente VG, Hentz JG, Adler CH, Caviness JN, Gwinn-Hardy K. The effect of temperature on hand function in patients with tremor. Journal of Hand Therapy [Online]. 2000;13(4):276–88. Available at: https://pubmed.ncbi.nlm.nih.gov/11129253/ [Accessed: 17-Jan-2022].

[9] Shawn, “What is EMG sensor, Myoware and how to use with Arduino?,” *Latest Open Tech From Seeed*, 05-Jul-2021. [Online]. Available: https://www.seeedstudio.com/blog/2019/12/29/what-is-emg-sensor-myoware-and-how-to-use-with-arduino/. [Accessed: 06-Mar-2022].

[10] Dielectric Manufacturing, “Material properties of thermoplastic nylon - oustanding wear,” *Dielectric Manufacturing*, 02-Jun-2021. [Online]. Available: https://dielectricmfg.com/knowledge-base/nylon/#:~:text=Nylon%20Characteristics,-

Nylon%20is%20a&text=Nylon%20is%20easy%20to%20machine,is%20an%20excellent%20electrical%20insulator. [Accessed: 06-Mar-2022].

[11] Sewport, “What is elastane fabric: Properties, how its made and where,” *Sewport*. [Online]. Available: https://sewport.com/fabrics-directory/elastane-fabric. [Accessed: 06-Mar-2022].

[12] “Carbon fiber insulated heater wire,” Calco Electric. [Online]. Available: https://www.calcoelectric.com/insulated-heater-wires/carbon-fiber-insulated-heater-wire. [Accessed: 06-Mar-2022].

[13] [“PDMonitor Solution, PDMonitor® | PD Neurotechnology.” https://www.pdneurotechnology.com/pd-monitor-solution/product/ (accessed Mar. 05, 2022).

[14] K. I. Tsamis, G. Rigas, K. Nikolaos, D. I. Fotiadis, and S. Konitsiotis, “Accurate Monitoring of Parkinson’s Disease Symptoms With a Wearable Device During COVID-19 Pandemic,” In vivo (Athens, Greece), vol. 35, no. 4, pp. 2327–2330, Aug. 2021, doi: 10.21873/INVIVO.12507.

[15] “Embrace2 Seizure Monitoring | Smarter Epilepsy Management | Embrace Watch | Empatica.” https://www.empatica.com/embrace2/ (accessed Mar. 05, 2022).

[16] “Seizure monitoring devices - from babies to adults - Epilepsy safety.” https://autismessentialsisrael.com/en/seizure-monitoring-devices/ (accessed Mar. 05, 2022).

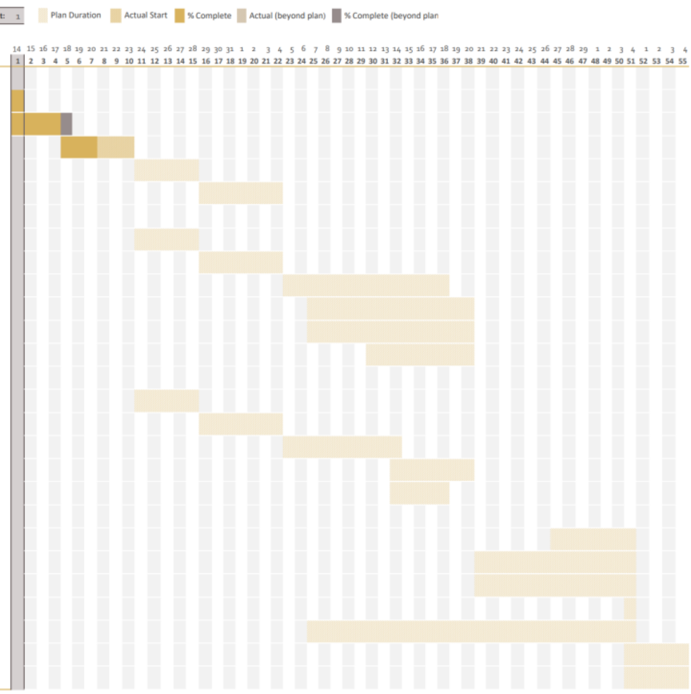
Appendices

Appendix A: Project Schedule

Preliminary Gantt Chart

DP 3 - Preliminary Gantt Chart

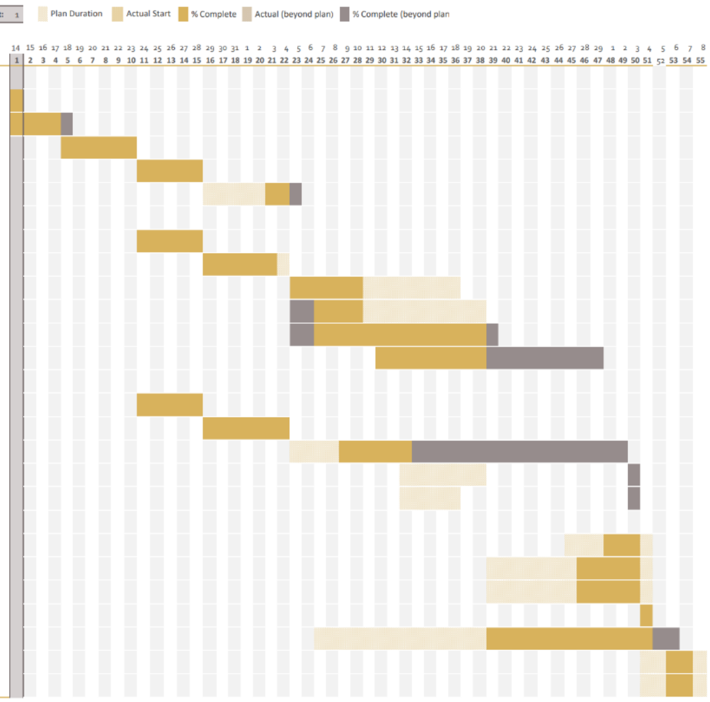
ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestones					
Milestone 0 (T)	1	1	1	1	100%
Milestone 1 (T)	1	4	1	5	100%
Milestone 2 (T/I)	5	6	5	6	50%
Milestone 3 (T/Comp/Mod)	11	5			0%
Milestone 4 (Comp/Mod)	16	7			0%
Computation Deliverables					
Preliminary Pseudocode & Flowchart	11	5			0%
Computer Program Workflow	16	7			0%
Function 1: Calculating rolling average of sensor data	23	14			0%
Function 2/3: Two processes performed on rolling average	25	14			0%
Function 4: Writing data to file for later use and analysis	25	14			0%
Design Verification	30	9			0%
Modelling Deliverables					
Preliminary Sketches of Pi Housing	11	5			0%
Refined & Detailed Sketches of Pi Housing	16	7			0%
Pi Housing Assembly Model (Inventor)	23	10			0%
Pi Housing Engineering Drawings	32	7			0%
3D Printed Pi Housing Assembly	32	5			0%
Final Team Deliverables					
Physical Computing Prototype	45	7			0%
Prep for iBiomed 1P10 Design Expo	39	13			0%
Prep for Individual Sub-Team Interviews	39	13			0%
Individual Technical Sub-Team Interviews	51	1			0%
Final Design Project Report	25	27			0%
Individual Reflection	51	6			0%
Self- and Peer-Evaluation	51	6			0%



Final Gantt Chart

DP 3 - Final Gantt Chart

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestones					
Milestone 0 (T)	1	1	1	1	100%
Milestone 1 (T)	1	4	1	5	100%
Milestone 2 (T/I)	5	6	5	6	100%
Milestone 3 (T/Comp/Mod)	11	5	11	5	100%
Milestone 4 (Comp/Mod)	16	7	21	3	100%
Computation Deliverables					
Preliminary Pseudocode & Flowchart	11	5	11	5	100%
Computer Program Workflow	16	7	16	6	100%
Function 1: Calculating rolling average of sensor data	23	14	23	6	100%
Function 2/3: Two processes performed on rolling average	25	14	23	6	100%
Function 4: Writing data to file for later use and analysis	25	14	23	17	100%
Design Verification	30	9	30	18	100%
Modelling Deliverables					
Preliminary Sketches of Pi Housing	11	5	11	5	100%
Refined & Detailed Sketches of Pi Housing	16	7	16	7	100%
Pi Housing Assembly Model (Inventor)	23	10	27	23	100%
Pi Housing Engineering Drawings	32	7	50	1	100%
3D Printed Pi Housing Assembly	32	5	50	1	100%
Final Team Deliverables					
Physical Computing Prototype	45	7	48	3	100%
Prep for iBiomed 1P10 Design Expo	39	13	46	5	100%
Prep for Individual Sub-Team Interviews	39	13	46	5	100%
Individual Technical Sub-Team Interviews	51	1	51	1	100%
Final Design Project Report	25	27	39	15	100%
Individual Reflection	51	6	53	2	100%
Self- and Peer-Evaluation	51	6	53	2	100%



Logbook of Additional Meetings and Discussions

Sunday, Jan. 16, 2021 @ 6:15 pm

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Emeline Bespalov**	**bespaloe**	**Yes**
Administrator 1	**Alexander Diab-Liu**	**diabliua**	**Yes**
Administrator 2	**Abby Benyair**	**benyaira**	**Yes**
Coordinator	**Mihnea Balan**	**balanm2**	**Yes**
Guest			

Meeting Minutes

1. Reviewing the progress made during our previous meeting
    a. We reiterated the big points touched upon during our design studio time (Personal Monitoring Device, Neuromuscular Disorders, etc.)
    b. The Milestone 1 advice given to us by our TA, Aiden Delaney, was considered (narrowing down demographic)
2. Discussing the possibility of changing our Area of Focus
    a. The novelty of our idea came into questions because popular devices such as the Apple Watch may have similar, yet less specialized, functions
    b. We decided to finish up the next two sections and then analyzing our progress before considering backtracking to be an option
3. Completing the Customer Demographic section
    a. We applied the advice from our TA and completed this part of Milestone 1 by adding individuals experiencing certain symptoms to our demographic in addition to examples of Neuromuscular Disorders
4. Researching Statements of Facts about the problems that our demographic faces
    a. We put aside around 15 minutes to individually find issues that people with epilepsy, Parkinson's, and multiple sclerosis must deal with, to define the problem at hand for our customer demographic
5. Scheduling another additional meeting to finish up Milestone 1
    a. Based on our schedules, we agreed to meet Monday, Jan. 16 at 7:00 pm to complete the List of Criteria and the Need Statement

Post-Meeting Action Items

1. *Review the statements of fact to enable quick criteria development tomorrow [**individual task, each team member**]*

Monday, Jan. 17, 2022 @ 7:00 pm

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Emeline Bespalov**	**bespaloe**	**Yes**
Administrator 1	**Alexander Diab-Liu**	**diabliua**	**Yes**
Administrator 2	**Abby Benyair**	**benyaira**	**Yes**
Coordinator	**Mihnea Balan**	**balanm2**	**Yes**
Guest			

Meeting Minutes

1. Reviewing objectives for the meeting
    a. The main objective for this meeting was to complete the last two sections for Milestone 1 (List of Criteria & Need Statement) to be able to submit before the Thursday deadline
2. Process for creating the List of Criteria (2 Options)
    a. First, we could create the criteria is by reviewing the Statements and addressing them directly with the criteria
    b. The second option for how we would create the criteria is by splitting the points into Objectives, Constraints, and Functions; then, we would insert the concept ideas that we brainstormed during the last meeting
3. Generating the List of Criteria
    a. In the end, we generated the criteria by creating Objective, Constraint, and Function subsections and reading through each Statement of Fact to determine what points could address them directly
    b. There was some disagreement about whether certain criteria would be Objectives or Functions (depending on how the project develops) so we assigned certain criteria to more than one subsection
4. Formulating a Need Statement
    a. The Need Statement was much easier to create compared to previous projects because we spend much more time defining the problem and debating who our customer demographic would be (Wk-1 Meeting & previous Additional Meeting)
    b. In the end, the Need Statement was quite detailed, but we managed to avoid being too specific to maintain design freedom → the general gist of Milestone 1 was still heavily elaborated on
5. Reviewing the reference list for Statements of Facts
    a. The final task for this meeting was to finish referencing the Statements of Facts list, which took a surprising amount of time to complete because of Word's formatting issues and delayed updating on SharePoint
    b. All references were done using IEEE format, as required for the 1P10 course

Post-Meeting Action Items

1. *Submit Milestone 1 on Avenue to Learn [**Alexander Diab-Liu**]*
2. *Come up with several concept ideas for device prior to Wk-2 Design Studio [**individual task; each group member**]*

Tuesday, Jan. 25, 2022 @ 1:00 pm

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Emeline Bespalov**	**bespaloe**	**Yes**
Administrator 1	**Alexander Diab-Liu**	**diabliua**	**No**
Administrator 2	**Abby Benyair**	**benyaira**	**Yes**
Coordinator	**Mihnea Balan**	**balanm2**	**Yes**
Guest			

Meeting Minutes

1. We agreed to meet in-person in PGCLL M21; easier to work face-to-face
    a. All members of the group were able to attend the in-person meeting except for ***Alexander Diab-Liu*** because of off-campus housing
2. Computing Sub-team (***Abby Benyair*** and ***Mihnea Balan***) Summary:
    a. We discussed the tasks outlined for the computer sub-team in the DP3 Project Module and Area of Focus 1 PDF files and chose one task each – LED output to user (***Mihnea Balan***) and exporting data from the sensor to a separate text file for storage (***Abby Benyair***)
    b. We decided that the easiest way to show our processes would be to create flowcharts rather than pseudocode, as visual representations are more engaging and often simpler (for the design review)
3. Modelling Sub-team (***Emeline Bespalov***) Summary:
    a. Since Emeline was the only member of the modeling sub-team able to attend the in-person meeting, her time was spend developing sketches of possible CAD designs for the EMG sensor's housing

Post-Meeting Action Items

1. *Share progress for modelling sub-team tasks with **Alexander Diab-Liu** [**Emeline Bespalov**]*
2. *Complete flowcharts for the computing sub-team's individual tasks and put images of them into the DP3 Milestone 3 Worksheet w/ bullet point descriptions [**Abby Benyair** and **Mihnea Balan**]*

Thursday, Jan. 27, 2022 @ 1:30 pm

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Emeline Bespalov**	**bespaloe**	**Yes**
Administrator 1	**Alexander Diab-Liu**	**diabliua**	**Yes**
Administrator 2	**Abby Benyair**	**benyaira**	**Yes**
Coordinator	**Mihnea Balan**	**balanm2**	**Yes**
Guest			

Meeting Minutes

1. The meeting was run in a hybrid in-person / online format
    a. ***Abby Benyair*** and ***Mihnea Balan*** [Computation Sub-team] attended the meeting at the design studio in ABB-C104 to start creating a low-fidelity prototype for the upcoming Milestone 3 design review
    b. ***Emeline Bespalov*** and ***Alexander Diab-Liu*** attended the meeting through a MS Teams call, offering feedback as the beginnings of the prototype came together
2. We began the meeting by taking stock of what materials were available to us
    a. Since we did not have access to a sleeve (***Emeline Bespalov*** not in-person) for our prototype, we looked for materials that could be used to symbolize the sensor housing, the user output LEDs, and the electrodes
    b. ***Mihnea Balan*** brought red, yellow, and red pins for the LEDs as well as elastic bands that could be cut to be placeholders for the muscle sensor's electrodes
    c. Cardboard was available for use in the design studio to be shaped into the sensor housing
3. Using the materials above, the low-fidelity prototype was assembled
    a. The carboard provided to us was shaped into a rectangular prism approximately the same size as the EMG muscle sensor that was shown to us by Parm
    b. Based on the arm lengths of ***Mihnea Balan*** and ***Abby Benyair***, the elastic bands were cut to an appropriate length to reach from the top of the forearm (sensor location) to the bicep, lower forearm, and hand (where the electrodes would be attached) and glued to the sensor housing
    c. Cardboard paper cut into small circles was glued to the free end of the elastic bands to better demonstrate the electrodes for the muscle sensor
    d. ***Emeline Bespalov*** and ***Alexander Diab-Liu*** reviewed the partial design over an MS Teams video call and the prototype (so far) received positive feedback

Post-Meeting Action Items

1. *Bring the rest of the required materials to the Milestone 3 meeting [**Emeline Bespalov** and **Mihnea Balan**]*
2. *Book a time ~30 min. prior to the Friday design studio to finish assembling the prototype [**Emeline Bespalov**]*

WEDNESDAY, FEB. 23, 2022 @ 11:00 AM

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Emeline Bespalov**	**bespaloe**	**Yes**
Administrator 1	**Alexander Diab-Liu**	**diabliua**	**No**
Administrator 2	**Abby Benyair**	**benyaira**	**Yes**
Coordinator	**Mihnea Balan**	**balanm2**	**Yes**
Guest			

MEETING MINUTES

1. The meeting was run in an online format during Reading Week
    a. During our progress update, we found that ***Abby Benyair*** and ***Mihnea Balan*** [Computation Sub-team] have completed more of their sub-team tasks compared to ***Emeline Bespalov*** and ***Alexander Diab-Liu*** [Modelling Sub-team] as of February 23, so we agreed to take on a larger portion of the project report written tasks
2. Assigning tasks for the Design Project Report
    a. ***Mihnea Balan*** agreed to take on the Market Analysis and Summary of Design Objectives written pieces
    b. ***Abby Benyair*** was assigned the Background and Research Summary task
    c. As Administrator 1, ***Alexander Diab-Liu*** will oversee the list of Subject Matter Sources
    d. Since they are both members of the modelling team and responsible for the CAD design, ***Emeline Bespalov*** and **Alexander Diab-Liu** will discuss how they will split the Description of Design and Design Critique, Discussion and Recommendation tasks
3. Planning design studio meetings to complete the rest of the Final Deliverables
    a. The week to come has been planned out to involve beginning the written pieces of the design project report by Monday evening as well as meeting Tuesday and Wednesday evenings during the extended walk-in design studio hours
    b. Thursday will be entirely devoted to design studio work after the final 1P10 lecture of the week, as well as offering a large time slot for completing any remaining written pieces for the project report once Friday's expo presentation has been finalized
    c. The weekend will allow us free time to complete incomplete areas of the design project report, as it is due on Sunday, March 6th at 11:59 pm

POST-MEETING ACTION ITEMS

1. *Watch the instructional videos for wiring the MyoWare Muscle Sensor to the breadboard [**Mihnea Balan**]*
2. *Update Alexander Diab-Liu about the events of this meeting during future sub-team work [**Emeline Bespalov**]*

Appendix B: Scheduled Weekly Meetings

IBEHS 1P10
MEETING WITH TEAM 36 – FRIDAY, JAN. 14, 2022

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Emeline Bespalov**	**bespaloe**	**Yes**
Administrator 1	**Alexander Diab-Liu**	**diabliua**	**Yes**
Administrator 2	**Abby Benyair**	**benyaira**	**Yes**
Coordinator	**Mihnea Balan**	**balanm2**	**Yes**
Guest	**TA Aiden Delaney**	**-**	**Yes**

AGENDA ITEMS

1. Decide on which administrative roles each team member will take [Milestone 0]
2. Take a team photo and upload it [Milestone 0]
3. Select an Area of Focus (personal monitoring or technology for the home) [Milestone 1]
4. Conduct preliminary research and market analysis for potential customer demographics [Milestone 1]
5. Decide on a broad customer demographic based on medical conditions, medical risk factors, or symptoms [Milestone 1]

MEETING MINUTES

1. Got acquainted with a new Design Project group and new TAs for the Winter term
   a. Introductions and administrative role assignment + initial TA check-in with Aiden Delaney
2. Area of Focus discussion (Personal Monitoring Device vs. Automating Home Tasks)
   a. Analyzing scenarios that would require one device or the other
   b. Discussing in what capacities these devices could be applied
3. Researched issues that can be plausibly solved by a Personal Monitoring Device (P.M.D.)
   a. Key avenues included cardiac issues, neuromuscular disorders, and Alzheimer's disease
4. Identifying a customer demographic for our Design Project
   a. We chose to focus our P.M.D. on people with neuromuscular disorders characterized by tics and tremors picked up by same sensor (seizures, Parkinson's, multiple sclerosis, etc.)
5. Final TA check-in with Aiden Delaney
   a. Feedback allowed us to alter our customer demographic to include more specific factors such as age and severity of condition to ensure our scope is not too broad

POST-MEETING ACTION ITEMS

1. *Create a group chat on Teams to allow easy correspondence outside of weekly meetings [**completed by Abby Benyair**]*
2. *Set up an additional meeting time to complete Milestone 1 prior to upcoming Thursday [**Sunday, Jan. 16 – decided by team**]*

IBEHS 1P10
MEETING WITH TEAM 36 – FRIDAY, JAN. 21, 2022

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Emeline Bespalov**	**bespaloe**	**Yes**
Administrator 1	**Alexander Diab-Liu**	**diabliua**	**Yes**
Administrator 2	**Abby Benyair**	**benyaira**	**Yes**
Coordinator	**Mihnea Balan**	**balanm2**	**Yes**
Guest			

AGENDA ITEMS

1. Ensure that every team member's preliminary concept solution sketches and descriptions have been copied into the Milestone 2 Team Worksheet
2. TA Meeting - Meet with our TA to discuss our team's progress and direction
   a. Ask any questions we have about the project so far
3. Concept Evaluation - Evaluate each concept solution using the Pugh Matrix included in the Milestone 2 Team Worksheet
   a. Decide on what criteria to use for evaluation and choose a baseline concept for reference
4. Concept Selection - Decide on which concept ideas are the most promising, and should therefore be refined / combined to create our solution
   a. Justify these choices on the Milestone 2 Team Worksheet
5. Design Refinement - Explore ways we could improve or elaborate on these chosen designs, and explain these intended design refinements on the Milestone 2 Team Worksheet
   a. Consider modifications based on features included in rejected designs, and those based on points emphasized during the Pugh Matrix concept evaluation

MEETING MINUTES

1. Sharing individual pre-Milestone concept sketches
   a. We explained our concepts one-by-one to get everyone up to speed on our varying ideas
   b. Seeing as our focus is neuromuscular disorders, the EMG sensor was the most frequently implemented, but some creative applications of the pulse sensor were also seen
2. Analyzing the concepts one-by-one via Pugh matrix
   a. Scoring ranged from +1 to 0 to -1 based on criteria such as user-friendliness, feasibility, and overall improvement in the wearer's quality of life
   b. Each point was judged in a rapid-fire manner to reflect our first impressions without bias
3. Brainstorming ways to synthesize multiple concepts
   a. Unfortunately, the pulse sensor-based designs were not as easy to mix with other designs, so our synthesized concept was based on the MyoWare muscle sensor concepts
   b. We decided to go for a glove-sleeve combo with multiple electrodes down the arm

IBEHS 1P10
MEETING WITH TEAM 36 – FRIDAY, JAN. 21, 2022

4. Second Pugh matrix (output devices) & design refinements
   a. Once our heated glove-electrode sleeve idea was chosen, we had to break down the advantages and disadvantages of certain output devices for the user
   b. In the end, the most beneficial output devices that we chose to focus on was

POST-MEETING ACTION ITEMS

1. *Complete the sketch description tables on the team Milestone 2 worksheet [**Abby & Emeline**]*
2. *Set up a meeting time for the Milestone 3 pre-Design Studio tasks [**discussion on Group Chat**]*

IBEHS 1P10
MEETING WITH TEAM 36 – FRIDAY, JAN. 28, 2022

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Emeline Bespalov**	**bespaloe**	**Yes**
Administrator 1	**Alexander Diab-Liu**	**diabliua**	**Yes**
Administrator 2	**Abby Benyair**	**benyaira**	**Yes**
Coordinator	**Mihnea Balan**	**balanm2**	**Yes**
Guest			

AGENDA ITEMS

1. Finish the final details of the low-fidelity prototype and take photos of it [Milestone 3 worksheet]
2. Prepare key talking points for the design review (go over who will discuss what, what will be said, etc.)
3. Narrow down our questions for the design reviewers to approximately 3
4. Complete the design review (present our idea & answer questions about it)
5. Document/take notes on the reviewer's feedback [Milestone 3 worksheet]
6. Come up with potential design refinements that will improve our design, based on our reviewer's feedback [Milestone 3 worksheet]

MEETING MINUTES

1. Although design studio officially started at 12:30 pm, we met in ABB at noon
   a. ***Emeline Bespalov*** and ***Mihnea Balan*** brought the remaining materials necessary to complete our low-fidelity prototype during the upcoming design studio
   b. We began discussing what the easiest method to put together the last few parts
2. To begin the design studio, we assembled our prototype immediately
   a. ***Alexander Diab-Liu*** and ***Mihnea Balan*** super-glued the cardboard sensor housing to the sleeve brought by ***Emeline Bespalov*** and 2 of the 3 electrodes to the sleeve, with the final electrode being attached to the glove brought by ***Mihnea Balan***
   b. We glued cut pipe-cleaners to the glove from each finger to the wrist as "heating wires"
3. Once the initial prototype was finished, we began rehearsing our design review
   a. ***Abby Benyair*** and ***Emeline Bespalov*** set up the format of our presentation, as they would be the ones joining the call to represent our team (not everyone brought headphones)
   b. ***Mihnea Balan*** put on the prototype, including the sleeve and glove – with the electrodes and sensor box placed in the correct locations – in preparation for a visual demonstration
4. We joined the design review call at 1:30 pm, and most of the discussion was with TA ***Ansh Kuckreja***
   a. Little was given for the sub-teams, with most points relating to our prototype, including: relocating the sensor box; adding a rechargeable battery for the heating parts; and internalizing the components (by sewing into the fabric or "sandwiching" w/ another layer)

POST-MEETING ACTION ITEMS

1. *Keep the low-fidelity prototype on-hand for future references [**Mihnea Balan**]*
2. *Refine the sub-team tasks in preparation for Milestone 4 [**individual work; Team 36**]*

IBEHS 1P10
MEETING WITH TEAM 36 – FRIDAY, FEB. 4, 2022

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Emeline Bespalov**	**bespaloe**	**Yes**
Administrator 1	**Alexander Diab-Liu**	**diabliua**	**Yes**
Administrator 2	**Abby Benyair**	**benyaira**	**Yes**
Coordinator	**Mihnea Balan**	**balanm2**	**Yes**
Guest			

AGENDA ITEMS

1. 10-minute check-in meeting with TA – bring up any individual sub-team questions as well as concerns about our current design
2. Ensure everyone's individual work has been copy and pasted into the team worksheet [Milestone 4 Team worksheet]
3. Modelling Sub-Team: exchange Pi housing sketches and note any differences/similarities [Housing Assembly Observations and Evaluation worksheet]
   a. Decide on and justify a final housing design to pursue in solid modelling
   b. Create a few housing components in Autodesk Inventor [Preliminary Modelling worksheet]
4. Computation Sub-Team: exchange flowcharts and note any differences/similarities [Workflow Peer-Review worksheet]
   a. Collaborate on pseudocode that outlines the high-level workflow of the computer program
   b. Begin translating the pseudocode into Python [Preliminary Program worksheet]
5. Make sure all sub-teamwork (screenshots of CAD parts and Python code) is uploaded to its corresponding worksheet

MEETING MINUTES

1. We began the meeting by brainstorming questions for the TA meeting
   a. Most of our discussions revolved around whether it would be a good idea to further specify our customer demographic, figuring out whether the EMG sensor can sense ambient electrodermal activity (or if it is muscle-specific), and how we would implement a placeholder for our heating function (since it is a potential hazard + we don't have the materials available)
2. Path became clearer after our TA meeting with Aiden Delaney
   a. We concluded that it is best to keep our customer demographic relatively broad because it grants us more freedom in terms of marketability (versatility is a big point – monitoring device applicable to a wide range of neuromuscular disorders with similar EMG severity)
   b. TA suggested vibration motor as simplest non-LED output to demonstrate heating function, as we cannot re-use LEDs (already implemented) and the buzzer is most likely too loud
   c. TA referred us to guest Monica De Paoli for confirmation on EMG sensor capabilities

IBEHS 1P10
MEETING WITH TEAM 36 – FRIDAY, FEB. 4, 2022

3. Computation Sub-team Progress
   a. For computing, the flowcharts were exchanged and reviewed by the sub-team's members to identify similarities and differences between the two processes
   b. Pseudocode was created for all four of the processes outlined in the Area of Focus 1 document (data input, rolling average, and 2 outputs) as well as the storage file function that has the processes listed above written to it
   c. The pseudocode for the data input and rolling average calculations were converted into Python code (but not utilizing object-oriented programming yet)
4. Modelling Sub-team Progress
   a. For modelling, the sub-team's members exchanged their sketched designs to evaluate each concept's pros and cons
   b. By the end of the meeting, the sub-team had established the dimensions for the CAD model

POST-MEETING ACTION ITEMS

1. *Brainstorm how to convert the rest of the functions from pseudocode to Python code [**Abby Benyair**]*
2. *Consider the difficulty of implementing object-oriented programming into the code [**Mihnea Balan**]*
3. *Continue revising key characteristics of the CAD design and start modelling [**Emeline Bespalov** and **Alexander Diab-Liu**]*

IBEHS 1P10
MEETING WITH TEAM 36 – FRIDAY, FEB. 11, 2022

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Emeline Bespalov**	**bespaloe**	**Yes**
Administrator 1	**Alexander Diab-Liu**	**diabliua**	**Yes**
Administrator 2	**Abby Benyair**	**benyaira**	**Yes**
Coordinator	**Mihnea Balan**	**balanm2**	**Yes**
Guest			

AGENDA ITEMS

1. TA meeting
    a. Working with the EMG sensors to figure out exactly where we need to place the sensors and electrodes on our medium-fidelity prototype
    b. Refining the Pi housing and the computation components independently, but will come together during DS to discuss the progress we've made in our individual sub-teams
    c. Continuing to work on coding and CADing for our design, aiming to have most of the code finished and to 3D-print before 18th (before reading week)
2. Sub-team questions
    a. Should we be trying to be unique in how we connect the pieces of our box together? I.e. would it be better to print all the sides of the box and then have them fit together in an interesting way, rather than just printing a whole box?

MEETING MINUTES

1. To begin the meeting, we received all the components we requested from Parm
    a. Parm gave us breadboarding advice for each component before putting them all in a bag with our team number on it, which we decided to store in the design studio for the time being
    b. We all signed off on an agreement to keep good care of the components (including two EMG muscle sensors, LEDs, a vibration motor, etc.) and to return them in the same condition that they were given to us
2. After receiving the DP3 device components, we split into our respective sub-teams
    a. The modelling sub-team continued with their assigned post-meeting action item from the previous week's meeting – continuing to develop the CAD model on Inventor based on the agreed-upon dimensions
    b. The computing team began working on the remaining pseudocode-only functions (LED output and heating function) into Python code, but still not yet incorporating O.O.P.
3. The LED output and heating functions (vibration motor) were developed with flags
    a. For both functions, we included True and False flags for the status of each output device so that they can be easily replaced with '.on' and '.off' methods as well as print statements

IBEHS 1P10
MEETING WITH TEAM 36 – FRIDAY, FEB. 11, 2022

4. With the help of the TAs present, we also managed to fix a previous function
    a. While developing the second function (rolling average), we made a mistake in our interpretation of the function: the 'rolling' meant to re-evaluate each time the 10th value was discarded and replaced, not to provide an average for each new 10 values
    b. We satisfied this condition by altering our loop to include an 'if' statement where the first 10 values are gathered and then an 'elif' statement where the last value is discarded using the '.pop' method and then replaced by appending a new value

POST-MEETING ACTION ITEMS

1. ***Mihnea Balan*** *to pick up the Team 36 breadboard component bag before Reading Week*

IBEHS 1P10
MEETING WITH TEAM 36 – FRIDAY, FEB. 18, 2022

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Emeline Bespalov**	**bespaloe**	**Yes**
Administrator 1	**Alexander Diab-Liu**	**diabliua**	**Yes**
Administrator 2	**Abby Benyair**	**benyaira**	**Yes**
Coordinator	**Mihnea Balan**	**balanm2**	**Yes**
Guest			

AGENDA ITEMS

1. Update on computing team progress
2. Update on modelling team progress
3. Go over what work will need to be completed over reading week (final deliverables, etc.)
4. Bring up any computing sub-team questions/concerns
5. Bring up any modelling sub-team questions/concerns
    a. Assembling the pi housing – would you recommend printing separate components for the main box, and then assembling them into a box after printing?

MEETING MINUTES

1. This meeting was conducted online rather than in-person
    a. No breadboarding components were needed for either sub-team's tasks, so it was not necessary to meet in the ABB design studio
    b. We had our TA meeting with Aiden Delaney through MS Teams, where general information about DP3 was confirmed, but we did not have many stand-out concerns aside from the modelling-sub team's inquiry about assembling the Raspberry Pi housing
2. There was not much overlap between the modelling sub-team and the computation sub-team's work for this design studio meeting, so we split up early into separate MS Teams calls
3. The computation sub-team spent the rest of the meeting incorporating O.O.P.
    a. Since all the pseudocode functions were converted to Python code in the previous meeting, the main objective was to implement object-oriented programming based on the functions provided in the 'sensor_library.py' file, which we believe was successfully completed (though we cannot test this until we move on to breadboarding)
    b. We also began putting together the storage file function based on the finished functions mentioned above, but did not have sufficient information about the print statements' format
4. The modelling sub-team continued working on the assembly based on the TA's feedback
    a. A discussion took place about how the CAD parts could be divided into separate pieces that can be assembled after being 3-D printed
    b. From there on, both members of the sub-team worked individually on modelling the pieces

IBEHS 1P10
MEETING WITH TEAM 36 – FRIDAY, FEB. 18, 2022

POST-MEETING ACTION ITEMS

1. *Find the required format for the storage file from the DP3 PDFs or inquire with a TA [**Mihnea Balan** and **Abby Benyair**]*
2. ***Mihnea Balan*** *to pick up the breadboarding components before Reading Week starts in case we move on to the breadboarding stage before returning to McMaster*

Appendix C: Design Studio Worksheets

MILESTONE 0 – COVER PAGE

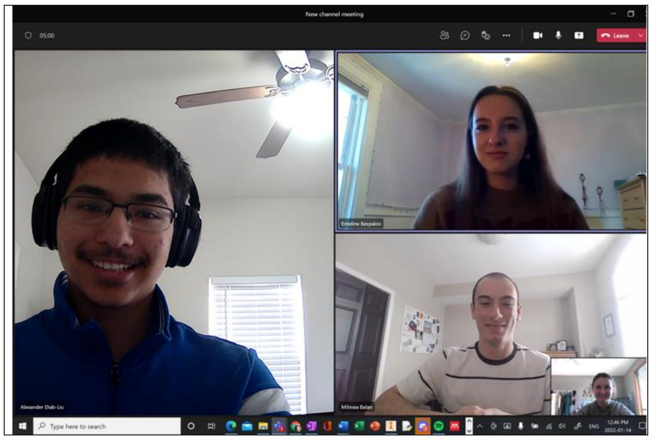
Team Number: 36

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Abby Benyair	benyaira
Emeline Bespalov	bespaloe
Alexander Diab-Liu	diabliua
Mihnea Balan	balanm2

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their DP-3 grade.

Please attach your Team Portrait in the dialog box below



MILESTONE 0 – TEAM CHARTER

Team Number: 36

Incoming Personnel Administrative Portfolio:

Prior to identifying Leads, identify each team members incoming experience with various **Project Leads**

	Team Member Name:	Project Leads
1.	Abby Benyair	☒M ☒A1 ☐A2 ☐C
2.	Emeline Bespalov	☐M ☐A1 ☒A2 ☒C
3.	Alexander Diab-Liu	☒M ☐A1 ☒A2 ☐C
4.	Mihnea Balan	☒M ☒A1 ☐A2 ☐C
		☐M ☐A1 ☐A2 ☐C

To 'check' each box in the Project Leads column, you must have this document open in the Microsoft Word Desktop App (not the browser and not MS Teams)

Project Leads:

Identify team member details (Name and MACID) in the space below.

Role:	Team Member Name:	MacID
Manager	Emeline Bespalov	bespaloe
Administrator 1	Alexander Diab-Liu	diabliua
Administrator 2	Abby Benyair	benyaira
Coordinator	Mihnea Balan	balanm2

MILESTONE 0 – TEAM CHARTER

Team Number: 36

Project Sub-Teams:

Identify team member details (Name and MACID) in the space below.

Sub-team:	Team Member Name:	MacID
Computing	Abby Benyair	benyaira
	Mihnea Balan	balanm2
Modelling	Alexander Diab-Liu	diabliua
	Emeline Bespalov	bespaloe

MILESTONE 1 – COVER PAGE

Team Number: 36

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Abby Benyair	benyaira
Emeline Bespalov	bespaloe
Alexander Diab-Liu	diabliua
Mihnea Balan	balanm2

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their DP-3 grade.

MILESTONE 1 (STAGE 1) – FOCUS AND DEMOGRAPHIC

Team Number: 36

Area of Focus

Indicate your team's chosen **area of focus** in the space below. There are two areas of focus you may choose from:

→ Personal monitoring devices
→ Technology for automating tasks in the home

Chosen Area of Focus:	Personal Monitoring Devices

Customer Demographic

Indicate the **customer demographic** your team will be targeting in the space below.

→ Your customer demographic may be *broad* or *specific*, and may be described in terms of a group of individuals (e.g., patients recovering from at home from a surgery) or a segment of the population (e.g., elderly with a particular disability)

Customer Demographic:	Individuals with Neuromuscular Disorders such as Epilepsy, Parkinson's, and Multiple Sclerosis; specifically, people experiencing muscle spasms, tremors, and seizures.

MILESTONE 1 (STAGE 2) – STATEMENTS OF FACTS

Team Number: 36

As a team, list your **statements of facts** in the space below. As there is an expectation that you conduct some preliminary research and market analysis, each statement of fact should be supported by evidence. That is, it should be properly referenced (using IEEE standards) and should not be a made up 'fact'.

- *Parkinson's disease often causes a tremor, usually starting in a limb such as the hands or fingers. This tremor often persists even when at rest [1]*
- *Parkinson's disease causes a strain not only on the patient themselves, but their families as well [2]*
- *Neuromuscular disorders are shown to have a correlation with depressive symptoms [3]*
- *Temperature has been shown to influence neuromuscular symptoms, particularly hand tremors [4]*
- *People with epilepsy, having two or more unprovoked seizures, are at greater risk for a seizure-related injury [5]*
- *People with epilepsy often experience changes in their quality of life such as less mobility, as well as impacts on learning, school attendance, employment, relationships, and social interactions [6]*
- *Multiple Sclerosis can involve painful muscle spasms, which can worsen over time as the condition progresses [7]*
- *Dystonia (involuntary muscle contractions) can be a side effect of surgery performed to treat symptoms of Parkinson's disease [8]*
- *It is difficult to estimate how quickly or slowly Parkinson's will progress in each person. Each person with Parkinson's is unique and each person may experience different symptoms [9]*

List any references from the statements you came up with as a team in the space below.

List your references here

[1] "Parkinson's disease," *Mayo Clinic*, 14-Jan-2022. [Online]. Available: https://www.mayoclinic.org/diseases-conditions/parkinsons-disease/symptoms-causes/syc-20376055. [Accessed: 16-Jan-2022].

[2] J. H. Carter, B. J. Stewart, P. G. Archbold, I. Inoue, J. Jaglin, M. Lannon, E. Rost-Ruffner, M. Tennis, M. P. McDermott, D. Amyot, R. Barter, L. Cornelius, C. Demong, J. Dobson, J. Duff, J. Erickson, N. Gardiner, L. Gauger, P. Gray, B. Kanigan, B. Kiryluk, P. Lewis, K. Mistura, T. Malapira, M. Pay, C. Sheldon, L. Winfield, K. Wolfington-Shallow, and K. Zoog, "Living with a person who has Parkinson's disease: The spouse's perspective by stage of disease," *International Parkinson and Movement Disorder Society*, 04-Nov-2004. [Online]. Available: https://movementdisorders.onlinelibrary.wiley.com/doi/abs/10.1002/mds.870130108. [Accessed: 18-Jan-2022].

[3] J. M. VanSwearingen, J. F. Cohn, and A. Bajaj-Luthra, "Specific impairment of smiling increases the severity of depressive symptoms in patients with facial neuromuscular disorders - aesthetic plastic surgery," *SpringerLink*, 01-Mar-2014. [Online]. Available: https://link.springer.com/article/10.1007%2Fs002669900312. [Accessed: 18-Jan-2022].

[4] Cooper C, Evidente VG, Hentz JG, Adler CH, Caviness JN, Gwinn-Hardy K. The effect of temperature on hand function in patients with tremor. Journal of Hand Therapy [Online]. 2000;13(4):276–88. Available at: https://pubmed.ncbi.nlm.nih.gov/11129253/ [Accessed: 17-Jan-2022].

[5] Peters, B., 2021. Risks and Complications of Seizures. [online] Verywell Health. Available at: https://www.verywellhealth.com/risks-and-complications-of-seizures-4685790 [Accessed 16 January 2022].

[6] "Living with epilepsy," *EFEPA*, 23-Jul-2019. [Online]. Available: https://www.efepa.org/living-with-epilepsy/#:~:text=People%20with%20epilepsy%20often%20experience,%2C%20relationships%2C%20and%20social%20interactions. [Accessed: 17-Jan-2022].

[7] A. B. O'Connor, S. R. Schwid, D. N. Herrmann, J. D. Markman, and R. H. Dworkin, "Pain associated with multiple sclerosis: Systematic review and proposed classification," *PAIN®*, 24-Oct-2007. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0304395907004605. [Accessed: 18-Jan-2022].

[8] E. Tolosa and Y. Compta, "Dystonia in Parkinson's Disease - Journal of Neurology," *SpringerLink*, Dec-2006. [Online]. Available: https://link.springer.com/article/10.1007/s00415-006-7003-6. [Accessed: 18-Jan-2022].

[9] Parkinson Canada. 2022. Progression of Parkinson's. [online] Available at: https://www.parkinson.ca/about-parkinsons/progression-of-parkinsons/ [Accessed 16 January 2022].

MILESTONE 1 (STAGE 3) – LIST OF CRITERIA

Team Number: 36

As a team, develop a list of criteria that your device is required to meet. List your criteria in the space below. These criteria are akin to *customer requirements*. As such, you should indicate whether each criterion is an objective, function, or constraint. As a reminder, requirements ***can be** more than one* of the three.

List your criteria in this field. Bullet-point format is acceptable. For each criterion, indicate (in parentheses) whether it is an objective, function, or constraint.

- *Objectives*
  - *Should be user-friendly/easy to operate*
  - *Should be lightweight*
  - *Should be applicable/useful for multiple disorders/severities of disorders*
  - *Should incorporate user input to help tailor feedback and alerts to the individual user's needs*
  - *Should provide a warning signal to the user as a predictive measure*
  - *Warns the user when a potentially dangerous medical event is about to happen*
- *Constraints*
  - *Device must be 'travel sized' - not too bulky*
  - *Device must be wearable*
  - *Must include a sensor connected to a Raspberry Pi*
  - *Code must be within the capabilities of a Raspberry Pi*
- *Functions*
  - *Must improve on the user's current lifestyle*
  - *Must directly address the user's disease*
  - *Records data received from the sensor*
  - *Stores data from the sensor for later use (i.e. for use in a patient profile for a doctor's appointment)*
  - *Passes information back to the user/device based on input from the sensor*
  - *Warns the user when a potentially dangerous medical event is about to happen*

MILESTONE 1 (STAGE 4) – NEED STATEMENT

Team Number: 36

Write your Need Statement in the space below. Recall that your need statement should:
→ Have a clearly defined problem (what is the need?)
→ Indicate your end-user (who has the need?)
→ Have a clearly defined outcome (what do you hope to solve and why is it important?)

NEED STATEMENT:	Design a wearable device for individuals suffering from neuromuscular disorders such as Epilepsy, Parkinson's, and Multiple Sclerosis. The device should detect symptoms and monitor disease progression, while collecting and storing information that can help direct their treatment. The device must gather data from a sensor and output relevant suggestions to the user that will improve their lifestyle. The device should help the user achieve more transparency, clarity, and autonomy regarding their disorder and medical care, thereby improving their quality of life.

Team Number: 36

Name: Alexander Diab-Liu	**MacID**: diabliua
Preliminary Concept Solution **#1**	

Type of information input from the physical environment

Muscle Electric Potential

Type of sensor required

Myoware Muscle Sensor

Type of output device(s) used for communication

Electricity/Temperature

How output devices will be implemented

Wires embedded in gloves, used as heating in collaboration with switch

MILESTONE 2 – COVER PAGE

Team Number: 36

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Alexander Diab-Liu	diabliua
Abby Benyair	benyaira
Emeline Bespalov	bespaloe
Mihnea Balan	balanm2

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their DP-3 grade.

MILESTONE 2 (STAGE 1) – PRELIMINARY CONCEPTS

Team Number: 36

You should have already completed this task individually *prior* to Design Studio.

1. Copy-and-paste each team member's preliminary concept sketches on the following pages (1 sketch per page)
   → Be sure to indicate each team member's Name and MacID
2. Copy-and-paste each team member's description of their chosen input and output devices on the following pages (1 description per page)
   → Be sure to indicate each team member's Name and MacID

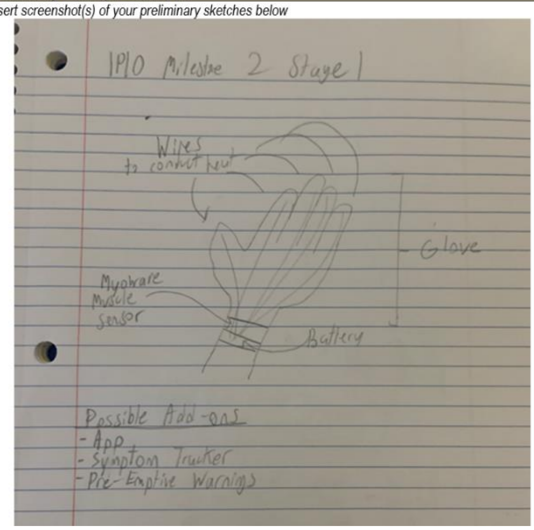
We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their preliminary concept sketches and description of their chosen input and output devices with the **Milestone Two Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Two Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 2*** of the milestone

Team Number: 36

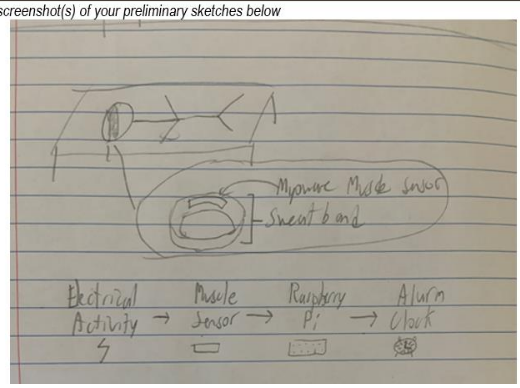
Name: *Alexander Diab-Liu*	**MacID**: diabliua
Preliminary Concept Solution **#1**	

Insert screenshot(s) of your preliminary sketches below



Team Number: 36

Name: Alexander Diab-Liu	**MacID**: diabliua
Preliminary Concept Solution **#2**	
Insert screenshot(s) of your preliminary sketches below	



Team Number: 36

Name: *Alexander Diab-Liu*	**MacID**: diabliua
Preliminary Concept Solution **#2**	

Type of information input from the physical environment

Muscle Electric Potential

Type of sensor required

Myoware Muscle Sensor

Type of output device(s) used for communication

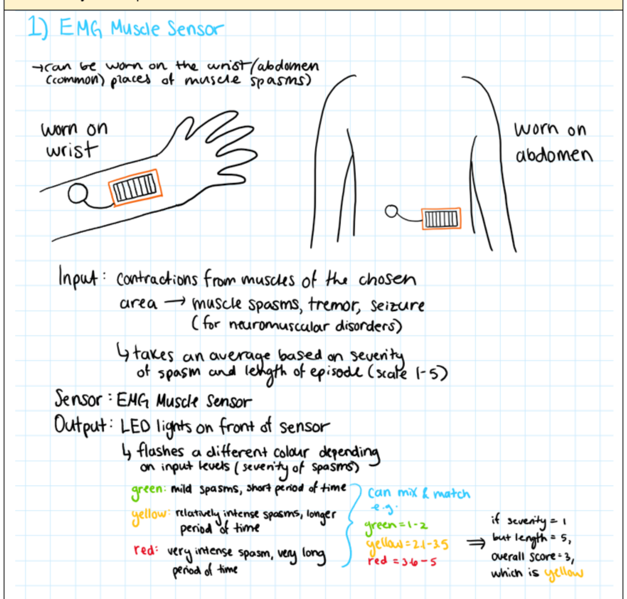
Sound through an alarm

How output devices will be implemented

Built in speakers

Team Number: 36

Name: Abby Benyair	**MacID**: benyaira
Preliminary Concept Solution **#3**	



Team Number: 36

Name: Abby Benyair	**MacID**: benyaira
Preliminary Concept Solution **#3**	

Type of information input from the physical environment

Contractions from muscles of the chosen area (e.g., wrist, abdomen). The device would take the average based on both severity and duration of the spasm (scale 1-5).

Type of sensor required

EMG muscle sensor.

Type of output device(s) used for communication

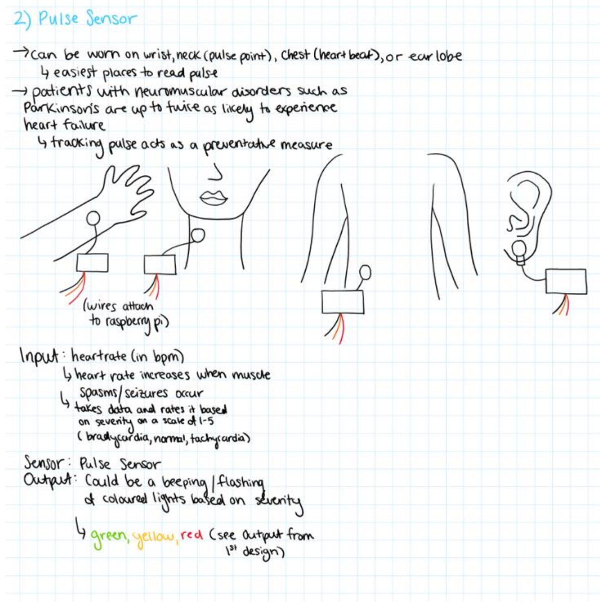
LED lights on the front of the sensor flashes a different colour depending on input levels (severity of spasms) e.g., green, yellow, red (see picture above for more detail).

How output devices will be implemented

A screen will be on the front of the sensor. The sensor will input data from the muscle spasm, and rate its severity from 1-5, its duration from 1-5, and then average the two to get a total rating from 1-5. Depending on its overall rating, it will display either green, yellow, or red on the screen for the user to see.

Team Number: 36

Name: Abby Benyair	**MacID**: benyaira
Preliminary Concept Solution **#4**	



Team Number: 36

Name: Abby Benyair	**MacID**: benyaira
Preliminary Concept Solution **#4**	

Type of information input from the physical environment

Heartrate in bpm: your heartrate increases leading up to, and in the event of muscle spasms/seizures. This device can be worn anywhere where a pulse can be read e.g., wrist, neck (pulse point), chest, earlobe. The pulse sensor will take this data and rate it based on severity on a scale of 1-5 (bradycardia, normal, tachycardia).

Type of sensor required

Pulse sensor.

Type of output device(s) used for communication

Could be:

LED lights on the front of the sensor flashes a different colour depending on input levels (severity of spasms) e.g., green, yellow, red (see picture above for concept sketch #3 for more detail).

Or

Beeping/buzzing if the sensor is in an area where the patient would not see the colours.

How output devices will be implemented

A screen will be on the front of the sensor. The sensor will input data from the muscle spasm, and rate its severity from 1-5, its duration from 1-5, and then average the two to get a total rating from 1-5. Depending on its overall rating, it will display either green, yellow, or red on the screen for the user to see.

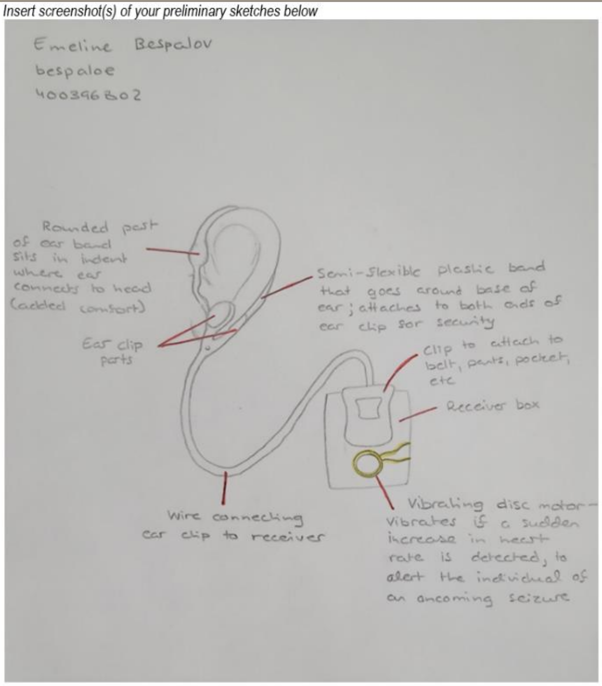
Or

Output speaker/small vibrating motor.

Team Number: 36

Name: Emeline Bespalov	**MacID**: bespaloe
Preliminary Concept Solution **#5**	

Insert screenshot(s) of your preliminary sketches below



Team Number: 36

Name: Emeline Bespalov	**MacID**: bespaloe
Preliminary Concept Solution **#5**	

Type of information input from the physical environment

Number of heart beats per minute (heart rate), detected at the ear lobe

Type of sensor required

Ear-Clip Heart Rate Sensor (Pulse Sensor)

Type of output device(s) used for communication

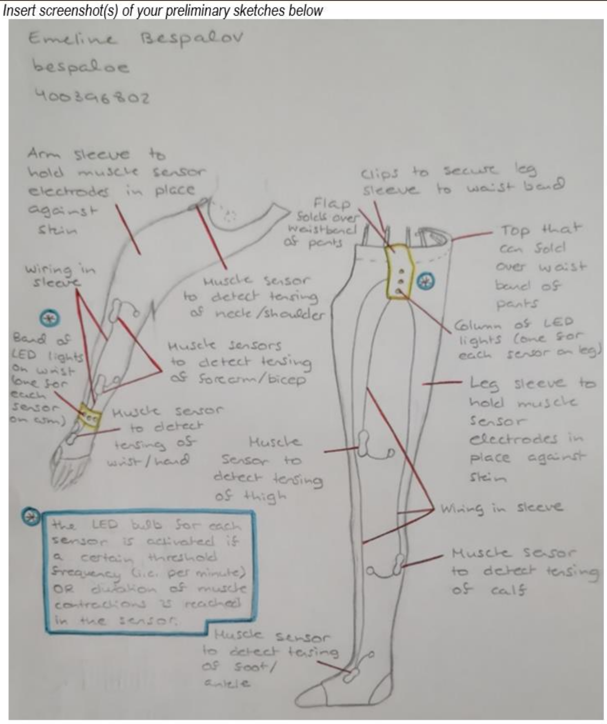
Vibration motor (mini vibrating disc motor)

How output devices will be implemented

A mini vibrating disk motor will be attached to the receiver box clipped onto the waistband/pocket of the user. A small power supply will also be installed on the receiver box that the vibrating disk motor will connect to. When the user's heart bpm exceeds a certain threshold in a certain amount of time (i.e., a rapid increase in heart rate), the motor will vibrate to alert the user that they should prepare for a potential seizure.

Team Number: 36

Name: Emeline Bespalov	**MacID**: bespaloe
Preliminary Concept Solution **#6**	
Insert screenshot(s) of your preliminary sketches below	



Team Number: 36

Name: Emeline Bespalov	**MacID**: bespaloe
Preliminary Concept Solution **#6**	

Type of information input from the physical environment

Electrical activity of muscle - detects the contracting and relaxing activity of muscles using electrodes

Type of sensor required

MyoWare Muscle Sensor (EMG)

Type of output device(s) used for communication

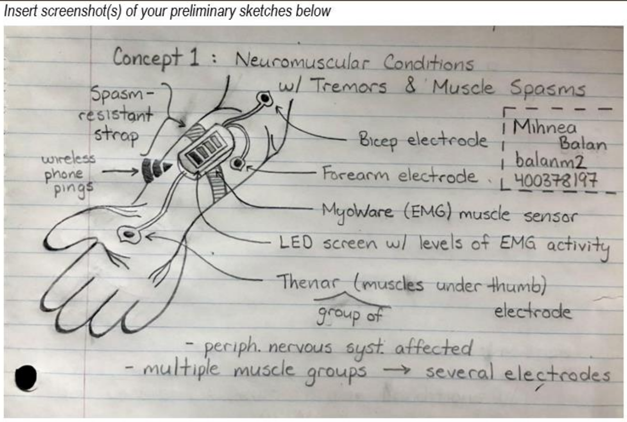
LED light bulbs

How output devices will be implemented

The LED light bulbs will be embedded either as a wrist band in the arm sleeve or a waistband flap in the leg sleeve. Wires will be sewn into the sleeves to connect the muscle sensors to the LED lights. Each bulb will respond to input from one of the sensors located in each of the sleeves (wrist/hand, forearm, bicep, and neck/shoulder for arm sleeve; ankle/foot, calf, and thigh for leg sleeve). A given bulb will light up if a certain threshold frequency of muscle contractions is detected in the respective sensor, or if a certain duration of muscle contraction is detected. This will allow the user to be aware of and track instances of both muscle spasms and muscle rigidity (e.g., caused by Parkinson's or Multiple Sclerosis). These LED bulbs could also be used as a warning system for seizures, in which case they would light up when the muscle sensors detect severe muscle tensing which is a precursor to seizures for many individuals.

Team Number: 36

Name: Mihnea Balan	**MacID**: balanm2
Preliminary Concept Solution **#7**	
Insert screenshot(s) of your preliminary sketches below	



Team Number: 36

Name: Mihnea Balan	**MacID**: balanm2
Preliminary Concept Solution **#7**	

Type of information input from the physical environment

- Electrical activity from several muscle groups in the arm (bicep, forearm, and hand)
  - Faulty electrical signaling from the CNS often leads to faulty responses in the PNS, such as involuntary movements (twitches, tremors, spasms, seizures, etc.)
  - One of the most common areas for these movements is in the arms (often on the dominant side for certain disorders)

Type of sensor required

- MyoWare EMG Muscle Sensor
  - Can measure the electrical activity of muscles by outputting a voltage and recording the ensuing potential, which is based on muscle activity
- **SAME** sensor as in Concept #8; **DIFFERENT** context, sensory parameters, & target disorders

Type of output device(s) used for communication

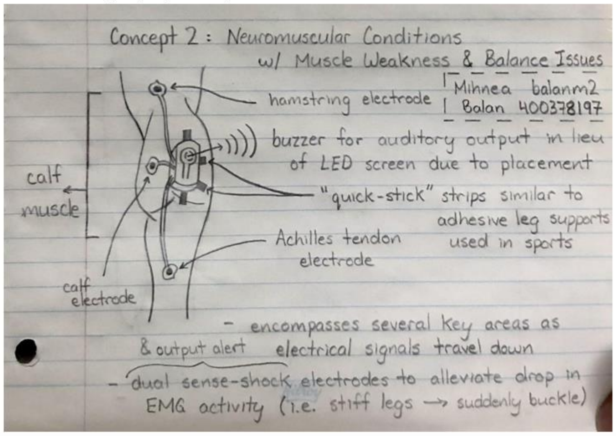
- LED board / screen that displays the levels of electrical activity picked up
- Utilizing the wireless capabilities of the Raspberry Pi 4 (if the starter kit includes it) to ping the user's phone

How output devices will be implemented

- Internet searches have found the MyoWare LED "shield" to have 10 bars that can light up sequentially to visually indicate the measured severity of muscular activity
  - Severity: 0 = off; 1 = resting; 2-4 = moderate; 5-7 = caution; 8-10 = dangerous
- Major episodes are often pre-signaled by high amounts of electrodermal activity (likely sensor can pick this up) and the user's phone can be pinged wirelessly to indicate upcoming spasms

Team Number: 36

Name: Mihnea Balan	**MacID**: balanm2
Preliminary Concept Solution **#8**	
Insert screenshot(s) of your preliminary sketches below:	



Team Number: 36

Name: Mihnea Balan	**MacID**: balanm2
Preliminary Concept Solution **#8**	

Type of information input from the physical environment

- Electrical activity in areas of the leg that are key to balance (hamstring, calf, Achilles' tendon)
- Electrodermal(?) activity throughout the same area (constantly high → muscles tight; stressed)
  - Quick activity drop could indicate sudden muscle weakness (i.e., legs buckling)

Type of sensor required

- MyoWare EMG Muscle Sensor
  - Can measure the electrical activity of muscles by outputting a voltage and recording the ensuing potential, which is based on muscle activity
- **SAME** sensor as in Concept #7; **DIFFERENT** context, sensory parameters, & target disorders

Type of output device(s) used for communication

- Since the sensor is not placed on an area typically in the user's field of vision, a buzzer would be a reasonable alternative (auditory output)
- Dual sense-shock electrodes alert user physically if activity indicates weakness/balance issues

How output devices will be implemented

- Two scenarios in which buzzer would go off:
  - Abnormally high electrical activity throughout areas of leg, indicating unpredictable muscle responses (can help avoid possible injuries)
  - High levels of electrodermal(?) activity indicating stressed muscles that may relax and therefore weaken unexpectedly (which can make balance a struggle and falls likely)
- In case auditory levels are high (e.g., loud TV in background), the electrodes can release an electric shock (like a miniature defibrillator) to warn user and help stop leg(s) from buckling

MILESTONE 2 (STAGE 2) – PUGH MATRIX

Team Number: 36

1. As a team, evaluate your concept solutions in the table below
   - → List your Criteria in the first column
     - You should include a minimum of 5 criteria
   - → Fill out the table below, comparing your designs against a baseline concept (the decision of a baseline concept is arbitrary and entirely up to your team to decide)
     - Replace "Concept 1", "Concept 2", etc. with more descriptive labels (e.g., a distinguishing feature or the name of student author)
     - Indicate a "+1" if a concept is better than the baseline, a "–1" if a concept is worse, or a "0" if a concept is the same

Table 1 – Concept Evaluation

	Alex 1 (Heated Glove for Hand Tremors)	**Alex 2 (Headband for Nocturnal Seizures)**	***Abby 1 (Muscle Sensor)***	***Abby 2 (Pulse Sensor)***	***Emeline 1 (Pulse Sensor Earpiece)***	***Emeline 2 (Muscle Sensor Sleeves)***	***Mihnea 1 (Arm Tremors & Spasms)***	***Mihnea 2 (Leg Weakness; Balance Issues)***
User Friendly	+1	0	+1	0	-1	+1	0	0
Versatility	0	-1	+1	+1	+1	+1	0	0
Practicality/Efficacy	0	0	0	0	0	0	0	0
Innovative	+1	0	-1	+1	+1	+1	+1	+1
Feasibility	0	+1	0	0	-1	-1	0	-1
Lifestyle Impact	0	0	0	0	0	0	+1	+1
Total +	2	1	2	2	2	3	2	2
Total –	0	1	1	0	2	1	0	1
Total Score	2	0	1	2	0	2	2	1

2. Indicate the concept(s) you have selected to pursue for further development and testing, include **justification**

We have decided to combine the heated gloves, arm sleeves, and arm tremor / spasm ideas into one. This would allow for the symptom management feature of the gloves (increasing temperature can help reduce the severity of muscle tremors) while maintaining the information gathering features of the arm tremor idea and keeping the comfortability of the arm sleeves. We will also be incorporating an output device design that will show the degree or severity of the muscle spasm, tremor, or contraction that is occurring.

Table 2 – Output Device/Method Evaluation

	Heated Elements	***LED (Colour Rating)***	***LED (10-pt. Scale)***	***Buzzer***	***Phone Notifications***	***LED (Sensor Location)***		
User Friendly	+1	+1	0	0	+1	+1		
Versatility	+1	0	0	+1	+1	0		
Practicality/Efficacy	0	+1	+1	0	+1	0		
Innovative	+1	0	0	+1	0	+1		
Feasibility	0	+1	+1	0	-1	0		
Lifestyle Impact	+1	0	+1	0	+1	-1		
Total +	4	3	3	2	4	2		
Total –	0	0	0	0	1	1		
Total Score	4	3	3	2	3	1		

3. Briefly describe any **design refinements** that your team will consider for the selected concept. Design refinements include any changes or modifications that deviate from the initial design. These changes or modifications may be based on *other* designs that were proposed but not selected, or they may be derived from discussions during your team's concept evaluation.

In terms of design refinements, we will be incorporating the heating elements beyond the glove into the sleeve, so that heating can be an output response to information gathered by any of the sensors up the arm. An LED colour scale (e.g., red, yellow, green) showing the degree of muscle contraction/spasm will also be incorporated. Meanwhile, the selected output devices (sensor location, 10-point scale, and buzzer) while be added into the phone notifications feature. This means that we will be storing information about where the muscle spasm/contraction occurred (i.e., which sensor detected it) and how severe it was on a 10-point scale.

MILESTONE 3 – COVER PAGE

Team Number: 36

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Abby Benyair	benyaira
Alexander Diab-Liu	diabliua
Emeline Bespalov	bespaloe
Mihnea Balan	balanm2

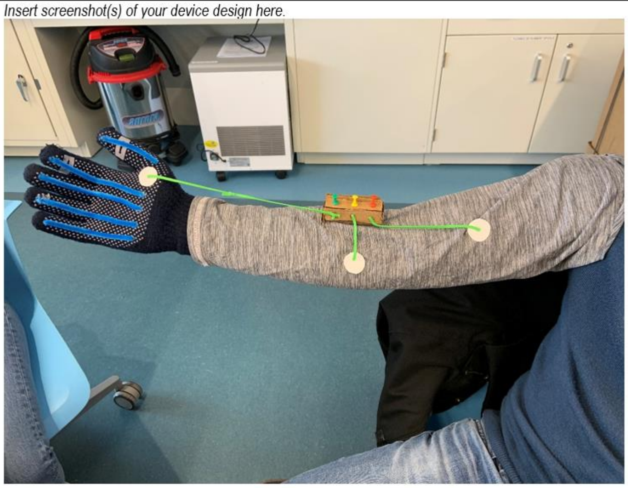
Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their DP-3 grade.

MILESTONE 3 (STAGE 1) – PRELIMINARY DESIGN OF DEVICE

Team Number: 36

As a team, create a preliminary presentation of your device, documenting your design via screenshots in the space below.

Insert screenshot(s) of your device design here.



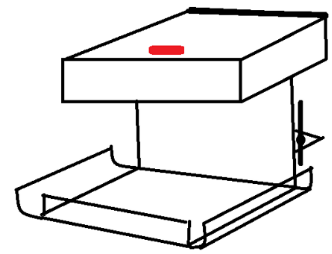
* For each screenshot, please copy-and-paste the above to a new page

MILESTONE 3 (STAGE 2) – PRELIMINARY SKETCH (MODELLING SUB-TEAM)

Team Number: 36

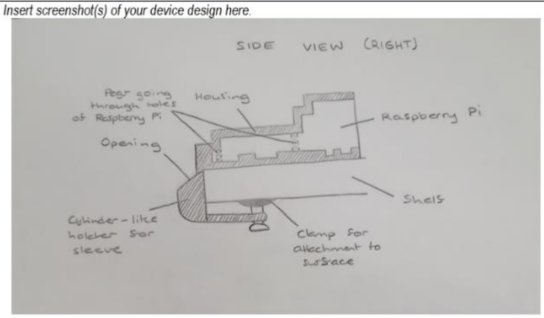
As a sub-team, create a preliminary sketch of your Raspberry Pi housing, documenting your housing via screenshots in the space below.

Insert screenshot(s) of your device design here.



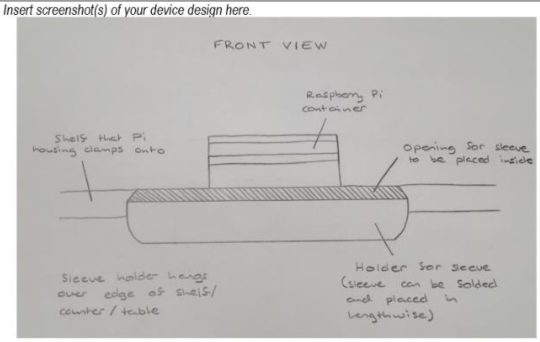
* For each screenshot, please copy-and-paste the above to a new page

Insert screenshot(s) of your device design here.



* For each screenshot, please copy-and-paste the above to a new page

Insert screenshot(s) of your device design here.



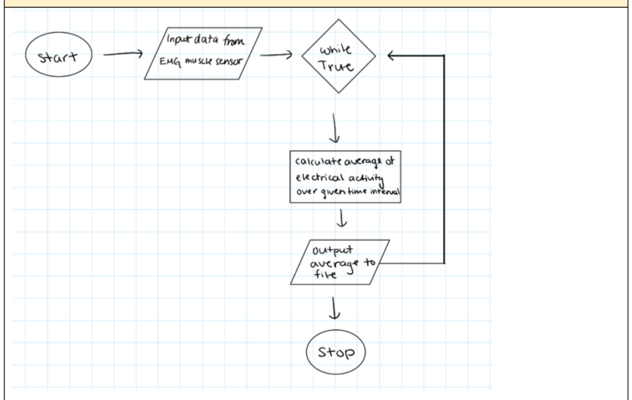
* For each screenshot, please copy-and-paste the above to a new page

MILESTONE 3 (STAGE 3) – PROCESSING INPUT AND COMMUNICATING OUTPUT (COMPUTATION SUB-TEAM)

Team Number: 36

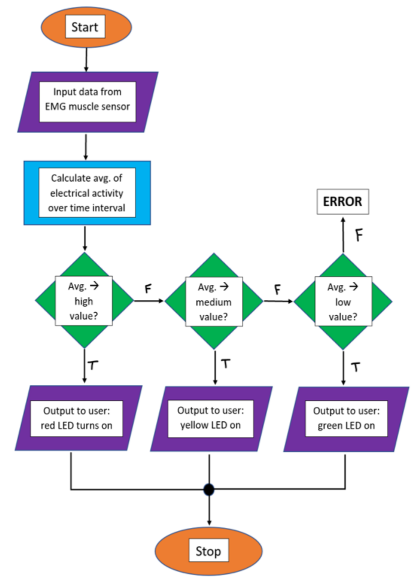
As a sub-team, complete your pseudocode or flowcharts in the space below. Alternatively, copy-and-paste screenshots of your pseudocode or flowchart below (1 screenshot per page)

Name: *Abby Benyair*	**MacID**: benyaira
After receiving the data from the EMG muscle sensor, the code will enter a while True loop, in which it will continuously calculate an average of the electrical activity over a given time interval. This process will continue within the infinite loop, continuously outputting the average into a text file for storage.	



* For each process (remember, there are 2!), please copy-and-paste the above to a new page

Name: *Mihnea Balan*	**MacID**:balanm2
• *Process would run inside of a "while True" infinite loop as long as the sensor is on, and power is supplied to it and the LEDs* • *The loop would repeat over a set time interval and analyze the average EMG activity during that period to determine the proper LED response for the data accumulated*	



* For each process (remember, there are 2!), please copy-and-paste the above to a new page

MILESTONE 3 (STAGE 4) – DESIGN REVIEW FEEDBACK

Team Number: 36

Use the space below to document mentor feedback for your design.

Sensor Box
- Not on / around elbow joint (uncomfortable and not very secure)
- Could relocate to wrist or back of arm
- Must make sure the wires connected to the electrodes and heating elements stay flush with the skin (i.e., they can't detach from the skin or bend when the arm bends)

Heating elements
- Can plug in to an outlet to heat up the elements (if the device is only being used at home)
- Heating can be dangerous so need to keep that in mind
- Portable battery for heating could be bulky and uncomfortable

Marketability
- Make the sensing and response unique for the individual
- Flesh out the personal profile and data records aspect
- Cater to the person's frequency and severity of tremor/spasm (e.g., higher threshold values for low, medium, and high activity levels for people with frequent spasms)

Use the space below to propose design refinements based on the feedback.

- Have all the elements (sensor box, electrodes, wires, heating elements) contained in the sleeve, either sewn into the sleeve or sandwiched between the sleeve and another fabric layer on top (like a heated blanket)
- Have a rechargeable battery for heating, so the sleeve can be plugged into a power source to recharge when it is not in use
- Move the sensor box to the back of the arm, so it is out of the way (like a glucose monitoring patch)

MILESTONE 4 – COVER PAGE

Team Number: 36

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Abby Benyair	benyaira
Alexander Diab-Liu	diabliua
Emeline Bespalov	bespaloe
Mihnea Balan	balanm2

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their DP-3 grade.

MILESTONE 4 (STAGE 1) – DETAILED SKETCHES (MODELLING SUB-TEAM)

Team Number: 36

You should have already completed this task individually *prior* to Design Studio.

1. Copy-and-paste each team member's detailed sketch of their housing assembly on the following pages (1 team member per page)
   → Be sure to clearly indicate who each sketch belongs to

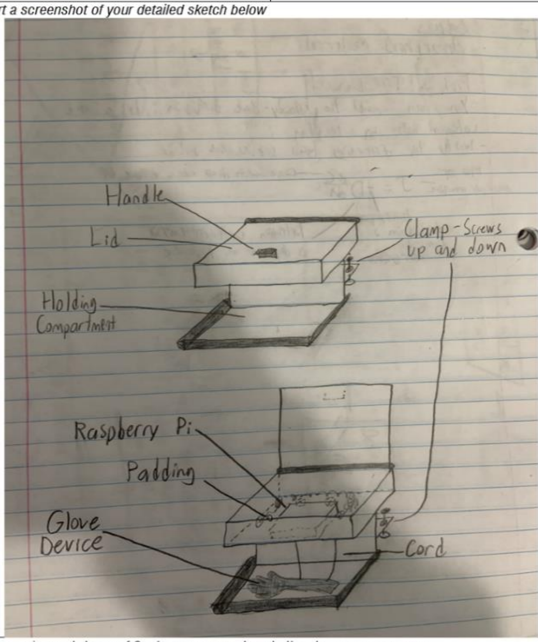
We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their detailed sketch screenshots with the **Milestone Four Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Four Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 3*** of the milestone

Team Number: 36

Name: Alexander Diab-Liu	**MacID**: diabliua

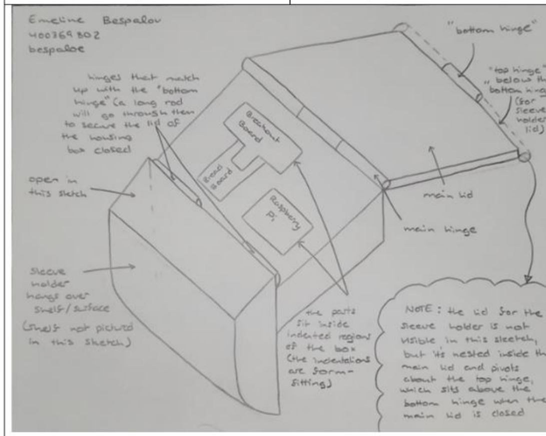
Insert a screenshot of your detailed sketch below



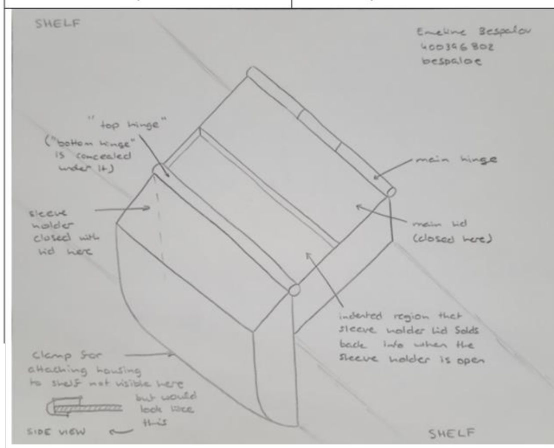
*If you are in a sub-team of 3, please copy and paste the above on a new page

Team Number: 36

Name: Emeline Bespalov	**MacID**: bespaloe



Name: Emeline Bespalov	**MacID**: bespaloe



MILESTONE 4 (STAGE 2) – COMPUTER PROGRAM WORKFLOW (COMPUTATION SUB-TEAM)

Team Number: 36

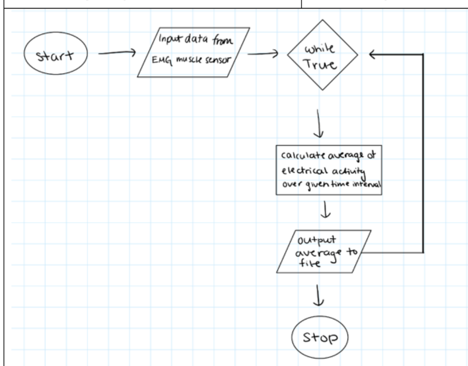
You should have already completed this task individually *prior* to Design Studio.

1. Copy-and-paste each team member's screenshots of their flowchart on the following pages (1 sub-team member per page)
   → Be sure to indicate each team member's Name and MacID

> We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:
> - Each team member needs to submit their flowchart screenshots with the **Milestone Four Individual Worksheets** document so that it can be ***graded***
> - Compiling your individual work into this **Milestone Four Team Worksheets** document allows you to readily access your team member's work
>   - This will be especially helpful when completing ***Stage 4*** of the milestone

Team Number: 36

Name: Abby Benyair	**MacID**: benyaira

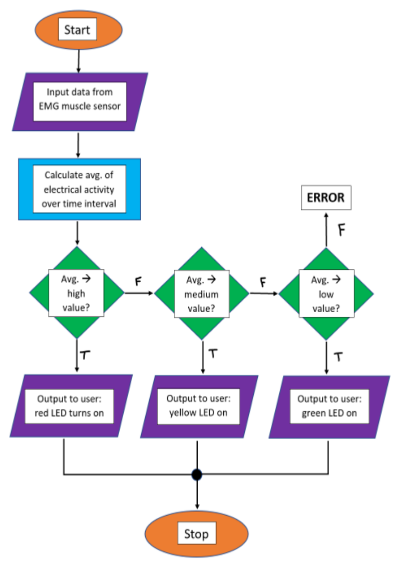


Input: Data from EMG muscle sensors (calculated from separate functions)
Output: Rolling average
Note: Would include object-oriented programming

Team Number: 36

Name: *Mihnea Balan*	**MacID**: *balanm2*

Insert screenshot(s) of your flowchart below:



- Points for further development (flowchart → pseudocode → coding):
  1. What are the units for the input data (context & calculations)?
  2. What number 'n' of data values or time interval would be appropriate for the rolling average?
  3. What sensor values would be considered normal (green), cautionary (yellow), or extreme (red)?
  4. How can this process repeat itself to provide continuous output (most likely an infinite loop, restarting at the end of each number 'n' of data points or time interval)?
  5. How can we incorporate object-oriented programming, as discussed in lecture?

MILESTONE 4 (STAGE 3A) – HOUSING ASSEMBLY OBSERVATIONS AND EVALUATION (MODELLING SUB-TEAM)

Team Number: 36

As a team, **document your observations**, specifically any **similarities and differences** between each team member's detailed sketch in the space below.

Document your observations for each detailed sketch here.

Our sketches are extremely similar, the only main difference being the shape of where the glove would be stored. Alex's design had an open-concept tray idea, while Emeline's design favoured a closed-off cubby route with a hinged door. We ended up going with Emeline's glove storage but with a rectangular shape instead of a rounded one, incorporating Alex's extensions of the device.

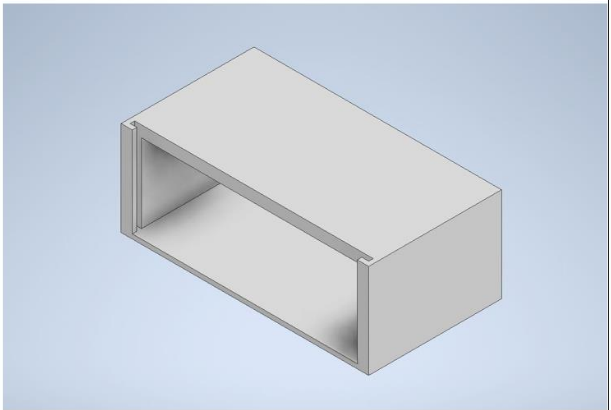
As a team, **document the outcome of your design evaluation**, including a **justification** for your decision, in the space below.

Document the outcome / justification here.

After our design evaluation, we decided to pursue a box-shaped housing unit with an open-front rectangular sleeve compartment that would sit under the shelf and below the box containing the Raspberry Pi and breadboard. The sleeve compartment would have a sliding door that would slide vertically along tracks on the front face of the sleeve compartment, and this door could be opened and closed easily when storing/taking out the sleeve. For the Raspberry Pi box itself, it would contain the Raspberry Pi, breadboard, and T-cobbler, which would fit side-by-side in the box. The box would be able to be opened and closed with a hinged lid, independent of the sleeve compartment door. To attach the housing unit to a surface, a clamp arm would be connected to the lower part of the back panel of the sleeve compartment, and this would be attached to a standard clamp that could be adjusted for various surfaces.

*You do ***not*** need to document the process of your design evaluation!

Insert screenshot(s) of your solid model(s) below

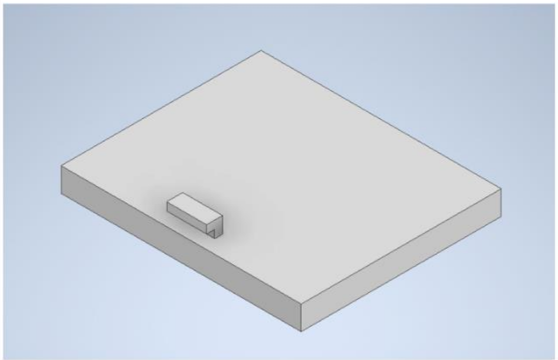


MILESTONE 4 (STAGE 3B) – PRELIMINARY MODELLING (MODELLING SUB-TEAM)

Team Number: 36

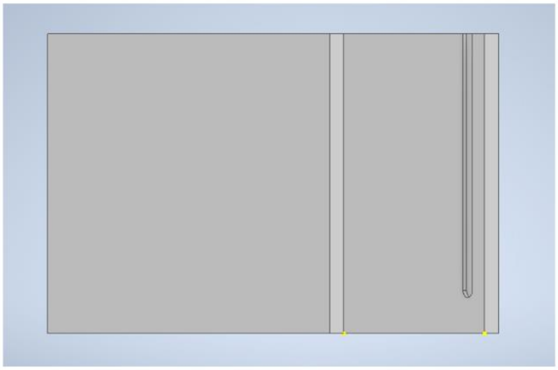
As a team, **begin modelling your Raspberry Pi Housing components** in Autodesk Inventor, documenting your progress via screenshots in the space below.

Insert screenshot(s) of your solid model(s) below



* For each screenshot, please copy-and-paste the above to a new page

Insert screenshot(s) of your solid model(s) below



Insert screenshot(s) of your solid model(s) below

MILESTONE 4 (STAGE 4A) – WORKFLOW PEER-REVIEW (COMPUTATION SUB-TEAM)

Team Number: 36

As a team, **document your observations**, specifically any **similarities and differences** between each team member's flowchart in the space below.

We both have the same inputs (calculated rolling average)

Different outputs → the data would be sent to a storage file for one, whereas the other would send out a signal to the LED lights to display a specific colour (red, yellow, green)

For the LED flowchart: the number of points included within the rolling average would be smaller, meaning the interval is shorter and the display of colours is more instantaneous

For the storage file flowchart: the number of points included within the rolling average would probably be larger, meaning the interval is larger (this would help to make the stored data easier to review since there isn't an endless amount of data)

Both flowcharts would need to have some sort of 'repeating' element (continuous), such as an infinite loop

As a team, **write out a pseudocode** outlining the *high-level workflow* of your computer program in the space below.

```
Import all functions from the sensor library file
Input data:
    Define a function that inputs instances of data from the MyoWare sensor:
        Initialize a blank list for sensor inputs
        Start a counter from zero
        As long as the counter is less than or equal to n:
            If the counter is less than n:
                Assign the scaled sensor data to a variable
                Append the variable to the blank list
                Add one to the counter
            Else if the counter is equal to n
                Return the list of sensor values
```

```
Writing Data to Storage File:
    Define a function that writes data from the MyoWare sensor to a storage file:
        Initialize a blank list for sensor inputs
        Start a counter from zero
        Assign a value to a variable t corresponding to the number of inputs over a given interval
        Within an infinite loop:
            As long as the counter is less than or equal to t:
                If the counter is less than t:
                    Assign the scaled sensor data to a variable
                    Append the variable to the blank list
                    Add one to the counter
                Else if the counter is equal to t
                    Return the list of sensor values
                    Assign the sum of the list divided by its length to a variable
                    Return the rolling interval average
                    Write the returned values to a storage file
```

```
Calculate Rolling Average:
    Define a function that calculates an average continuously using the list from Input Data:
        Within an infinite loop:
            Call the function from Input Data, divide the sum of the returned list by its length, and assign this value to a variable
            Return the value of the rolling average
Process A (LED Lights):
    Define a function that outputs a visual message to the user through LEDs:
        Within an infinite loop:
            Set all LEDs off by default
            Call the function from Calculate Rolling Average and assign this value to a variable
            If the average is greater than the extreme threshold value:
                Turn on the red LED
            If the above is false and the average is greater than the cautionary threshold value:
                Turn on the yellow LED
            If the above is false and the average is in the normal range:
                Turn on the green LED
            If all statements above are false:
                Turn on the red LED
                Turn on the yellow LED
                Turn on the green LED
                Display an error message
Process B (Heating):
    Define a function that outputs heating through the sleeve:
        Within an infinite loop:
            Set the heating off by default
            Call the list from Input Data and assign it to a variable
            Calculate the slope from the first data point within the list to the last
            If the slope is above or equal to a certain threshold value:
                Turn on the heating
            If the above is false and the slope is below the given threshold value:
                Keep heating turned off
```

MILESTONE 4 (STAGE 4B) – PRELIMINARY CODE (COMPUTATION SUB-TEAM)

Team Number: 36

As a team, **begin writing your computer program in Python**, documenting your progress via screenshots in the space below.

****NOTE*: *the code below does not call functions from sensor_library.py → it is meant to serve as a basis for transferring our pseudocode plans into Python*

```
#1) continuously input data

def function1():
    list_1 = []
    count = 0
    while True:
        while count <= 5:
            if count < 5:
                x = 10
                list_1.append(x)
                count += 1
            elif count == 5:
                return list_1

#2) calculate rolling average

def function2():
    while True:
        list_2 = function1()
        avg = sum(list_2) / len(list_2)
        return avg
```

Appendix D: Comprehensive List of Sources

Citations

[1] "Parkinson's disease," Mayo Clinic, 14-Jan-2022. [Online]. Available: https://www.mayoclinic.org/diseases-conditions/parkinsons-disease/symptoms-causes/syc-20376055. [Accessed: 16-Jan-2022].

[2] Peters, B., 2021. Risks and Complications of Seizures. [online] Verywell Health. Available at: https://www.verywellhealth.com/risks-and-complications-of-seizures-4685790 [Accessed 16 January 2022].

[3] E. Tolosa and Y. Compta, "Dystonia in Parkinson's Disease - Journal of Neurology," SpringerLink, Dec-2006. [Online]. Available: https://link.springer.com/article/10.1007/s00415-006-7003-6. [Accessed: 18-Jan-2022].

[4] Parkinson Canada. 2022. Progression of Parkinson's. [online] Available at: https://www.parkinson.ca/about-parkinsons/progression-of-parkinsons/ [Accessed 16 January 2022].

[5] Ucl, "About neuromuscular diseases," Queen Square Centre for Neuromuscular Diseases, 17-Oct-2019. [Online]. Available: https://www.ucl.ac.uk/centre-for-neuromuscular-diseases/about-neuromuscular-diseases. [Accessed: 06-Mar-2022].

[6] "Parkinson's disease," Mayo Clinic, 14-Jan-2022. [Online]. Available: https://www.mayoclinic.org/diseases-conditions/parkinsons-disease/symptoms-causes/syc-20376055. [Accessed: 16-Jan-2022].

[7] A. B. O'Connor, S. R. Schwid, D. N. Herrmann, J. D. Markman, and R. H. Dworkin, "Pain associated with multiple sclerosis: Systematic review and proposed classification," PAIN®, 24-Oct-2007. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0304395907004605. [Accessed: 18-Jan-2022].

[8] J. M. VanSwearingen, J. F. Cohn, and A. Bajaj-Luthra, "Specific impairment of smiling increases the severity of depressive symptoms in patients with facial neuromuscular disorders - aesthetic plastic surgery," SpringerLink, 01-Mar-2014. [Online]. Available: https://link.springer.com/article/10.1007%2Fs002669900312. [Accessed: 18-Jan-2022].

[9] "Living with epilepsy," EFEPA, 23-Jul-2019. [Online]. Available: https://www.efepa.org/living-with-epilepsy/#:~:text=People%20with%20epilepsy%20often%20experience,%2C%20relationships%2C%20and%20social%20interactions. [Accessed: 17-Jan-2022].

[10] J. H. Carter, B. J. Stewart, P. G. Archbold, I. Inoue, J. Jaglin, M. Lannon, E. Rost-Ruffner, M. Tennis, M. P. McDermott, D. Amyot, R. Barter, L. Cornelius, C. Demong, J. Dobson, J. Duff, J. Erickson, N. Gardiner, L. Gauger, P. Gray, B. Kanigan, B. Kiryluk, P. Lewis, K. Mistura, T. Malapira, M. Pay, C. Sheldon, L. Winfield, K. Wolfington-Shallow, and K. Zoog, "Living with a person who has Parkinson's disease: The spouse's perspective by stage of disease," International Parkinson and Movement Disorder Society, 04-Nov-2004. [Online]. Available:

https://movementdisorders.onlinelibrary.wiley.com/doi/abs/10.1002/mds.870130108. [Accessed: 18-Jan-2022].

[11] Stoppler MC. Multiple Sclerosis Symptoms, Causes, Treatment, Diagnosis, and Life Expectancy [Internet]. Davis CP, editor. eMedicineHealth. eMedicineHealth; 2019 [cited 2022Mar6]. Available from: https://www.emedicinehealth.com/multiple_sclerosis/article_em.htm

[12] Cooper C, Evidente VG, Hentz JG, Adler CH, Caviness JN, Gwinn-Hardy K. The effect of temperature on hand function in patients with tremor. Journal of Hand Therapy [Online]. 2000;13(4):276–88. Available at: https://pubmed.ncbi.nlm.nih.gov/11129253/ [Accessed: 17-Jan-2022].

[13] Shawn, "What is EMG sensor, Myoware and how to use with Arduino?," *Latest Open Tech From Seeed*, 05-Jul-2021. [Online]. Available: https://www.seeedstudio.com/blog/2019/12/29/what-is-emg-sensor-myoware-and-how-to-use-with-arduino/. [Accessed: 06-Mar-2022].

[14] M. A. Cavalcanti Garcia and T. M. M. Vieira, "Surface electromyography: Why, when and how to use it," *Revista Andaluza de Medicina del Deporte*, 01-Jan-2011. [Online]. Available: https://www.elsevier.es/es-revista-revista-andaluza-medicina-del-deporte-284-articulo-surface-electromyography-why-when-how-X1888754611201253. [Accessed: 06-Mar-2022].]

[15] Dielectric Manufacturing, "Material properties of thermoplastic nylon - oustanding wear," *Dielectric Manufacturing*, 02-Jun-2021. [Online]. Available: https://dielectricmfg.com/knowledge-base/nylon/#:~:text=Nylon%20Characteristics,-Nylon%20is%20a&text=Nylon%20is%20easy%20to%20machine,is%20an%20excellent%20electrical%20insulator. [Accessed: 06-Mar-2022].

[16] Sewport, "What is elastane fabric: Properties, how its made and where," *Sewport*. [Online]. Available: https://sewport.com/fabrics-directory/elastane-fabric. [Accessed: 06-Mar-2022].

[17] "Carbon fiber insulated heater wire," Calco Electric. [Online]. Available: https://www.calcoelectric.com/insulated-heater-wires/carbon-fiber-insulated-heater-wire. [Accessed: 06-Mar-2022].

[18] "PDMonitor Solution, PDMonitor® | PD Neurotechnology." https://www.pdneurotechnology.com/pd-monitor-solution/product/ (accessed Mar. 05, 2022).

[19] K. I. Tsamis, G. Rigas, K. Nikolaos, D. I. Fotiadis, and S. Konitsiotis, "Accurate Monitoring of Parkinson's Disease Symptoms With a Wearable Device During COVID-19 Pandemic," In vivo (Athens, Greece), vol. 35, no. 4, pp. 2327–2330, Aug. 2021, doi: 10.21873/INVIVO.12507.

[20] "Embrace2 Seizure Monitoring | Smarter Epilepsy Management | Embrace Watch | Empatica." https://www.empatica.com/embrace2/ (accessed Mar. 05, 2022).

[21] "Seizure monitoring devices - from babies to adults - Epilepsy safety." https://autismessentialsisrael.com/en/seizure-monitoring-devices/ (accessed Mar. 05, 2022).

Appendix E: Additional Documentation

Screenshots of Computer Program

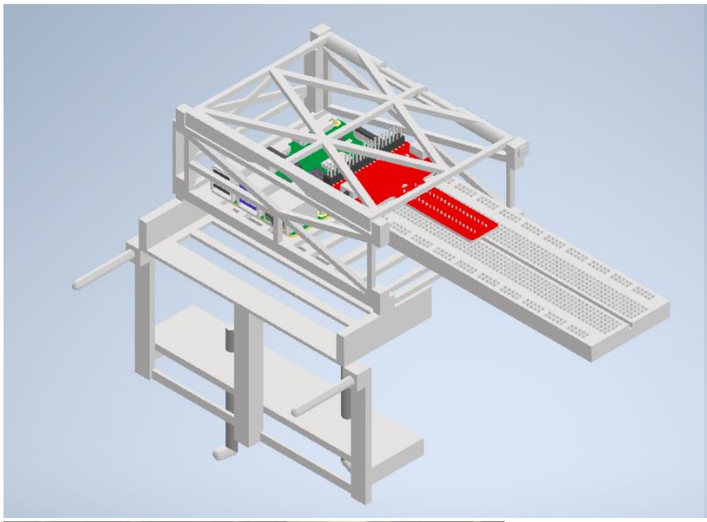
```python
from sensor_library import *
import busio
import board
import smbus
import time
from math import pow
from gpiozero import LED
import sys

    #1) continuously input data

list_of_data = []

def data_input():
    while True: #must infinitely input data
        if len(list_of_data) < 10:
            sensor1 = Muscle_Sensor(0)  #two inputs; one from each of the AIN pins the sensors are connected to
            sensor2 = Muscle_Sensor(1)
            EMG_input = int(sensor1.muscle_scaled(10)) + int(sensor2.muscle_scaled(10))
            list_of_data.append(EMG_input)    #the sum of the two readings is gathered and appended to the list initialized above
        elif len(list_of_data) == 10:
            list_of_data.pop(0)    #once the list has 10 values, the oldest value is discarded
            sensor1 = Muscle_Sensor(0)
            sensor2 = Muscle_Sensor(1)
            EMG_input = int(sensor1.muscle_scaled(10)) + int(sensor2.muscle_scaled(10)) #same function as identical code in "if" above
            list_of_data.append(EMG_input)    #the new value calculated above replaces the "popped" function
            return list_of_data

    #2) calculate rolling average

def calc_rolling_avg(data_list):    #requires a list of sensor values as an argument, runs infinitely in main()
    avg = sum(data_list) / len(data_list)    #basic math calculations to get average
    return avg
```

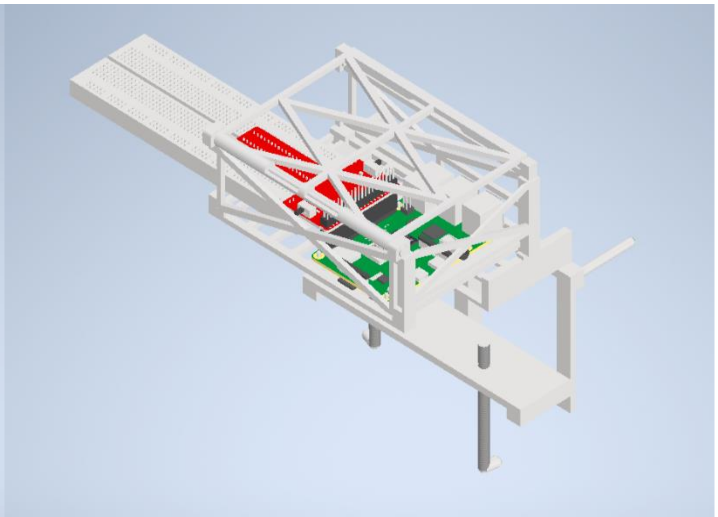
```python
    #3) LED output

def LED_output(data_list):  #requires a list of sensor values as an argument, runs infinitely in main()
    led_red = LED(26)
    led_red.off()
    led_yellow = LED(13)
    led_yellow.off()
    led_green = LED(15)
    led_green.off()         #LED gpios are defined here to match the breadboard; all LEDs off by default

    avg = calc_rolling_avg(data_list)
    if avg >= 12:
        led_red.on()        #red LED turns on in response to high avg, rest turned off
        led_yellow.off()
        led_green.off()
        print('Sensor Data: '+str(data_list)+'\t'+'Rolling Average: '+str(avg)+'\n')
        print("Extreme EMG activity; red LED on. \n")
    elif avg < 12 and avg >= 6:
        led_red.off()
        led_yellow.on()     #yellow LED turns on in response to cautionary avg, rest turned off
        led_green.off()
        print('Sensor Data: '+str(data_list)+'\t'+'Rolling Average: '+str(avg)+'\n')
        print("Cautionary EMG activity; yellow LED on. \n")
    elif 0 < avg < 6:
        led_red.off()
        led_yellow.off()
        led_green.on()      #green LED turns on in response to normal avg, rest turned off
        print('Sensor Data: '+str(data_list)+'\t'+'Rolling Average: '+str(avg)+'\n')
        print("Normal EMG activity; green LED on. \n")
    else:
        led_red.on()
        led_yellow.on()
        led_green.on()
        print('Sensor Data: '+str(data_list)+'\t'+'Rolling Average: '+str(avg)+'\n')    #prints data list and average to shell, not repeated in heating_fn()
        print("Invalid data input; all LEDs on. \n")     #in case invalid numbers are read (i.e., negatives) then all LEDs are on to notify user
    time.sleep(0.5)
```

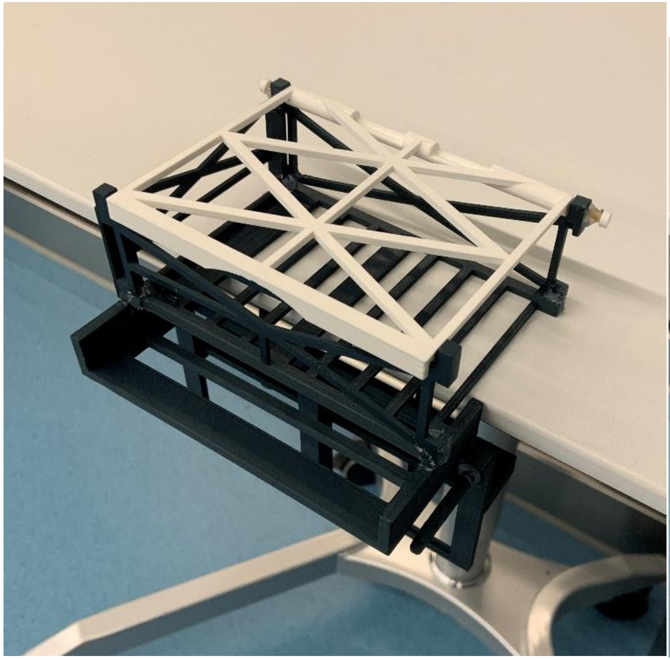
```
    #4) Heating element(s)

def heating_fn(data_list):  #requires a list of sensor values as an argument, runs infinitely in main()
    heat = LED(17)
    heat.off()      #vibration motor (heating placeholder) gpio defined; turned off by default

    avg = calc_rolling_avg(data_list)
    if avg >= 12:
        heat.on()   #heating is turned on to soothe muscles when EMG average is high
        print("High EMG activity; heating on. \n")
    elif avg < 12 and avg >= 6:
        if (data_list[-1] - data_list[0]) / 10 > 0.5:  #predictive function is implemented when EMG activity is cautionary
            heat.on()
            print("Increasing EMG activity; initializing heating. \n")
        else:
            heat.off()
            print("Stable EMG activity; heating off. \n")
    elif avg > 0 and avg < 6:
        heat.off()  #if the average is in a normal range, the heating stays off / is turned off
        print("Normal EMG activity; heating off. \n")
    else:
        heat.off()  #in case invalid numbers are read (i.e., negatives) then the heat is instantly off
        print("Invalid data input; heating off. \n")
    time.sleep(0.5)
```

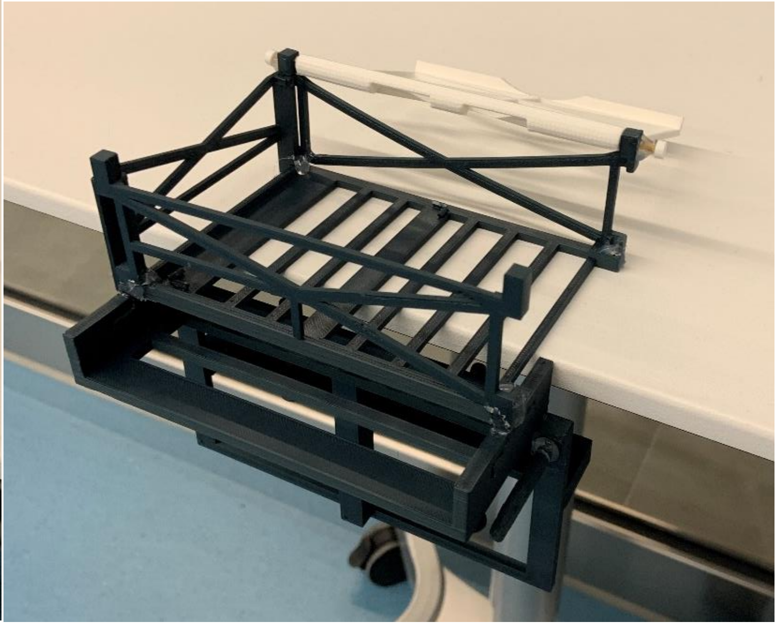
```
    #5) Storage file

def store_data(file, data_list):    #takes the file's name as an argument as well as the list of sensor inputs
    txt_file = file      #meant to be used with Libre Office on pi VNC viewer, size 6 font with the horizontal margins extended
    storage_file = open(txt_file,'a')   #the named file is opened and the "header" for upcoming data below is appended to the file
    storage_file.write('Raw Data:'+'\t'+'\t'+'\t'+'\t'+'Processed Average:'+'\t'+'\t'+'Red LED:'+'\t'+'Yellow LED:'+'\t'+'Green LED:'+'\t'+'Heating Function:

    storage_list = data_list
    store_avg = sum(storage_list) / len(storage_list)
    if store_avg >= 12:
        storage_file = open(txt_file,'a')
        storage_file.write(str(storage_list)+'\t'+str(store_avg)+'\t'+'\t'+'\t'+'On'+'\t'+'Off'+'\t'+'\t'+'Off'+'\t'+'\t'+'On'+'\n')
        storage_file.write('\n')
    elif store_avg < 12 and store_avg >= 6:
        storage_file = open(txt_file,'a')
        storage_file.write(str(storage_list)+'\t'+str(store_avg)+'\t'+'\t'+'\t'+'Off'+'\t'+'On'+'\t'+'\t'+'Off'+'\t'+'\t'+'Predictive Function'+'\n')
        storage_file.write('\n')
    elif store_avg > 0 and store_avg < 6:
        storage_file = open(txt_file,'a')
        storage_file.write(str(storage_list)+'\t'+str(store_avg)+'\t'+'\t'+'\t'+'Off'+'\t'+'Off'+'\t'+'\t'+'On'+'\t'+'\t'+'Off'+'\n')
        storage_file.write('\n')    #the sensor list, average, and status of outputs are appended to the storage file, with their format matching the header
    else:
        storage_file = open(txt_file,'a')
        storage_file.write('Error'+'\t'+'Error'+'\t'+'Error'+'\t'+'Error'+'\t'+'Error'+'\t'+'Error'+'\n')
        storage_file.write('\n')    #in case the conditions above are not met, an error message is displayed instead

    storage_file.close()

    #6) Main function

def main():
    filename = 'Stored Data File'   #this is the name of the storage file included with the program (together in .zip folder)
    while True:     #to satisfy the infinite loop requirement, a while True loop is used
        data_list = data_input()
        LED_output(data_list), heating_fn(data_list), store_data(filename, data_list)   #based on the list of sensor values defined above, the output functio
```

Screenshots and Photos of Raspberry Pi Housing (CAD Model and Physical 3D Print)

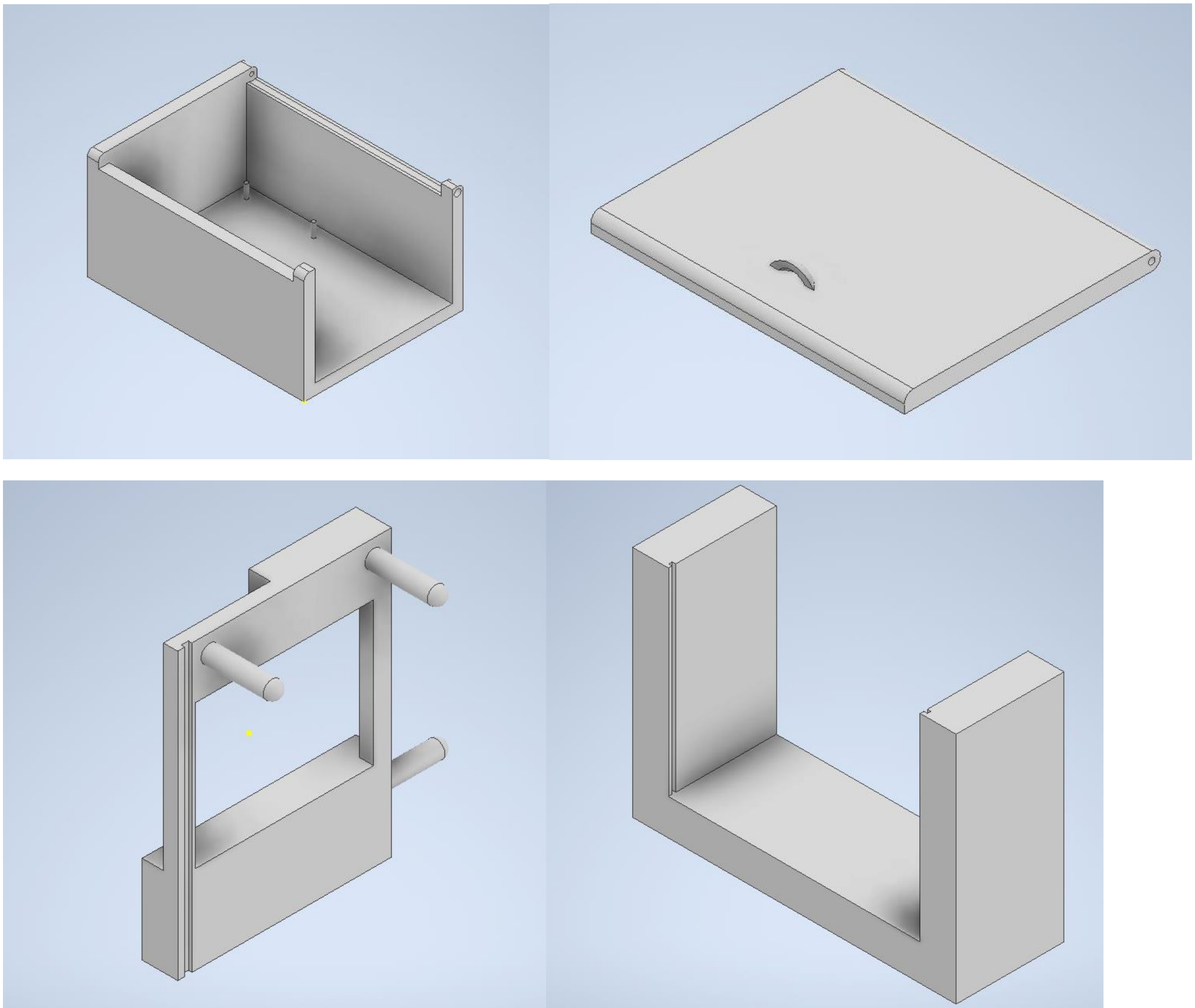




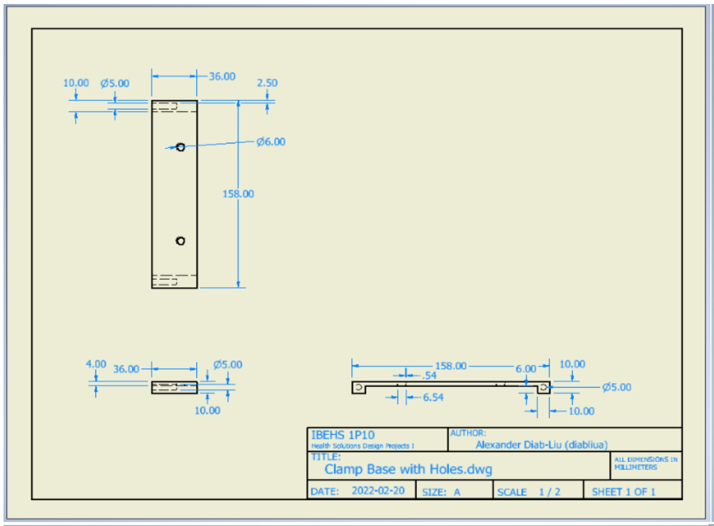


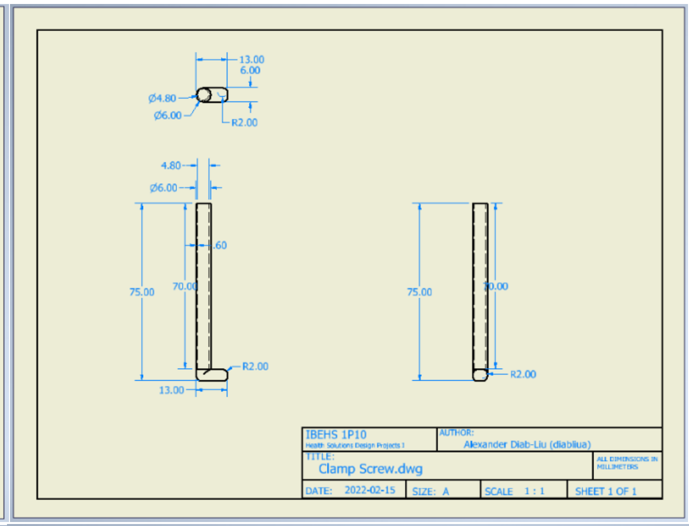


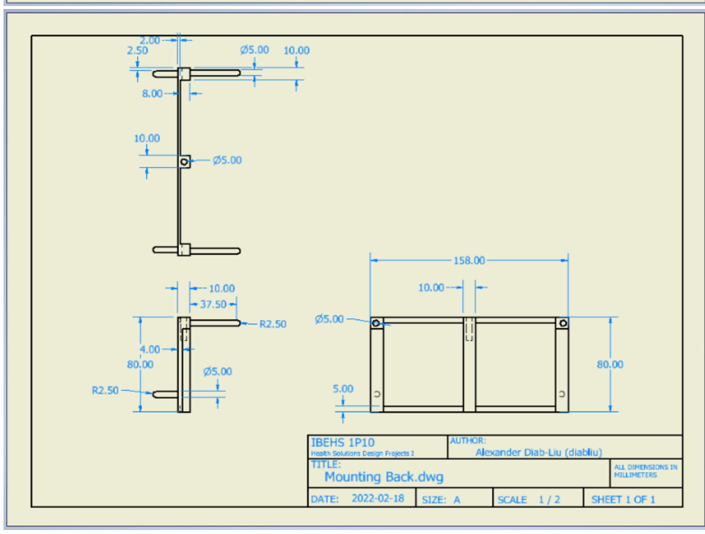
Early Iterations of Raspberry Pi Housing

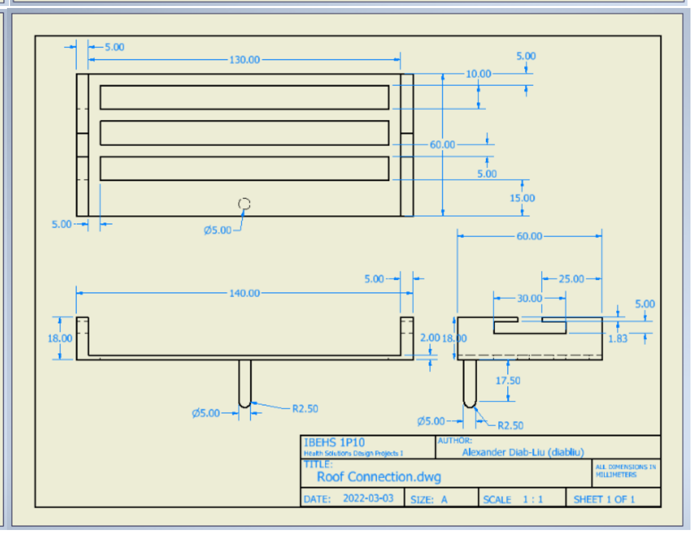


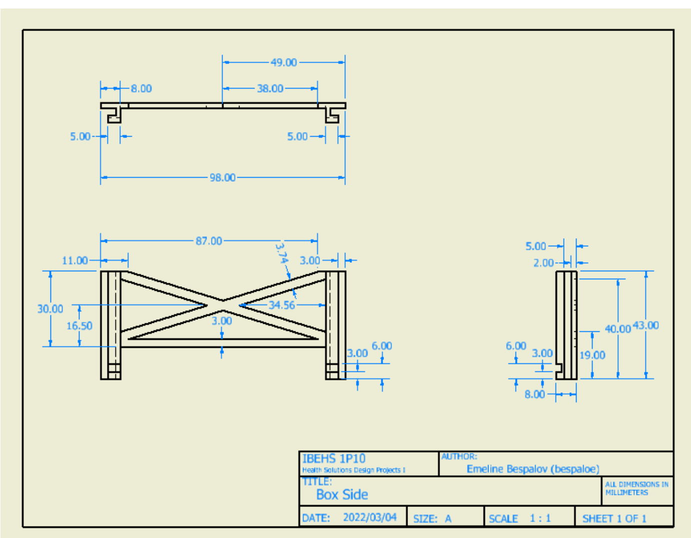
Engineering Drawings of Raspberry Pi Housing

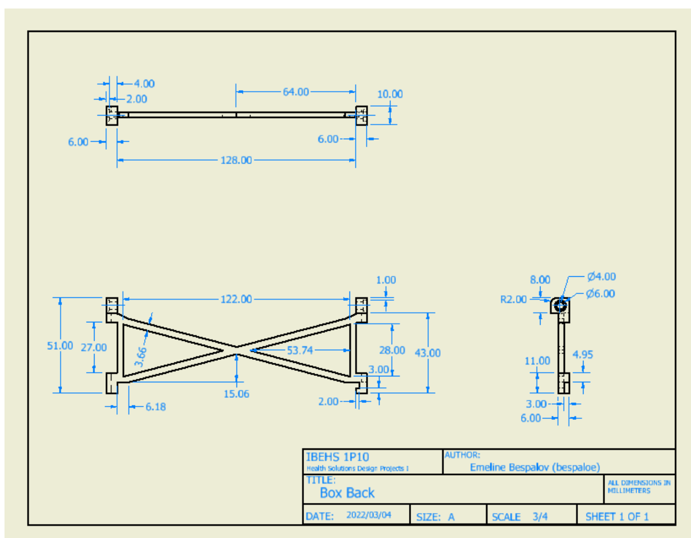


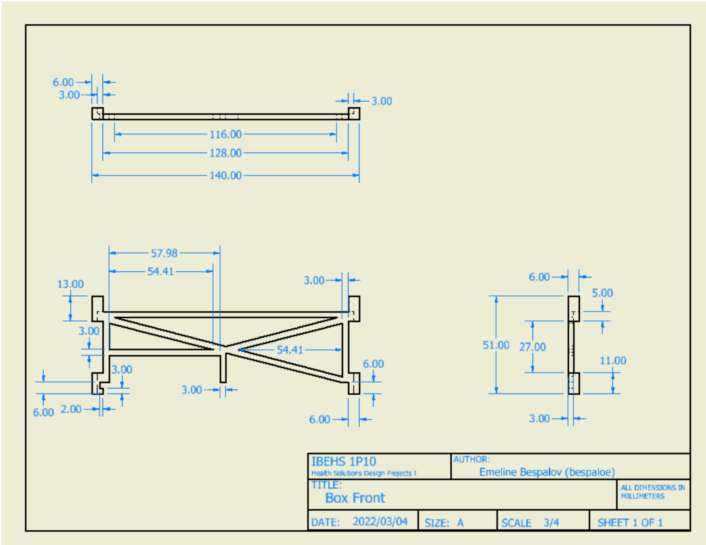


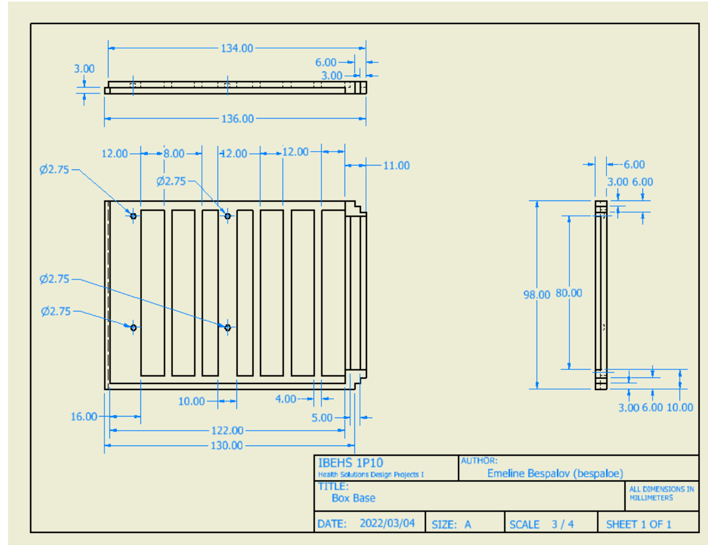


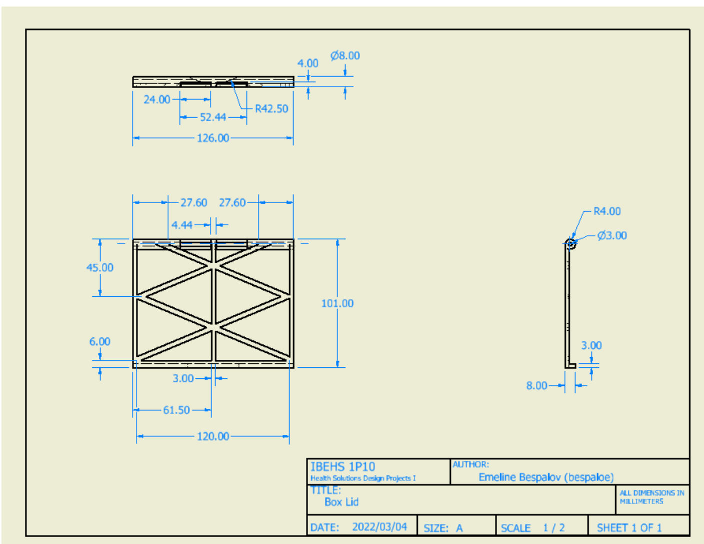


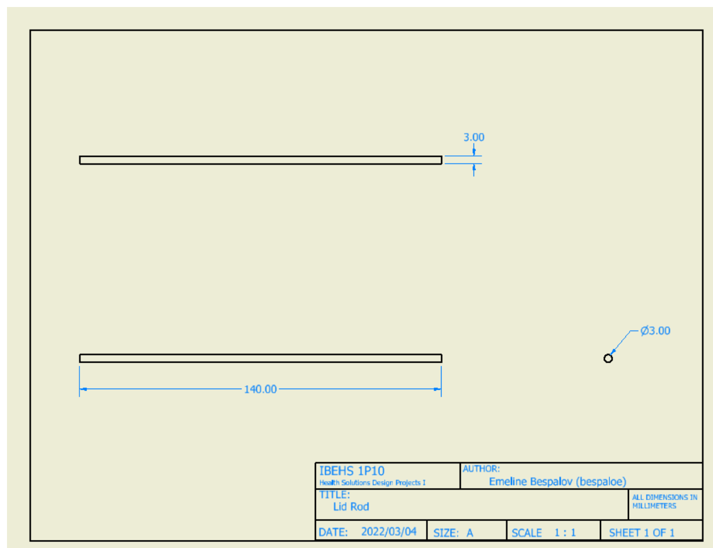


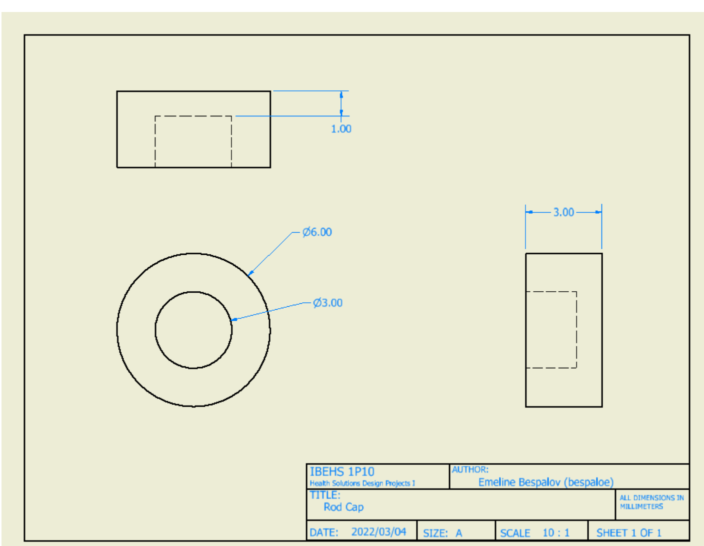


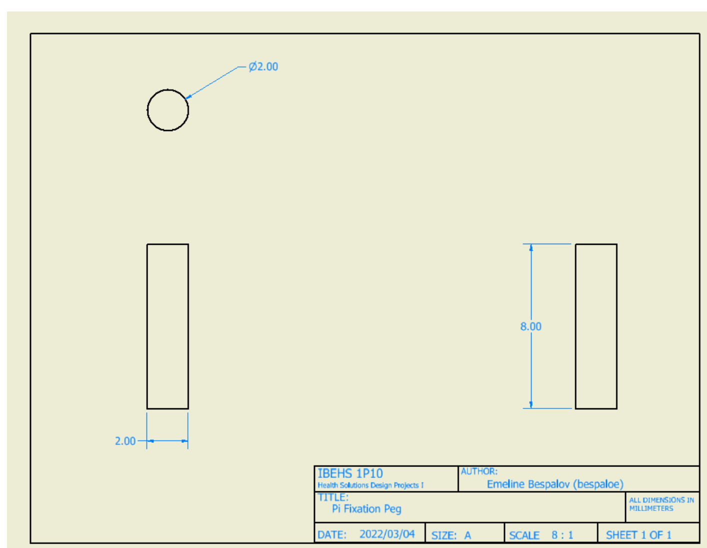

IBEHS 1P10
Health Solutions Design Projects I
AUTHOR:
Emeline Bespalov (bespaloe)
TITLE:
Box Front
ALL DIMENSIONS IN MILLIMETERS
DATE: 2022/03/04
SIZE: A
SCALE 3/4
SHEET 1 OF 1

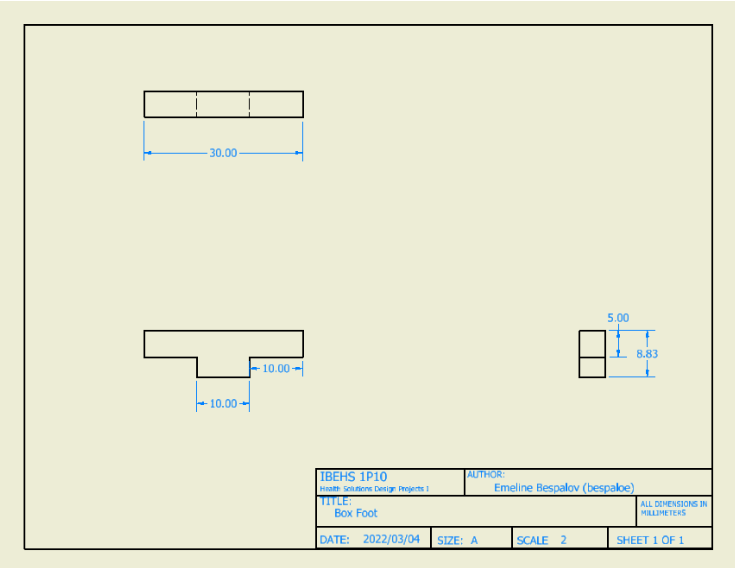

IBEHS 1P10
Health Solutions Design Projects I
AUTHOR:
Emeline Bespalov (bespaloe)
TITLE:
Box Base
ALL DIMENSIONS IN MILLIMETERS
DATE: 2022/03/04
SIZE: A
SCALE 3 / 4
SHEET 1 OF 1


IBEHS 1P10
Health Solutions Design Projects I
AUTHOR:
Emeline Bespalov (bespaloe)
TITLE:
Box Lid
ALL DIMENSIONS IN MILLIMETERS
DATE: 2022/03/04
SIZE: A
SCALE 1 / 2
SHEET 1 OF 1


IBEHS 1P10
Health Solutions Design Projects I
AUTHOR:
Emeline Bespalov (bespaloe)
TITLE:
Lid Rod
ALL DIMENSIONS IN MILLIMETERS
DATE: 2022/03/04
SIZE: A
SCALE 1 : 1
SHEET 1 OF 1


IBEHS 1P10
Health Solutions Design Projects I
AUTHOR:
Emeline Bespalov (bespaloe)
TITLE:
Rod Cap
ALL DIMENSIONS IN MILLIMETERS
DATE: 2022/03/04
SIZE: A
SCALE 10 : 1
SHEET 1 OF 1


IBEHS 1P10
Health Solutions Design Projects I
AUTHOR:
Emeline Bespalov (bespaloe)
TITLE:
Pi Fixation Peg
ALL DIMENSIONS IN MILLIMETERS
DATE: 2022/03/04
SIZE: A
SCALE 8 : 1
SHEET 1 OF 1


30.00
5.00
8.83
10.00
10.00
IBEHS 1P10
Health Solutions Design Projects I
AUTHOR:
Emeline Bespalov (bespaloe)
TITLE:
Box Foot
ALL DIMENSIONS IN MILLIMETERS
DATE: 2022/03/04
SIZE: A
SCALE 2
SHEET 1 OF 1