Design Document

VR Learning Environment with Real Time Brain Signal Monitoring

Brendan Jenkins, Ethan Li, Jacob Mitchell. Yumna Rizvi, Zayne Frabutt

FS: Nathalia Piexoto

ECE 492-001

November 13th, 2020

Problem Statement

Introduction/Motivation

During the COVID -19 pandemic, learning can be extremely difficult due to the situation it puts students and teachers in. With most schools and universities transitioning to virtual learning, it can be especially tough for those students who benefit the most from in-person teachings. As this has been a pressing issue over the past seven months, the issue needs a solution to help both students and teachers in this situation. Most students learn in different ways and most can't focus in these virtual learning environments as external factors can take over that would otherwise not be there in a classroom environment. This creates major limitations in virtual learning environments. Shown in figure 1, is a study which teachers and students identified the limitations of virtual learning as a whole.

	Limitations	
Inefficiency	Unable to teach skills	"In anatomy, the study through models was good. But hands on training is not possible, the student will not be able to understand properly. Skills needs actual hands on training".
	Lack of student feedback	"I find it annoying that during lectures you don't have students feedback whether they are getting the point or not".
	Limited attention span	"There is no continuity of lecture. We lose our concentration and the syllabus is so lengthy."
	Lack of attentiveness	"As the students know that they will get the recordings, they don't listen the lecture properly".
	Resource intensive	"Lots of people might not be having these gadgets. Buying these gadgets comes an extra burden on them in such stressful situation".
Maintaining academic integrity	Lack of discipline	"There is some problem coming with discipline, some students use to misbehave during lectures".
	Plagiarism	As this system is new to everyone, it is difficult to have individual assessment. During assignment, they easily copy paste stuff from web."

Figure 1: Limitations with online learning environments.

Source: Adapted from [1]

This has been an obvious issue since march 2020 to present (September 2020) and there haven't been many major ways this issue has attempted to be mitigated. Our virtual reality learning environment could help not only students but teachers as well. Creating an affordable learning environment through monitoring different aspects of brain signals can help identify what help is really needed for every individual. Overall, many studies such as the one shown in figure 1, identify a multitude of issues with online learning and this project is a great opportunity to help identify and solve these issues.

Identification of need

In this project, our VR environment would need to help monitor the different aspects of learning in an educational environment such as attention span, stress, and other variables through an EEG. Through this data our VR environment would need to provide feedback to the user in order to help each individual with specific issues. This would need to be a low cost solution so it can be accessed by multiple students/teachers.

Market/Application

This product can directly be used by learning institutions specifically for students and teachers who need it. A prevalent problem in the education system amidst a pandemic is the lack of a personalized digital educational experience. A tool to assist learning retention in online education environments via an extended reality platform that is low-cost and accessible for those underrepresented in educational environments and for educators to monitor the effectiveness of their lessons as the goal of the project is to monitor brain signals.

Project Requirements Specification

Mission Requirements

- We will use the Emotiv headband to collect brain signal data as inputs for an educational virtual reality environment.

Input/Output Requirements

- The Emotiv shall output brain signal data packets.
- The computer shall accept an input from a user through brain signal data via data exported.
- The computer shall provide power to the VR headset and its components.
- The computer will use the data and output the results into the VR environment.
- The computer shall accept an input from the user through the VR controllers.
- VR controllers will receive power from a 5V micro-usb input.

Functional Requirements

- The Emotiv will record brain signals at a rate of 128 samples per second.
- The Emotiv shall send data over to the computer with no packet loss.
- The software will detect variations in brain signals while interacting with a virtual reality environment.
- The program will be written efficiently to prevent data loss and reduce latency.

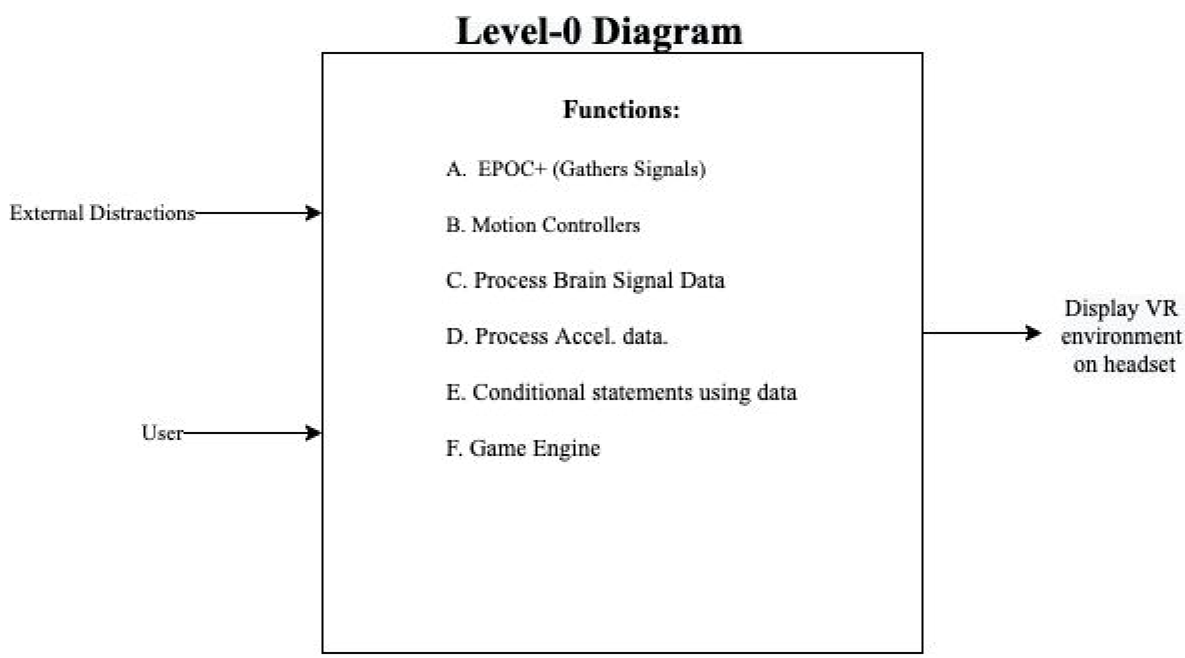
Technology and System-Wide Requirements

- A dedicated series graphics card with HDMI output ports.
- two USB 2.0 ports (at least one them is powered)
- Bluetooth will be required for use of Emotiv and controllers for data transmission.
- Windows 7 or higher operating system.
- Our VR headset will be cost efficient as possible to fit the needs of affordability for students.
- Controllers will use an accelerometer with I2C interface to help locate placement of the user in game.
- Hardware will be simplified and straightforward for easy integration with software.

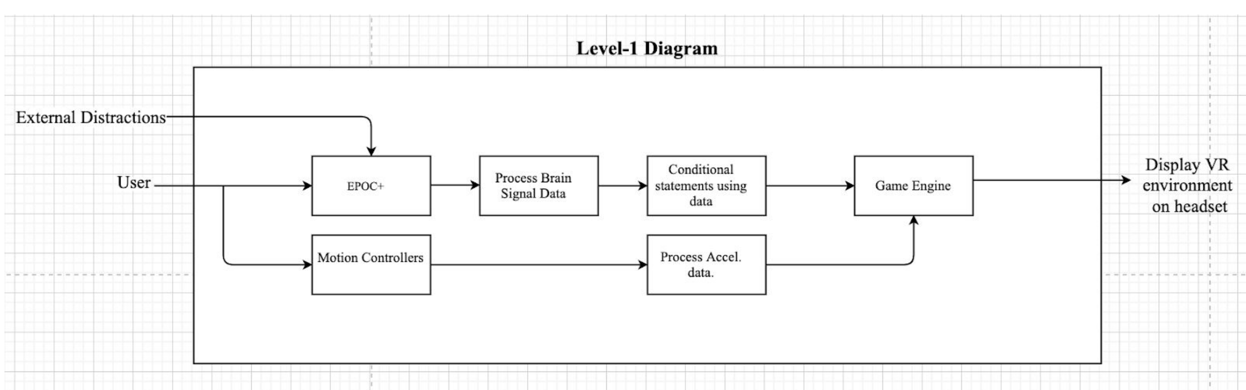
System Design/Architecture

Functional decomposition

Level-0 System Decomposition

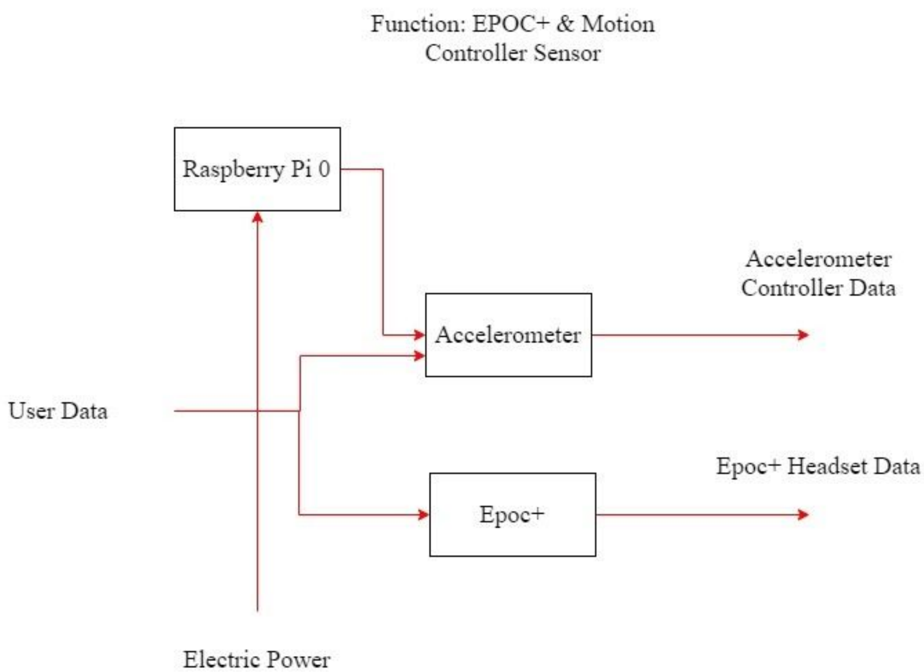


Level-1 System Decomposition

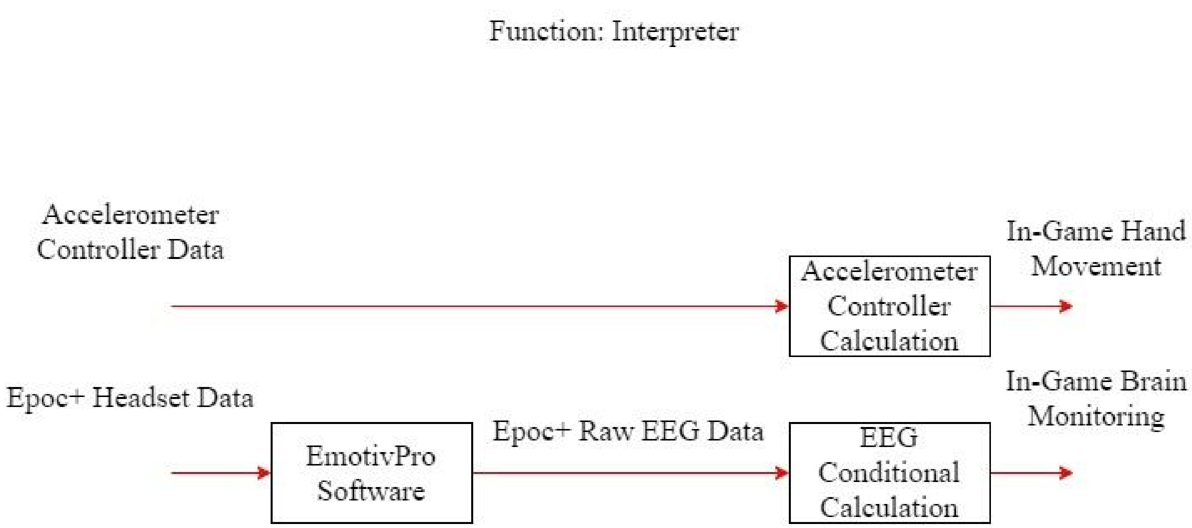


Level-2 System Decomposition

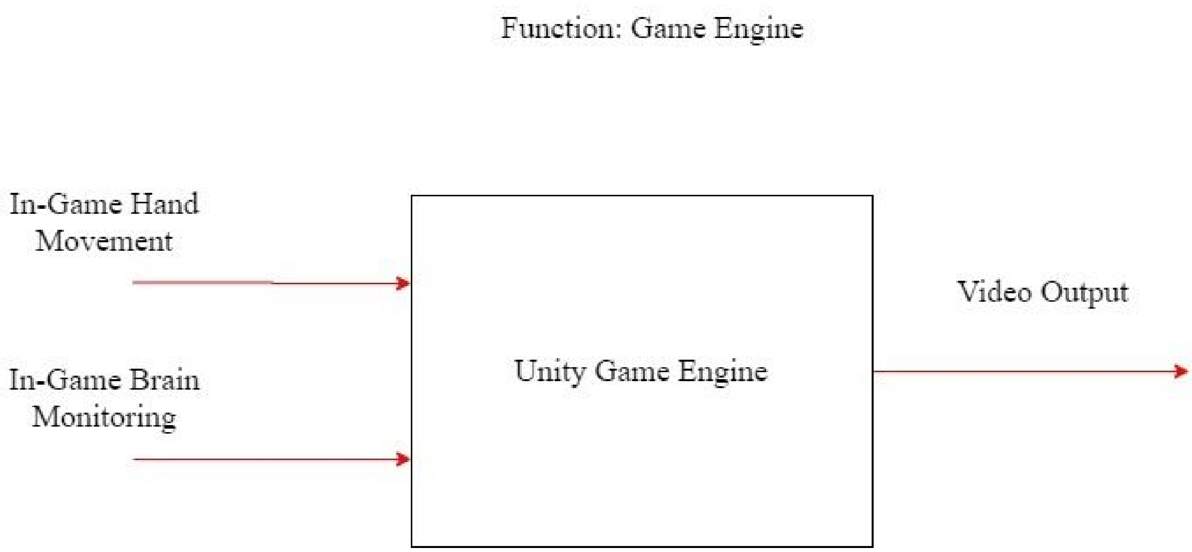
- Breakdown Of Functions A & B (EPOC+ & Motion Controllers)



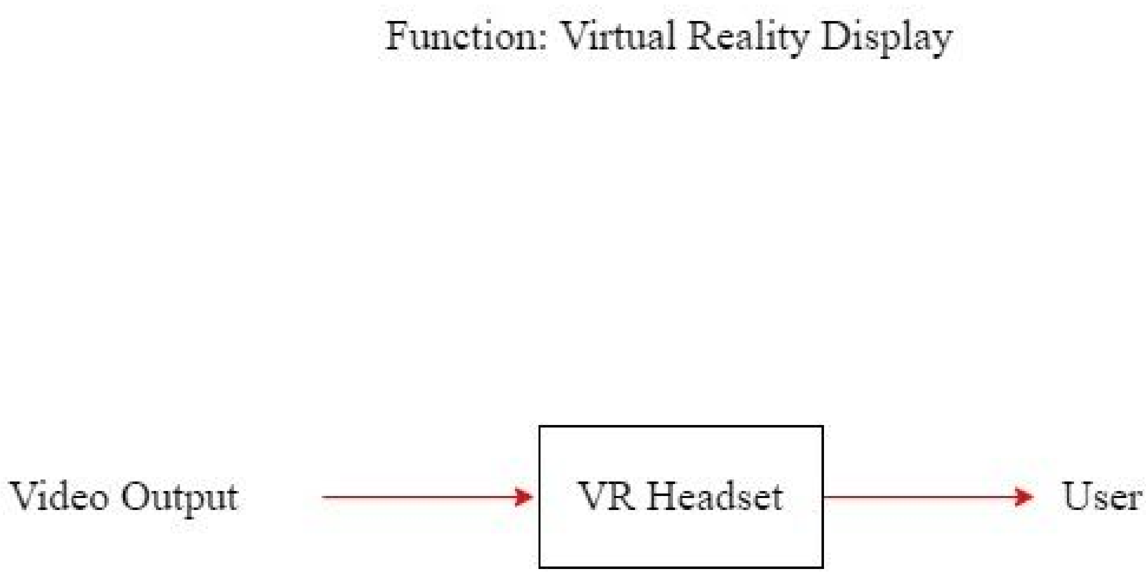
- Breakdown Of Functions C, D, & E (Processing of Data)



❖ Breakdown Of Functions F (Game Engine)



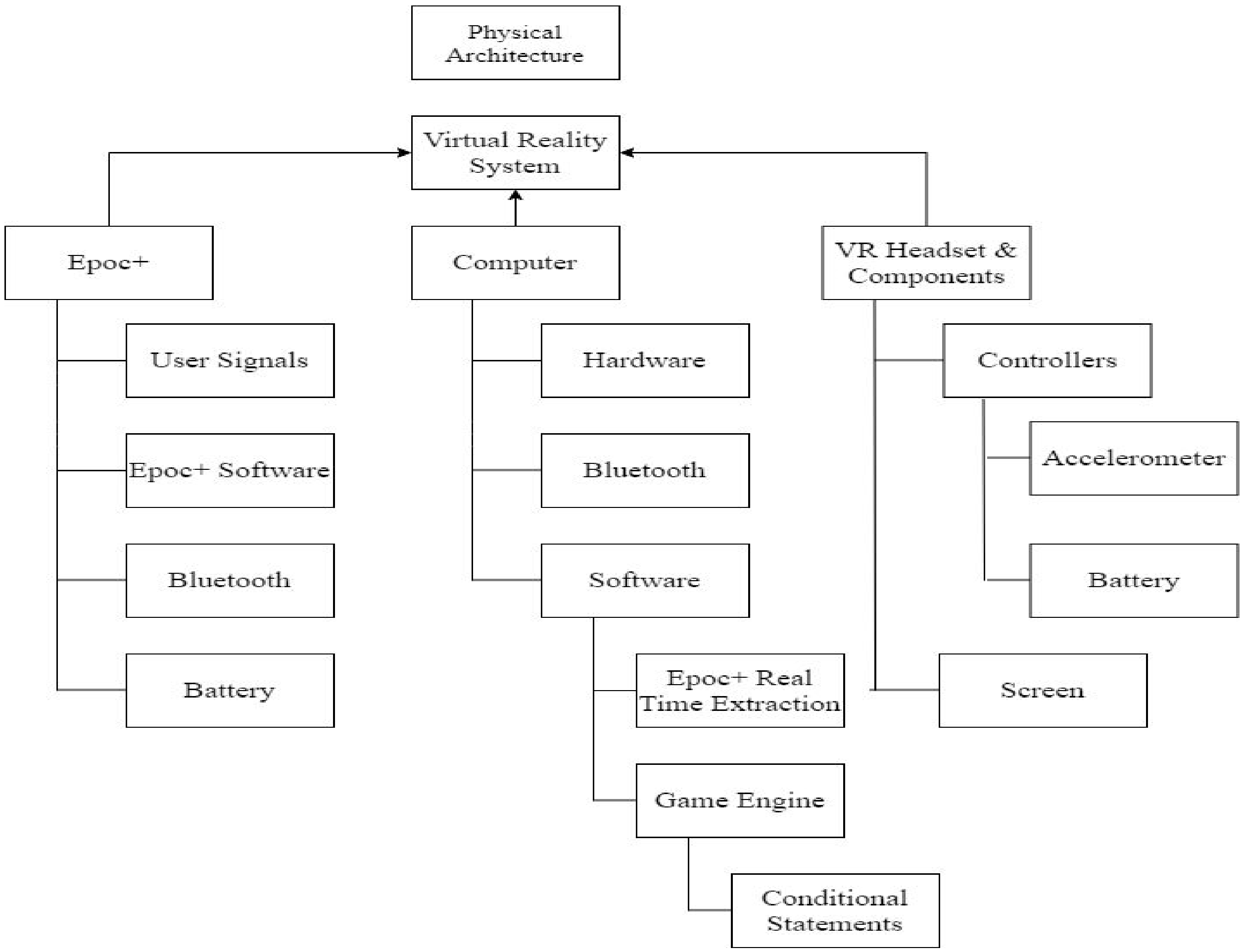
❖ Breakdown Of Output



System Architecture

Physical Architecture

❖ This Figure shows a breakdown of Architecture the physical architecture of our three main components and their associated components.



System Architecture diagram

- This Figure shows a combined process from both our decomposition and physical architecture to show the process of how each of these components work.

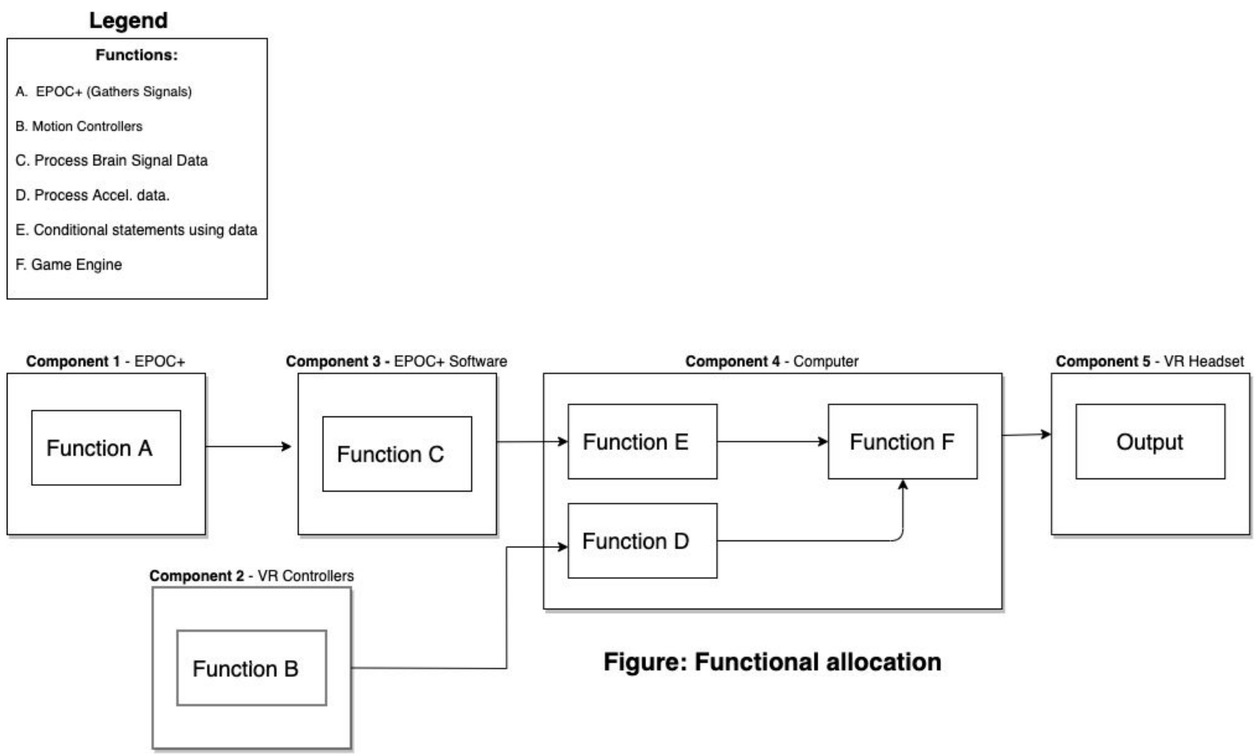


Figure: Functional allocation

Background Knowledge/Phenomenology

❖ Accelerometer as a 3D positioning mechanism

Accelerometers are sensitive to both linear acceleration and the local gravitational field. Changes in orientation are described by rotations in roll φ, pitch θ and yaw ψ about the x, y and z axes respectively

Equations to calculate pitch (y-axis), roll (x-axis), and yaw (z-axis) angles:

$$\tan \phi_{yxz} = \frac{G_{py}}{\sqrt{G_{px}^2 + G_{pz}^2}}$$

Figure: Eq. for Pitch
Source: Adapted from [9]

$$\tan \theta_{xyz} = \frac{-G_{px}}{\sqrt{G_{py}^2 + G_{pz}^2}}$$

Figure: Eq. for Roll
Source: Adapted from [9]

Where G_{px}, G_{py}, and G_{pz} are raw data outputs are read from the accelerometer that must be scaled to an interpretable value. The arctangent is taken on the right side of the equation to help get angle values.

Angle calculations were used in our code to help with angle positioning. Show below is a snippet of our code used with these equations:

```
float yAngle = atan( ay / (sqrt((ax*ax) + (az*az))))*180/M_PI;
float zAngle = atan( sqrt((ax*ax) + (ay*ay)) / az)*180/M_PI;
float xAngle = atan( ax / (sqrt((ay*ay) + (az*az))))*180/M_PI;
```

❖ EEG for sampling of Brain Signals

An EEG picks up the electric potential differences, on the order of tens of µV. The potentials measured therefore reflect neuronal activity and can be used to study a wide array of brain processes [3]. To collect EEG data, electrodes are placed on the scalp and wet with conducting liquid to facilitate the measurement of the electrical activity using scalp electrodes [10].

Event-related potentials (ERPs) are electrical potentials in the brain in response to specific events. While the EEG records ongoing signals from the electrodes in the EPOC+, different types of events are presented for the brain to respond to; for example, written or spoken words, letters, pictures, or sounds. By measuring the brain’s response to these different kinds of events, conclusions can be drawn about how the brain processes different types of information [7].

The table below shows the brain waves the EPOC+ measures. They are classified as gamma, beta, alpha, theta, and delta, each measured at different frequencies [3]. These different brain wave categories are responsible for different brain functions. Applications and monitoring of these allow unbiased measures of, for instance, an individual's level of fatigue, mental workload, mood, or emotions. Beta waves, typically ranging from 12 to 38 hertz [4]. These types of waves are ideal for studying brain function, making them an ideal method to determine brain state during our designed modules. Alpha waves generally signal thoughts, aiding in, “ mental coordination, calmness, alertness, mind/body integration and learning” [4]. Alpha waves will also be very important when monitoring the physiological state of a student. Tracking these waves provides a good indication of the active thought process and potential attention span. Theta waves act as a gateway to cognition, demonstrating when the user is in the process of falling asleep or waking up [4].

TABLE 2.1 Characteristics of the Five Basic Brain Waves

Frequency band	Frequency	Brain states
Gamma (γ)	>35 Hz	Concentration
Beta (β)	12–35 Hz	Anxiety dominant, active, external attention, relaxed
Alpha (α)	8–12 Hz	Very relaxed, passive attention
Theta (θ)	4–8 Hz	Deeply relaxed, inward focused
Delta (δ)	0.5–4 Hz	Sleep

Table showing characteristic of basic brain waves
Source: Adapted from [4]

The EPOC+ headset includes 14 sensors and 2 ground reference points to which the voltage of all other sensors are compared. The 14 scalp sensors (channels) are high-pass filtered with a 0.16 Hz cut-off, pre-amplified, and low-pass filtered at an 83 Hz cut-off. The analog signals are then digitized at 2048 Hz. The digitized signal is filtered using a 5th-order sinc notch filter (50–60 Hz), low-pass filtered, and down-sampled to 128 Hz. The effective bandwidth measured is 0.16–43 Hz. [2]

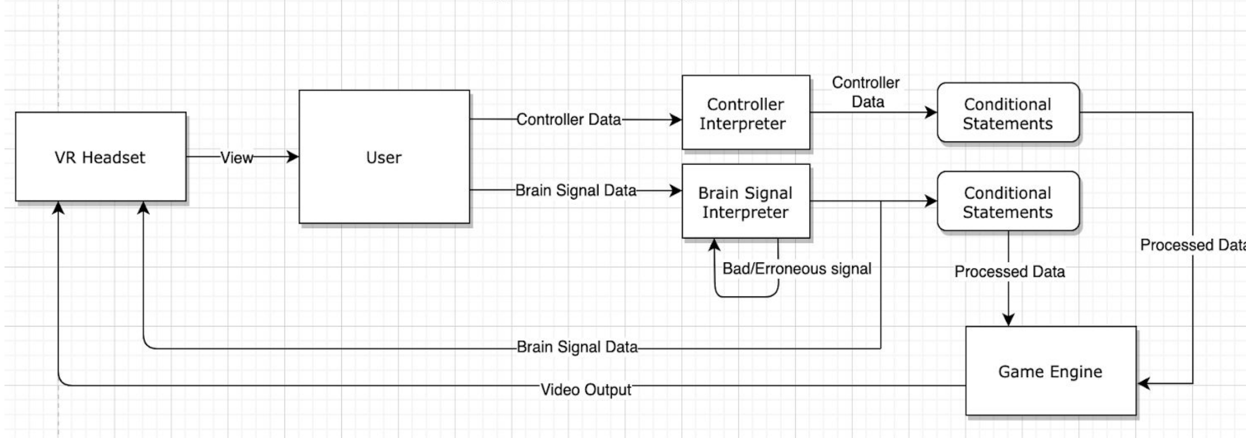
Even though the EEG is a critical tool to this project, it is still important to acknowledge that it suffers from a few limitations that hinder its effective analysis and processing. An EEG has a low signal-to-noise ratio (SNR). The brain activity measured can be often buried under multiple sources of environmental, physiological, and activity-specific noise of similar or greater amplitudes. The EPOC+ uses various filtering and noise reduction techniques to minimize the impact of these noise sources and extract true brain activity from the recorded signals [10].

A problem that may be encountered is that the EEG is a non-stationary signal, and its statistics vary across time. As a result, a characteristic trained on a temporally-limited amount of user data might generalize poorly to data recorded at a different time on the same individual. This is important for instances where the EGG is working with limited amounts of data [10].

Detailed Design

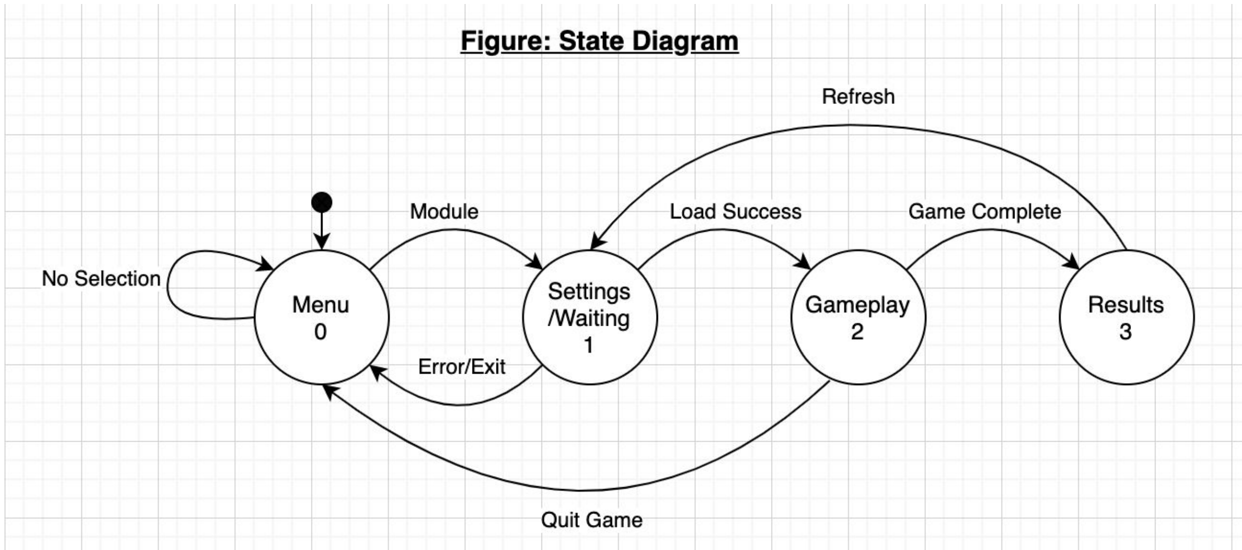
Data Flow Diagram

Figure: Data Flow Diagram



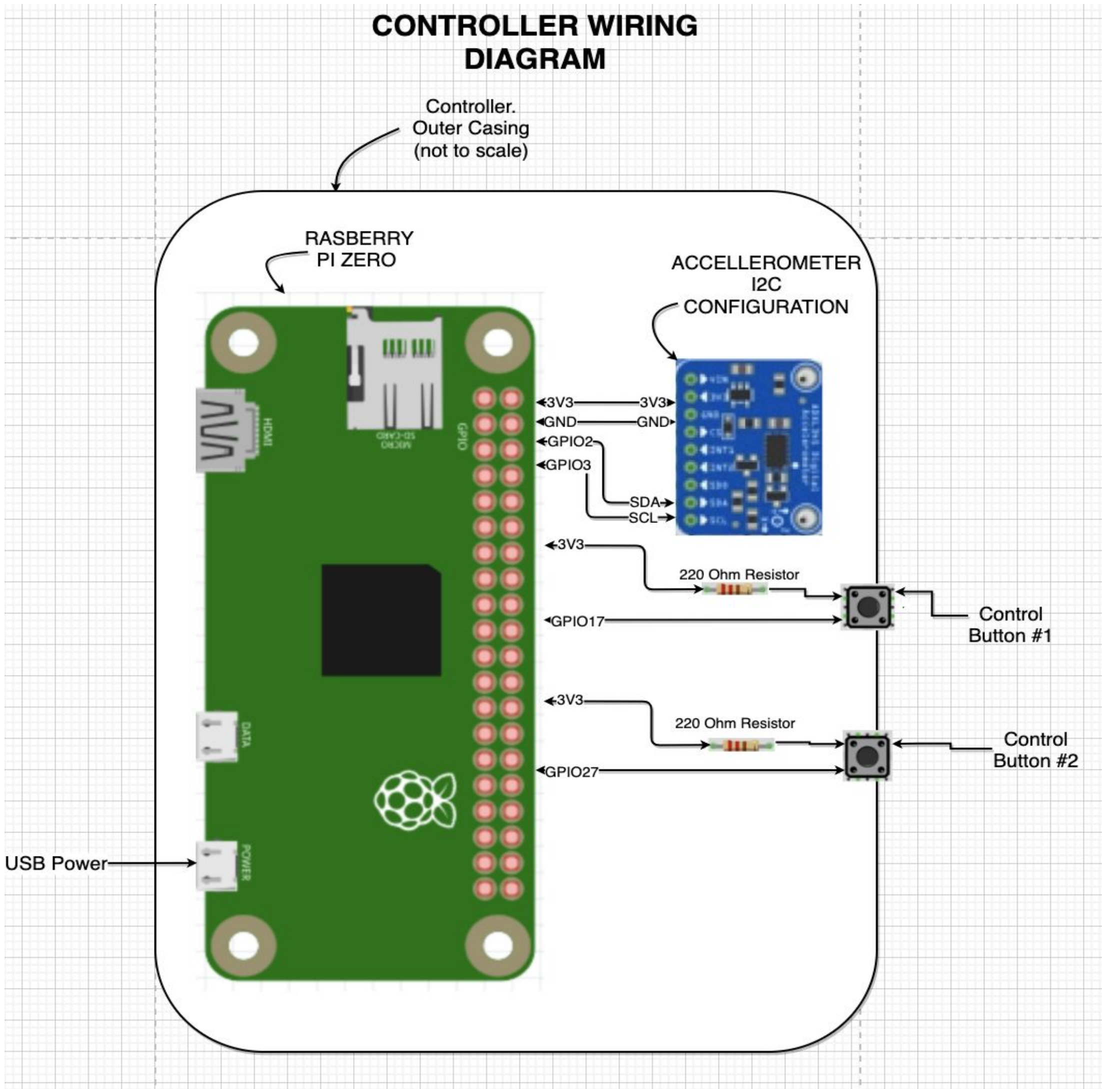
The data flow diagram above depicts how the data will move and be analyzed throughout our project. The EPOC+ will gather brain signal data and input it into a program that will analyze the data and allow us to use the data to modify how the module progresses. While this happens, the user will also be using the controller. The data extracted from the controller will then be interpreted by a different program that will allow the user to move within the virtual environment. These two things together will then be analyzed by the game engine to provide an accurate video output to the user's headset.

Data Flow Diagram



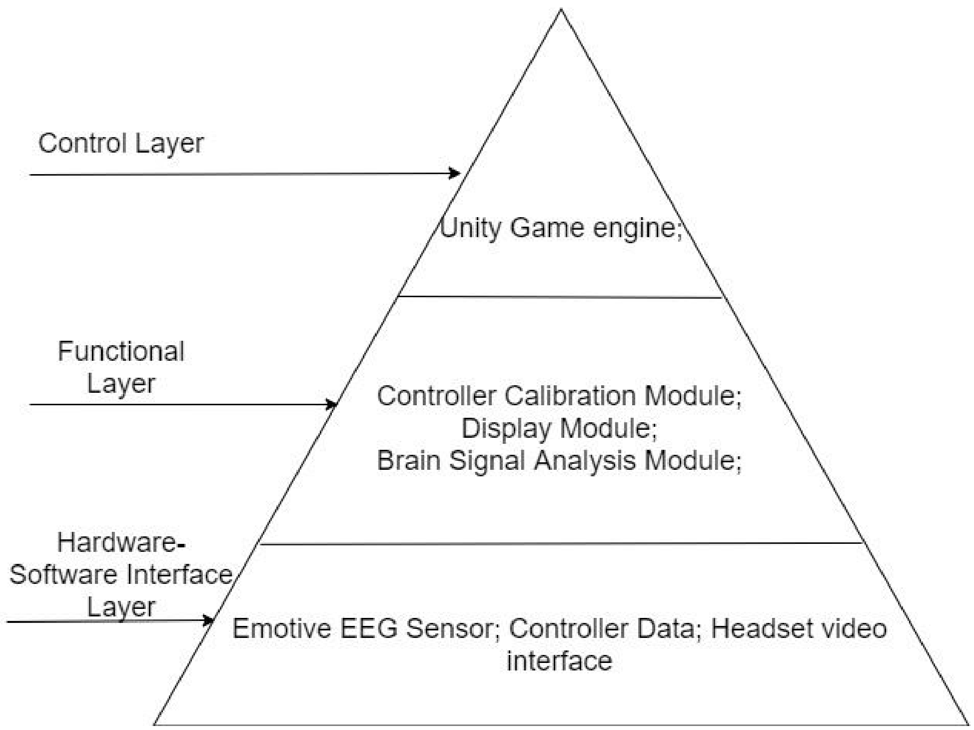
The state diagram above depicts exactly how the software will make decisions within our modules. It will constantly loop back to itself until a decision is made while in the main menu. After choosing a module, the module will then load the "gameplay" for the module. This will be where the module reads brain signals and where the user interfaces with the module itself. While in the module, the user can quit back to the main menu, or complete the game to see the results. From there, the user can either refresh to play the game again or quit to the main menu.

Controller Schematics



The wiring diagram above describes how the handheld controllers will be made. The controller will contain a raspberry pi zero that will be powered with a usb cable and interface with the computer using a bluetooth connection. There is also an accelerometer interfacing with the raspberry pi zero using the GPIO 2 and 3 pins. This accelerometer gathers the movement data of the controller. There are also two simple push buttons which interface with the pi zero using GPIO pins 17 and 27.

Software Structure



As Hardware, we have the Epoc+ sensors, accelerometer controllers, and the virtual reality headset. To bridge them to software, we have the controller calibration module, display module, and the brain signal analysis module. All of these will lead into our control layer, the unity game engine.

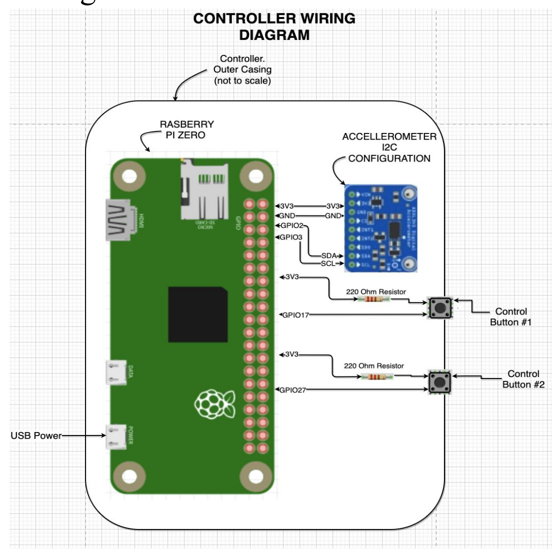
Prototyping progress report

Task #1) Controller Modeling

- Objective: Create a CAD model for a 3D controller

3D Model:

Wiring Schematic:

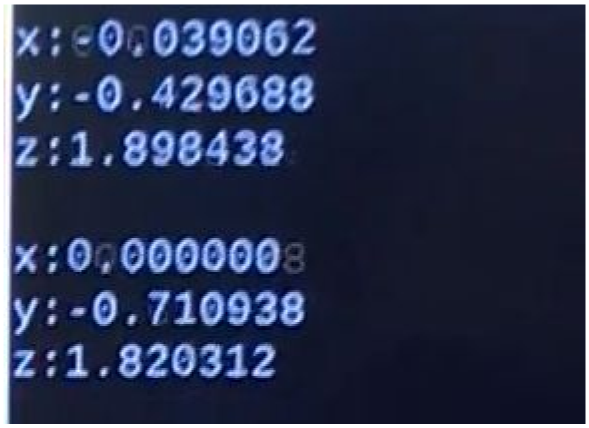


- Controller Information:
  - Two Buttons
    - Action
    - Settings Menu
  - Raspberry Pi Zero
    - Sized to fit within casing
    - Ability to communicate with environment via bluetooth
  - ADXL345
    - Maps information on x, y, and z planes
  - Dimensions: 105x45x22 mm
- Conclusion:
  - A model for a controller can be designed to fit within a single handed controller given the components are small enough
  - A controller design can be created simple enough for use by anyone
    - This still requires calibration and mapping of the ADXL
  - A single cord can connect the controller to the computer due to the capabilities of the Raspberry Pi Zero
  - Mounting the accelerometer in a centralized location of the controller will allow for the most accurate tilt measurement

<u>Task #2) Mapping the ADXL345</u>

- Objective: Create a program that can interpret accelerometer data
  - Getting uniform values from the accelerometer (defined range)
  - Calibration of sensor to understand tilt behavioral curve
- Terminal Output:
  - Stores values for x, y, and z plane

        - X and Y display values from -2 to 2
        - Z displays values from 0 to 4
    - Communication with the accelerometer follows I2C protocol

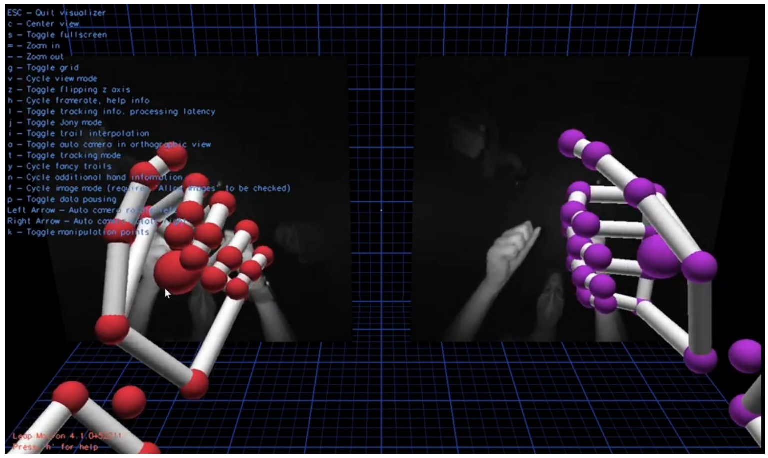


Output Readings from Created Program

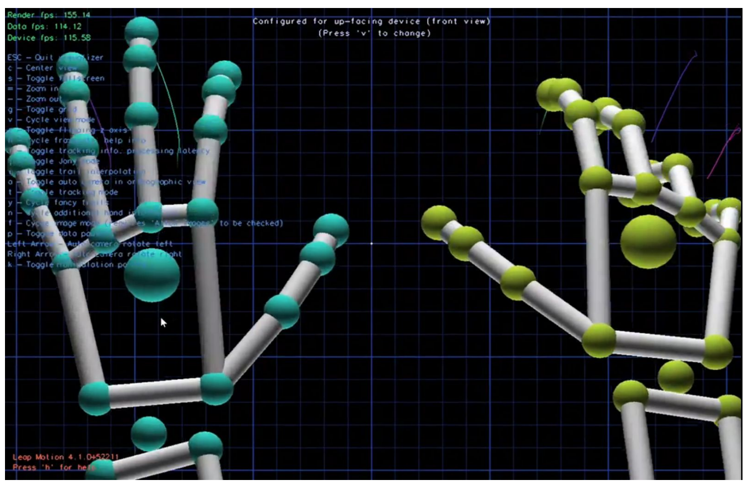
- Conclusion:
    - Understanding the values from the program is important, but it will be necessary to calibrate the sensor to better understand the angle vs program output
    - After calibration of the sensor, this information should be able to map accelerometer movement in our environment
    - It may only be necessary to calculate the values of X and Y, as determining depth into the environment may not be necessary for implementation

<u>Task #3) Leap Motion Experimentation</u>

- Objective: Understand capabilities of Leap Motion
    - Determine possible benefits to using over the controller
    - Determine the capabilities for hand recognition from different angles
- Leap Motion Viewpoint on Table:



- Leap Motion Head Mounted

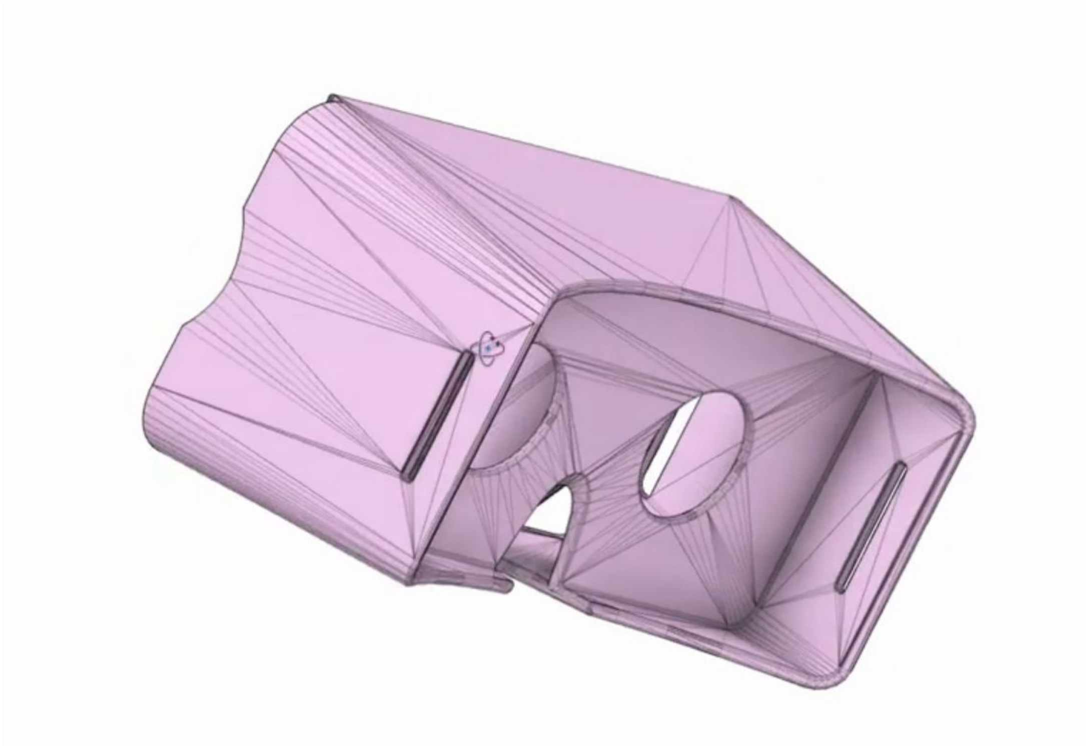


- Conclusions
    - Module in unity that allows for Leap Motion interaction with created environment
        - Still need to do testing with this to see capabilities inside the created environment
    - Leap Motions adaptability allows for diverse possibilities for implementation in our design
    - The software maps each hand by joint. This allows for hands shapes to be determined through mapping and multiple contract points when being used for interacting with objects.

<u>Task #4) Creation of Headset 3D Model</u>

- Objective: Create a 3D model for a headset that will allow for use without interfering with EMOTIV EPOC+ sensor placement
    - Look into possibility of mounting Leap Motion on front of headset
- Current Design:

- Design Components:
    - Main Housing
    - Front Panels
    - Lens Holders
    - LCD Clip



Prototype for 3D Model of Headset

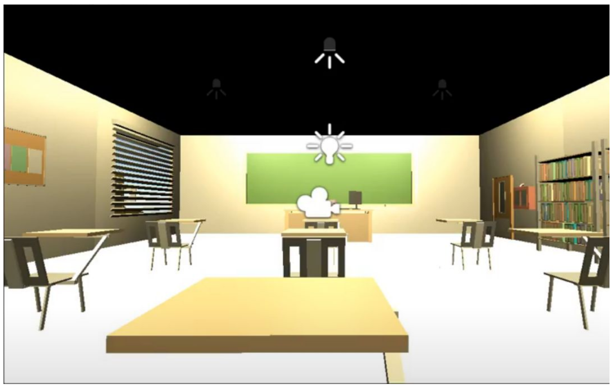
- Conclusions:
    - Although the group is limited with experience regarding 3D headset modeling, this seems well within the range of our capabilities
    - Casing was never the issue with sensor placement, but custom design allows for implementation with leap motion if that route is chosen
    - The biggest issues with VR headset interfering with EPOC+ sensor placement stem from the parts of the headset that aren't 3D modeled.
        - This includes the straps that will need to sit on the head. These straps cannot take up a lot of space, but they still need to be strong enough to keep the headset stable.
    - Designing/Finding lenses that fit with a custom model may be difficult.

<u>Task #5) Creation of Unity Virtual Environment</u>

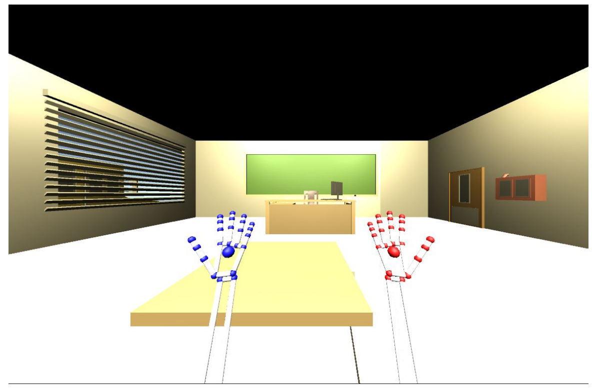
- Objective: Familiarize ourselves with the capabilities of Unity Development Software
- Test Design:
    - Implemented the basics of unity design for creation of a classroom environment

    - Used lighting sources to provide an ample experience in scene and game view
    - Implemented prefabs for classroom items
        - Several possibilities for use of prefabs
        - Custom objects can also be created as desired

Scene View:



Game View:

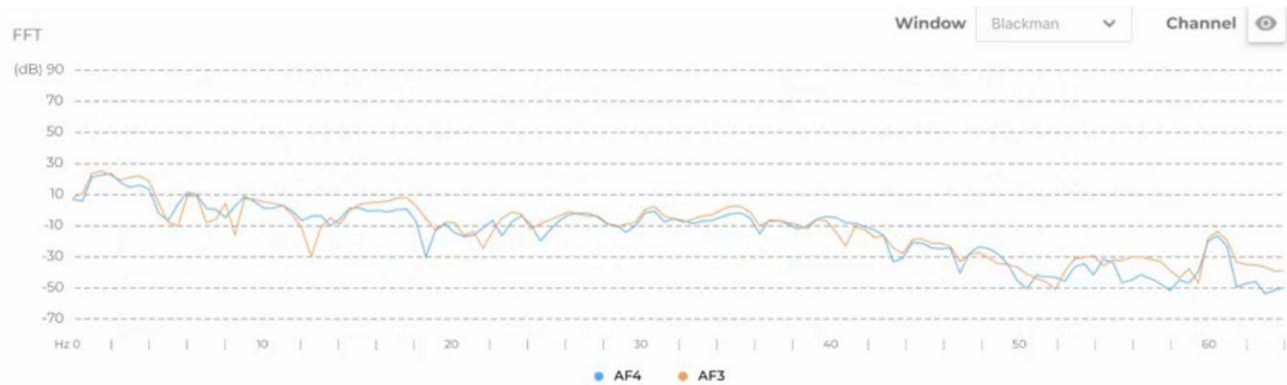


- Conclusions:
    - Using different scenes allows us to create multiple modules for interactive learning
    - This design for the classroom has capabilities as a main menu
        - Using a text mesh can create dialogue on the chalkboard than can be used to select modules
    - Environment design is relatively straight forward. Creation of custom objects and displaying proper lighting conditions provide the biggest issues with development
    - Leap Motion POV allows for easy implementation with Leap Motion software. The camera angle shown in the game view above will be loaded with a virtual set of hands mapped to the Leap Motion.

<u>Task #6) Epoc+ Testing and Data Gathering with Emotivepro</u>

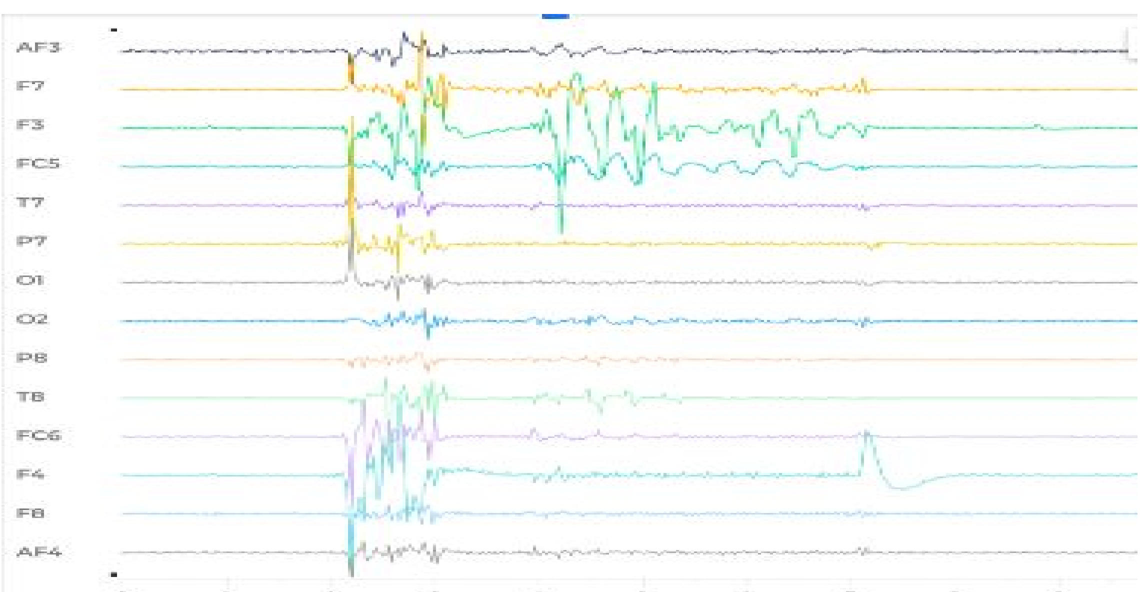
- Objective: Obtain brain signal data while conducting various tasks
    - Understand how to position EMOTIV EPOC+ sensors
    - Familiarize ourselves with the capabilities of EMOTIV software

        ■ Experiment with extracting raw data
- Testing:
    - Playing a game
        - Provides example wave patterns for a relaxed and concentrated state of mind
    - Reading/Solving Math Problems
        - Provides example wave patterns for concentration and potential stress
    - Reading with Distractions
        - Provides example wave patterns for losing concentration when focussing on a task



AF3 and AF4 Sensors vs Time. Taken while playing a game.

- Emotive Pro Software:
    - Gives access to numerical data instead of only graphical data
    - Can give data from every sensor at one time
        - Allows for calculations of average and standard deviation of signals over the duration of the scan.



Brain Signal Waveforms from Every Sensor

title: Focu	start timest	stop timest	headset typ	headset seri	headset firn	subject nam	channels:1(	sampling ra	samples:21	version:2.0						
Timestam	EEG.Counte	EEG.Interpo	EEG.AF3	EEG.F7	EEG.F3	EEG.FC5	EEG.T7	EEG.P7	EEG.O1	EEG.O2	EEG.P8	EEG.T8	EEG.FC6	EEG.F4	EEG.F8	EEG.AF4
2.6E+09	87	0	4155	4150.256	4184.615	4348.077	4171.539	4170.256	4175.256	4184.487	4189.359	4189.103	4170.256	4188.205	4202.051	4183.59
2.6E+09	88	0	4150.385	4142.308	4179.231	4349.231	4168.461	4170	4167.436	4180.641	4179.872	4182.308	4166.539	4180.385	4193.59	4182.564
2.6E+09	89	0	4150.128	4143.59	4183.333	4350.128	4167.692	4169.231	4171.154	4180.513	4179.615	4182.051	4165.385	4181.539	4196.026	4183.846
2.6E+09	90	0	4157.436	4154.615	4189.231	4354.359	4177.82	4172.949	4184.744	4186.539	4196.41	4197.949	4170.897	4197.308	4208.333	4190.385
2.6E+09	91	0	4158.718	4154.487	4183.333	4351.923	4178.59	4175.513	4178.974	4187.564	4193.461	4198.461	4171.795	4195.256	4204.359	4188.846
2.6E+09	92	0	4151.923	4147.436	4179.615	4347.564	4167.18	4173.333	4169.872	4180.897	4177.564	4183.205	4165.897	4177.82	4194.487	4177.308
2.6E+09	93	0	4150.513	4151.923	4182.308	4350	4171.923	4169.487	4180.769	4180.128	4182.692	4182.564	4167.18	4177.436	4197.436	4177.82
2.6E+09	94	0	4153.077	4155.256	4180.641	4347.051	4180.385	4172.18	4191.795	4183.077	4186.667	4186.154	4167.18	4183.461	4193.59	4183.461
2.6E+09	95	0	4153.205	4151.41	4182.564	4339.487	4175.256	4174.103	4177.949	4181.539	4177.564	4180.513	4164.103	4182.18	4184.487	4178.59
2.6E+09	96	0	4159.359	4154.103	4190.385	4342.051	4176.923	4166.667	4159.231	4173.333	4181.539	4182.564	4168.974	4186.026	4194.231	4180.128
2.6E+09	97	0	4163.59	4160.513	4185.769	4341.41	4182.692	4162.18	4160.128	4168.205	4187.308	4188.461	4173.846	4190.256	4205.128	4190.128
2.6E+09	98	0	4156.41	4157.692	4177.949	4327.308	4179.872	4169.487	4169.487	4177.051	4180.385	4187.18	4170.513	4185.897	4201.923	4190.641
2.6E+09	99	0	4151.026	4152.051	4179.487	4320.256	4177.949	4174.872	4168.846	4182.692	4176.41	4185.256	4167.564	4184.359	4196.154	4181.154
2.6E+09	100	0	4151.795	4154.103	4176.923	4314.231	4172.436	4165.385	4157.18	4173.077	4174.487	4182.949	4169.744	4182.051	4192.051	4176.923
2.6E+09	101	0	4150.641	4154.231	4173.077	4297.82	4164.744	4161.026	4152.18	4166.026	4167.692	4181.026	4167.051	4177.436	4188.718	4180
2.6E+09	102	0	4151.41	4153.333	4177.308	4291.795	4173.974	4171.154	4162.949	4170.256	4170.513	4184.487	4165.256	4179.744	4192.564	4184.744
2.6E+09	103	0	4162.692	4161.923	4181.795	4296.282	4182.564	4172.564	4173.718	4171.539	4183.205	4188.718	4170.385	4190.385	4201.154	4188.974
2.6E+09	104	0	4171.539	4167.949	4181.795	4289.359	4176.667	4168.59	4175.641	4173.461	4187.436	4189.359	4174.231	4194.744	4201.923	4191.667
2.6E+09	105	0	4170.513	4166.154	4183.846	4278.974	4175.897	4171.154	4175.513	4181.795	4186.795	4192.949	4175.897	4196.026	4199.615	4195.641
2.6E+09	106	0	4167.692	4161.923	4183.461	4275.769	4176.154	4167.564	4173.59	4184.103	4187.82	4198.846	4175.769	4197.692	4201.41	4192.692
2.6E+09	107	0	4167.82	4159.487	4177.82	4267.18	4171.026	4163.59	4169.744	4177.82	4187.692	4198.333	4172.436	4190.385	4201.154	4187.564
2.6E+09	108	0	4169.615	4160.385	4180.256	4261.539	4175.385	4171.667	4174.359	4174.872	4186.923	4196.282	4170.769	4182.436	4195.513	4190.769
2.6E+09	109	0	4169.872	4164.744	4187.564	4263.205	4181.923	4176.795	4176.154	4180.256	4184.615	4194.359	4173.461	4186.026	4193.846	4194.872
2.6E+09	110	0	4169.103	4162.564	4185.641	4255.641	4174.615	4173.077	4169.231	4180.256	4181.539	4191.026	4173.59	4191.154	4198.718	4190.128
2.6E+09	111	0	4169.231	4160.256	4180	4247.692	4172.308	4172.564	4176.282	4179.231	4183.846	4190.513	4170.897	4187.82	4200.769	4189.231
2.6E+09	112	0	4165.897	4160.641	4179.487	4247.308	4172.564	4172.436	4182.436	4180.128	4187.564	4188.59	4171.795	4185.128	4194.487	4190.641
2.6E+09	113	0	4161.539	4156.667	4176.667	4243.59	4167.051	4169.103	4170.769	4177.308	4183.846	4182.949	4171.539	4186.154	4190.256	4184.359
2.6E+09	114	0	4165.769	4158.59	4178.846	4243.205	4174.615	4169.103	4164.231	4175.385	4183.461	4183.461	4170.513	4186.923	4192.82	4184.231
2.6E+09	115	0	4173.333	4166.282	4187.949	4248.718	4187.18	4170.513	4170.513	4176.795	4187.18	4187.436	4169.103	4190.385	4191.539	4191.41
2.6E+09	116	0	4171.667	4163.333	4188.461	4248.59	4184.103	4169.359	4173.333	4172.436	4180.641	4181.282	4168.205	4191.795	4186.539	4191.41
2.6E+09	117	0	4168.718	4155.769	4185.769	4246.154	4178.846	4168.974	4169.744	4168.077	4173.205	4177.436	4168.974	4190	4184.231	4187.18
2.6E+09	118	0	4169.359	4157.308	4186.923	4245.256	4178.205	4174.103	4171.667	4178.718	4178.846	4183.461	4169.487	4189.103	4184.487	4189.231
2.6E+09	119	0	4168.59	4159.744	4182.051	4244.103	4175	4176.795	4172.18	4186.026	4190	4187.308	4169.103	4189.359	4184.487	4188.846
	Working Data															
		EEG.AF3	EEG.F7	EEG.F3	EEG.FC5	EEG.T7	EEG.P7	EEG.O1	EEG.O2	EEG.P8	EEG.T8	EEG.FC6	EEG.F4	EEG.F8	EEG.AF4	
	Average of Data	4186.1939	4173.60065	4174.29136	4188.92033	4173.91447	4167.03363	4171.45904	4169.63611	4171.97037	4171.47898	4163.84031	4173.68632	4163.90743	4172.44125	
	Std. Dev	32.7370644	46.3543029	10.6259435	107.271927	12.7559304	13.0468561	15.6983844	21.4624505	28.26517	41.7259209	44.472743	31.0268126	98.9966371	28.3951943	

Corresponding Waveform Numerical Data from Test Above

- Conclusions:
  - Sensor is very specific and requires a good amount of saline solution for proper connections
  - Software allows viewing of all channels at once. It also allows viewing of individual channels for specific sensor monitoring
  - Having pictures of the brainwave graphs can be useful for monitoring from an outside perspective. However, the numerical data will be the most useful for implementation in learning module software.

Testing plan

- **Test #1 (Get Brainwave Information from EMOTIV EPOC+)**
  - Goal: Understand sensor placement and brain wave patterns from different stimuli
  - System Components: EMOTIV EPOC+, EMOTIV PRO software
  - Testing Process:
    - Configure the EPOC+ with sensor placements in the correct place. Proper placement is demonstrated through green indication in EMOTIV software.
    - Performance of tasks related to situations students will be subjected to when using our software
    - Data collection from EPOC+ in real time alongside screen recording of desired task
  - Data Processing and Visualization: Raw data will be displayed in graphical and numerical forms. This allows for the calculation of wave amplitudes at specific

points in the video. Also, graphical representation allows for demonstration of patterns.
  - Evaluation: Focus on graph characteristics that show differences from steady state wave patterns, as well as differences in patterns in unique tasks.

- **Test #2 (Evaluation of Controller Capabilities):**
  - Goal: Understand how our created controller can be used to interact with a virtual environment.
  - System Components: Raspberry Pi, ADXL345, Push Buttons
  - Testing Process:
    - Push button activated at different times. Observe response from Raspberry Pi.
    - Create a program that takes accelerometer data and stores in into Raspberry Pi registers
    - Map obtained data into a designated range
  - Data Processing and Visualization: Data will be observed within the terminal. A button press should show the programmed response on screen, while the ADXL should output mapped positional data at designated frequency.
  - Evaluation: The main focus for this testing is understanding the ADXL data. Calibrating values to degrees of tilt will allow for a cursor to be moved across the screen.
  - Note: With this information, a cursor can be moved at one set speed when the threshold value of the accelerometer passes a specific mapped value. Cursor acceleration can also be implemented using different angular ranges

- **Test #3 (Understand Capabilities of Leap Motion Controller)**
  - Goal: Understand capabilities of Leap Motion
  - System Components: Leap Motion, PC, Leap Motion compatible software
  - Testing Process:
    - Play premade games to understand ability to distinguish premade hand signals
    - Enter premade environments to understand virtual hand collision box
  - Data Collection: No numerical data is obtained from this test. This experiments allows us to understand which controller may be best suited for interaction with virtual environment
  - Evaluation:
    - Focus on mapping of joints that Leap Motion provides
    - Understand which hand signals can be used. This can allow for item selection and options menu to be mapped for specific hand shapes

        - Interaction with the virtual environment allows the user to understand the capability of Leap Motion. When creating our program, we can model human interactions based on this information,

- **<u>Test #4 (Understand Capabilities of Unity Software)</u>**
    - <u>Goal</u>: Have group members learn the basics of Unity and understand possibilities for environment creation with this software
    - <u>System Components</u>: PC, Unity Software
    - <u>Testing Process</u>:
        - Create a closed classroom setting. Requires implementation of shape creation and custom lighting
        - Model preset shapes into items. Save shapes as prefabs for use across entire project
            - Experimentation with texture creation to add color and features to created shapes
        - Implementation of prefabs created by other users. Learn to implement premade objects into the environment
        - Implement object motion and Unity physics
    - <u>Evaluation</u>: Upon completion of this experiment, the user should understand the basics of scene creation in Unity
    - <u>Note</u>: Understanding the capabilities of Unity will allow for realistic expectations when creating classroom models. Understanding and learning software at this point in the project will allow for efficient environment creation when implementing our learning modules.

- **<u>Test 5 (Implementation of Controller and Environment Together)</u>**
    - <u>Goal</u>: Allow for our chosen controller option to interact with a created unity environment
    - <u>System Components</u>: Leap Motion, Custom Controller, Unity, PC
    - <u>Testing Process</u>:
        - Connect the controller into the virtual environment
        - Use controller to interact with different items and trigger in game events
        - Open settings menu at any point of during environmental interaction
    - <u>Evaluation</u>: The controller should be able to control every aspect within the virtual environment. This should allow for the user to complete the module with no inputs besides the controller

List and description of tasks (for ECE 493)

List of Tasks and subtasks for 493 including allocation of responsibility

1. **3D designing and begin printing our VR headset housing.**
   i. 3D CAD Model of Headset - **Brendan/Yumna** (Done)
   ii. Begin 3D Printing Headset - **Brendan/Ethan** (In Progress)

2. **Controller Prototyping and Assembly**
   i. Buy Parts - **Team** (In Progress)
   ii. 3D CAD Model of controller. - **Brendan** (Done)
   iii. Finish code for Raspberry pi 0+. - **Zayne** (In Progress)

iv. Begin wiring hardware components and check for quality control. - **Yumna**

vi. Continue the use of leap motion (alternative controller) and integration into the environment - **Jacob** (In Progress)

3. **Continue writing software for our VR game.**
   i. Continue use of unity to create our game. **-Zayne/Ethan/Jacob**

   ii. Find a way to seamlessly incorporate the brain signal data into the game with minimal latency. **Brendan/Yumna/Jacob**

   ➔ **These tasks <u>will</u> be completed in parallel.**
4. **Begin testing Hardware - Team**
5. **Begin testing Software - Team**
6. **Test hardware/software compatibility - Team**

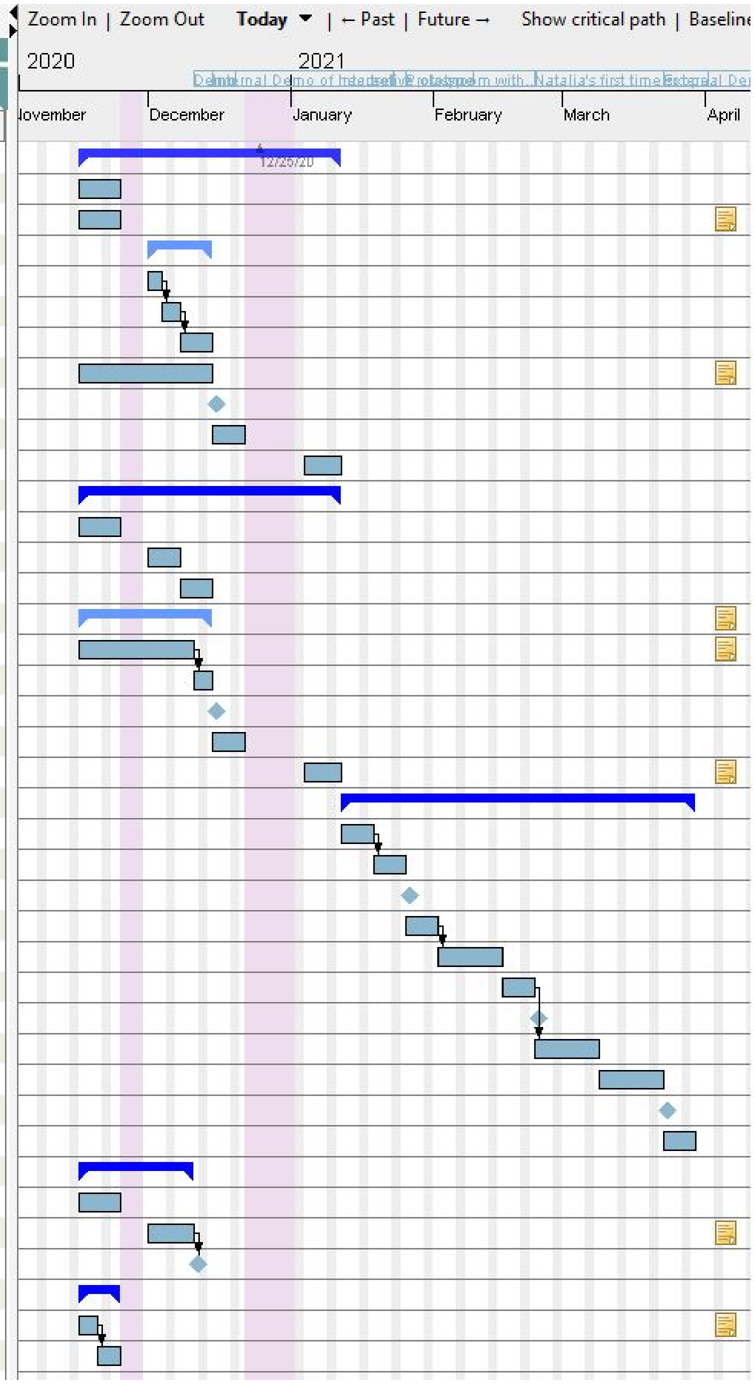
****All Tasks allocated are subject to change and are not final****

<u>Schedule and milestones</u>

Tasks

Name	Begin date	End date
Software	11/16/20	1/11/21
Have an interactive environment running	11/16/20	11/24/20
Controller Testing *Into a random environment at first*	11/16/20	11/24/20
Interactive classroom environment	12/1/20	12/14/20
Interactive classroom	12/1/20	12/3/20
Objects for class	12/4/20	12/7/20
Classroom Modules Loaded	12/8/20	12/14/20
Implement Controller with interactive *Interactive environnment -> using controllers as a goal* *interactive classroom -> using controllers as a must*	11/16/20	12/17/20
Internal Demo of interactive classroom with controller	12/15/20	12/15/20
Visualize and act on brain signal	12/15/20	12/21/20
Small Debug phase	1/4/21	1/11/21
Hardware	11/16/20	1/11/21
3D print of headset	11/16/20	11/24/20
set up headset	12/1/20	12/7/20
Test Headset On sample VR game	12/8/20	12/14/20
Brain Signal Data *Have conclusive evidence on each node*	11/16/20	12/17/20
Sample Data *Please don't stress to work over break*	11/16/20	12/10/20
Decypher nodes	12/11/20	12/17/20
Internal Demo of headset	12/15/20	12/15/20
Secondary Controller 3d print and circuit	12/15/20	12/21/20
Controller testing and calibration with I2C *Calibration meaning the hands move accordingly with the body*	1/4/21	1/11/21
Integration of software and hardware	1/12/21	3/29/21
Initial meet up - piecing things together	1/12/21	1/18/21
Experimental Phase 1	1/19/21	1/25/21
Prototype	1/26/21	1/26/21
Experimental Phase 2	1/26/21	2/1/21
Debug problems	2/2/21	2/15/21
Small Presentation to Natalia	2/16/21	2/22/21
Natalia's first time scope	2/23/21	2/23/21
Accommodate to Natalia's changes	2/23/21	3/8/21
External Demo	3/9/21	3/22/21
External Demo!! Almost there	3/23/21	3/23/21
Tidy Up	3/23/21	3/29/21
Low latency communication of EEG data	11/16/20	12/10/20
Find efficient was of communication	11/16/20	11/24/20
Send through internet protocols *Host a local server on your computer and ping it, asking for the message.* *Find the Rount trip time and print the message*	12/1/20	12/10/20
Demo	12/11/20	12/11/20
Buying	11/16/20	11/24/20
Initial buy *Talk with team to see what is 100% needed*	11/16/20	11/19/20
Checker Buy	11/20/20	11/24/20

Name	Begin date	End date
Software	11/16/20	1/11/21
Have an inte...	11/16/20	11/24/20
Controller T...	11/16/20	11/24/20
Interactive c...	12/1/20	12/14/20
Interacti...	12/1/20	12/3/20
Objects ...	12/4/20	12/7/20
Classroo...	12/8/20	12/14/20
Implement ...	11/16/20	12/14/20
Internal De...	12/15/20	12/15/20
Visualize an...	12/15/20	12/21/20
Small Debu...	1/4/21	1/11/21
Hardware	11/16/20	1/11/21
3D print of h...	11/16/20	11/24/20
set up heads...	12/1/20	12/7/20
Test Headse...	12/8/20	12/14/20
Brain Signal ...	11/16/20	12/14/20
Sample ...	11/16/20	12/10/20
Decyphe...	12/11/20	12/14/20
Internal De...	12/15/20	12/15/20
Secondary C...	12/15/20	12/21/20
Controller te...	1/4/21	1/11/21
Integration of s...	1/12/21	3/29/21
Initial meet ...	1/12/21	1/18/21
Experimenta...	1/19/21	1/25/21
Prototype	1/26/21	1/26/21
Experimenta...	1/26/21	2/1/21
Debug probl...	2/2/21	2/15/21
Small Prese...	2/16/21	2/22/21
Natalia's firs...	2/23/21	2/23/21
Accommod...	2/23/21	3/8/21
External De...	3/9/21	3/22/21
External De...	3/23/21	3/23/21
Tidy Up	3/23/21	3/29/21
Low latency co...	11/16/20	12/10/20
Find efficien...	11/16/20	11/24/20
Send throug...	12/1/20	12/10/20
Demo	12/11/20	12/11/20
Buying	11/16/20	11/24/20
Initial buy	11/16/20	11/19/20
Checker Buy	11/20/20	11/24/20



Bibliography

[1] K. Mukhtar *et al*, "Advantages, Limitations and Recommendations for online learning during COVID-19 pandemic era," *Pakistan Journal of Medical Sciences Quarterly,* vol. 36, 2020. DOI: 10.12669/pjms.36.COVID19-S4.2785

[2] P. A.Abhang, B. W.Gawali, S. C.Mehrotra, "Chapter 2 - Technological Basics of EEG Recording and Operation of Apparatus," in Introduction to EEG- and Speech-Based Emotion Recognition, P. A. Abhang, B. W. Gawali, and S. C. Mehrotra, Eds. Amsterdam: Academic Press, 2016, pp. 19-50. DOI: https://doi.org/10.1016/B978-0-12-804490-2.00002-6

[3] Z. Scavotto, N. Peixoto, "Video games and brain wave frequencies," 2020. [Online]. Available: http://gamingwaves.onmason.com/

[4] Brainworks, "What Are Brain Waves?," 2020. [Online] Available: https://brainworksneurotherapy.com/what-are-brainwaves

[5] Emotiv, "How Does an EEG Work?," 2020. [Online] Available: https://www.emotiv.com/eeg-guide/

[6] Suneth Pathirana, M'd Gapar M'd Johar, David Asirvatham, "Applicability of multi-agent systems for electroencephalographic data classification," *P.C.S.*, vol. 152, pg. 36-43, 2019. 10.1016/j.procs.2019.05.024

[7] Dartmouth College, Reading Brains Lab: THE ERP Technique. "Reading brains lab: the ERP technique" [Online]. Accessed: 05-Nov-2020. Available: https://www.dartmouth.edu/~readingbrains/ResearchFiles/ERPTechnique.html

[8] N. Badcock, P. Mousikou, Y. Mahajan, P. De Lissa, J. Thie, G. McArthur, . . . KE, S. "Validation of the Emotiv EPOC® EEG gaming system for measuring research quality auditory ERPs," P.J., Feb. 2013, 10.7717/peerj.38

[9] Mark Pedley, "Tilt sensing using a three-axis accelerometer," NXP Semicon. N.V, AN3461 Rev. 6 Mar. 2013. [Online] Available: https://www.nxp.com/files-static/sensors/doc/app_note/AN3461.pdf

[10] Yannick Roy, Hubert Banville, Isabela Albuquerque, Alexandre Gramfort, Tiago H Falk, Jocelyn Faubert. "Deep learning-based electroencephalography analysis: a systematic review," J. Neural Eng., vol 16, pg.5, 2019, 10.1088/1741-2552/ab260c