Thomas Jefferson High School for Science and Technology Neuroscience Research Lab

Fight or Flight Instinct in Virtual Reality Simulation versus Non-Immersed Simulation

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November 9th, 2016

Abstract

Virtual Reality is the newest addition in the entertainment industry. It provides a level of immersion never achieved before, by immersing the user's visual sense in the simulation through gyroscopic and spatial measurement tools contained within the device. To measure the effectiveness of this extra immersion, horror simulations on both a computer screen and the Gear VR was used as a stimulus and Mu and Beta waves strengths were measured through a 32 channel EEG headset measuring data at 256 Hz in the frontal lobe, motor cortex, and the occipital lobe. Horror simulations were specifically used because fear will produce a stronger signal for the EEG headset to read compared to emotions such as compassion or anger. Fear is also an easier signal to stimulate compared to other emotions. The Virtual reality headset is expected to create a significantly stronger Beta wave and a significantly weaker Mu rhythm than the signals from the screen simulation because Beta wave activity is associated with increased activity and Mu rhythms are associated with a calm mind. OpenViBE was used to collect the data and run a Spectral Analysis on the data. Despite difficulty with setting up the virtual reality system, the Gear VR used with the Samsung Galaxy S6 Edge, strong data was collected with the Virtual Reality horror simulation, *Sisters*, resulting in eight times stronger beta waves signal strength at the time of a jump scare. Sadly, the Mu rhythm data and all of the screen simulation data was either corrupted or not collected using the right method resulting in a lack of data to complete the study. In the future, more time should be partitioned for data collection and more participants should be used, so that the data is more varied and stable.

Introduction

The fight or flight instinct is a response that transcends time, is still imbedded into the core of our brain, and determines the actions one take when faced by danger. It is a naturally occurring defense system that increases blood pressure, releases hormones, and takes control of the body.

This instinct is often triggered by emotions such as fear or sadness, and is enhanced by self-awareness. The ability to fear is genetically transferred; however, only through experience do animals learn to fear certain objects, also called fear conditioning. The brains defense mechanism recognizes a threat by a unique signal and an associated source of pain. Once learnt the brain recognizes the signals and responds without having to learn the signal again. The defense mechanism can also be weakened by signaling a threat but not delivering any pain but will quickly be relearned by experiencing pain. The defense mechanism is also responsible for other behaviors and instincts such as aversion of the signal completely.

In the brain, fear conditioning involved the right amygdala, the region of the brain associated with fear and anxiety, and this region can be observed to assess the amount of fear the recipient experiences. Many fear disorders see an increase in activity in the amygdala such as post-traumatic stress disorder (PTSD), phobia, depression, and schizophrenia. By studying fear conditioning we can shed light on these disorders (Debiec & LeDoux, 807-815). Fear conditioning, often performed on lab rats for experimentation, is commonly utilized in horror videogames to repeatedly scare players at a consistently high level. By repeatedly scaring after a signal and giving an empty signal the game is able to keep the events unexpected and the fear high. In addition, during an emotional experience, such as a fearful one, the brain loses the function to analytically respond to a situation (Goslin & Morie, 97). However, the emotional response dulls as the experience becomes increasingly immersive. This was tested by testing the research participants' response to emotional stimuli. Participants who played more immersive videogames were less sensitive to pain and also responded less emotionally to pictures of people in displeasure that participant who spent less time playing videogames (Loughnan & Weger).

Virtual Reality presents certain benefits for the future of the medical industry, not just in the entertainment industry. This technology has the capability to help improve the lives of paraplegics, disabled, and people with phobias, through different simulations and human-computer interface software that can help make the player feel more immersed. This study of the difference between Virtual Reality and Non-Immersive Simulation is a study into how effective this technology is, and provides an idea on how effective it will be as a contribution to the health industry.

Background

Currently, because more immersive simulation technologies, Virtual reality (VR), exist such as the Google Cardboard, Oculus Rift, PlayStation VR, HoloLens, the level of immersion of entertainment systems, and especially videogames, have drastically increased from the previous generation of non-immersive technology, such as television and computer screen hosted simulations. In addition, the graphics levels of these videogames have to also be considered as increased immersion because increased graphics have given developers the utility to spur stronger emotions, through vivid details and crisp images, in their user base. Virtual and Augmented reality have an upper hand in spurring emotions because they have the ability to take data of the player’s involuntary movement and give another dimension of immersion to the simulation developers.

The increased levels of immersion have been played with through movies like The Matrix, and its implications, whether good or evil, have been debated (Virtual Reality, 1992). By taking a step back from the in depth analysis of the future of virtual reality, the question arises, however, whether virtual reality and the extra “level of immersion” truly does what it is made to do: immerse the user better than a normal screen. This study pursues this question through the Brain Computer Interface (BCI) available at Thomas Jefferson High School for Science and Technology and other resources available.

The 32 electrode BioSemi MKI/MKII that collects data at 256 Hz was used for this experiment along with OpenViBE, an open-source platform for collecting, parsing, and testing BCI data. This software is also compatible with other BCI hardware and will soon expand to the Emotiv. OpenViBE is able to collect the data and parse the data for useful information regarding the frequency of signals collected, the strength of the signals, and able to perform analysis of the data. For this project, the Spectral Analysis was used to read the amplitude, and therefore strength, of the Mu and Beta wave frequencies. Because the Beta wave covers a larger portion the frequency spectrum the frequency was split into Beta 1, 2, and 3 so that the data would be more accurate, and mirror the Mu rhythm data collection better.

The Gear VR virtual reality device was also used as the virtual reality medium for this experiment. The opportunity was also open to use the Oculus Rift DK2, which is able to sense the not only gyroscopic movements of the head, but also location of the head in 3D space. However, without the expertise or hardware to use the DK2, along with the time restraint, the Oculus Rift was abandoned for the Gear VR. The Gear VR poses several pros and cons for this experiment. Much like the Oculus Rift, the Gear VR came with the standard gyroscopic readings of the movement of the head, but it did not read positional movement in neither 3D nor 2D space using the accelerometer. However, the Gear VR is relevant to the experiment because it is the most consumer friendly VR device for its price on the market and allows the study of Virtual Reality capabilities with what is available to current consumers.

Methods/Materials

The first process to complete is the setup of the subject. The 32 electrode EEG cap must be placed on the head, with the tag at the back of the head. Measure 20 cm from the bridge of the nose to Cz node directly up on the z axis of the cap. Use electrode gel, a conductive substance that helps create a strong connection between the electrodes and the head of the subject. Use the following diagram for reference.

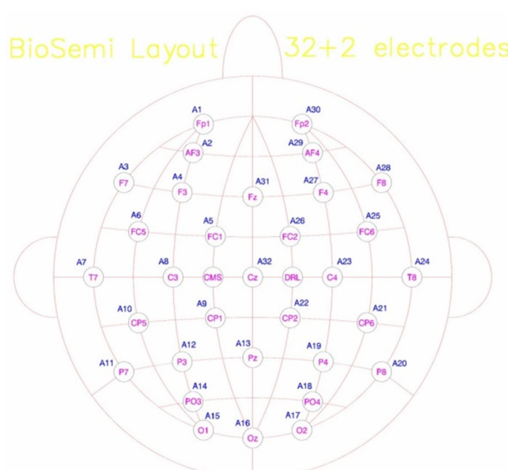

Figure 1: BioSemi MKI/MKII 32 Node electrode layout

Before setting up the subject on the BCI, open OpenViBE to create a new template for data collection and data analyzing. The first template will be the read data template.

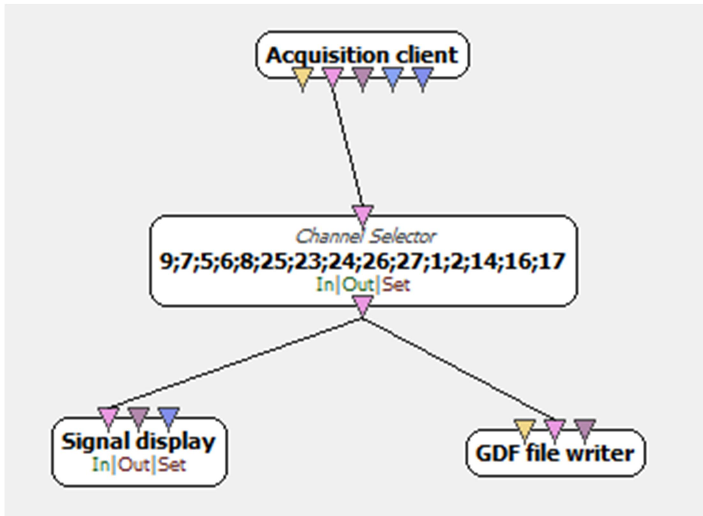

Figure 2: OpenViBE setup to collect and write data into a GDF file

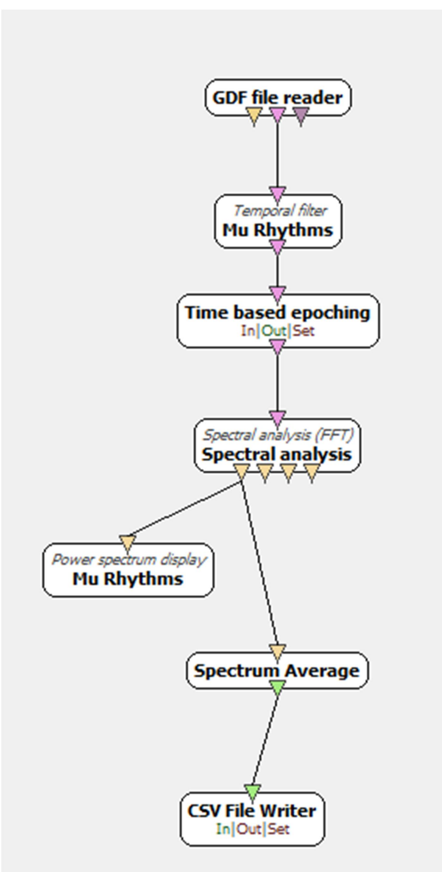

Figure 3: OpenViBE setup to implement spectral analysis and save as CSV file.

The Channel Selector collects data from specific channels on the BCI System. The numbers in Figure 2 coincide with the electrodes along the motor cortex, parietal lobe, and frontal lobe. The full list of number to node correlation is in the Spectrum Analysis Protocol. The data from the needed electrodes are then saved into a GDF file writer, so that the data can be parsed multiple times over.

Refer to Figure 3 for the OpenViBE setup to implement Spectral Analysis and save data in a .csv file format (readable by excel).

Use the temporal filter to cut off unnecessary frequencies. When defining the low pass and high pass slightly overcut the low pass and undercut the high pass. This is needed so that not too much excess data will be collected using either of the two methods, Butterworth or Chebychev. Both methods are used to filter the needed frequencies; however, they each have their own benefits and flaws.

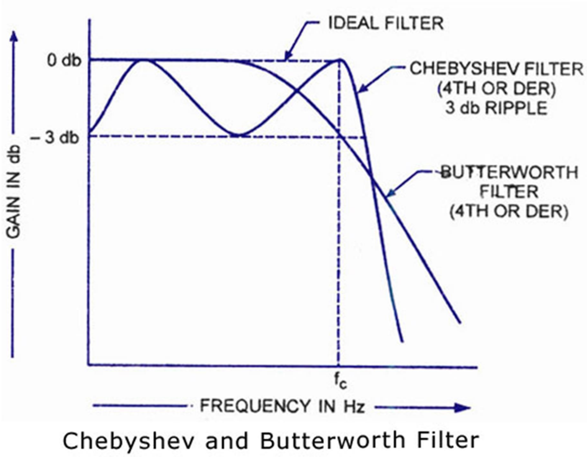

Figure 4: Butterworth vs Chebychev Filters

Chebychev will exclude data that should be included within the range so that it will precisely cut off at the frequency high pass. Butterworth however, will include excess data in order to preserve the integrity of the data collected. Butterworth was used in this study in order to collect the data; and the undercut and over cut were used to compensate for the extra data collected by the system of filtration.

The spectral analysis will take each frequency of the data and read the information on its amplitude. The power spectrum display, shown in Figure 5, will help visualize the amplitude change through a histogram. The x-axis labels the different frequencies. The bleed in data from the Butterworth filtration system can be seen within this snapshot. The Channels along the y-axis are the different data streams from the electrodes. The height of the each histogram is the power of the frequencies.

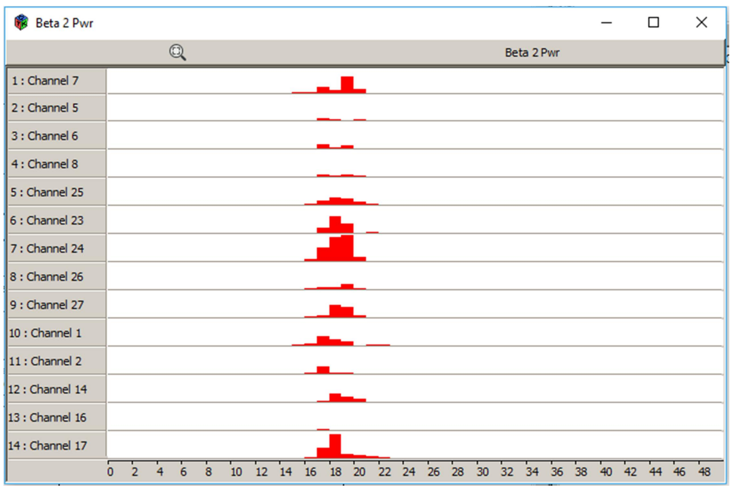

Figure 5: Power Spectrum Display

If the data is saved from the Spectral Analysis into the CSV File Writer, the system will save the amplitude of each frequency and not every snapshot in time of data. The Spectral Analysis has to go through the Spectral Average, which takes the average value of the spectrum in each time epoch and can then be saved into the .csv file.

The Generic Stream Reader box can be used instead of the acquisition client to test the OpenViBE system you created instead of connecting a subject to test. After connecting the subject to the BCI, place the Gear VR on the subjects head, careful not to snag the electrodes out of their nodes, and collect data.

Charts/Tables Results

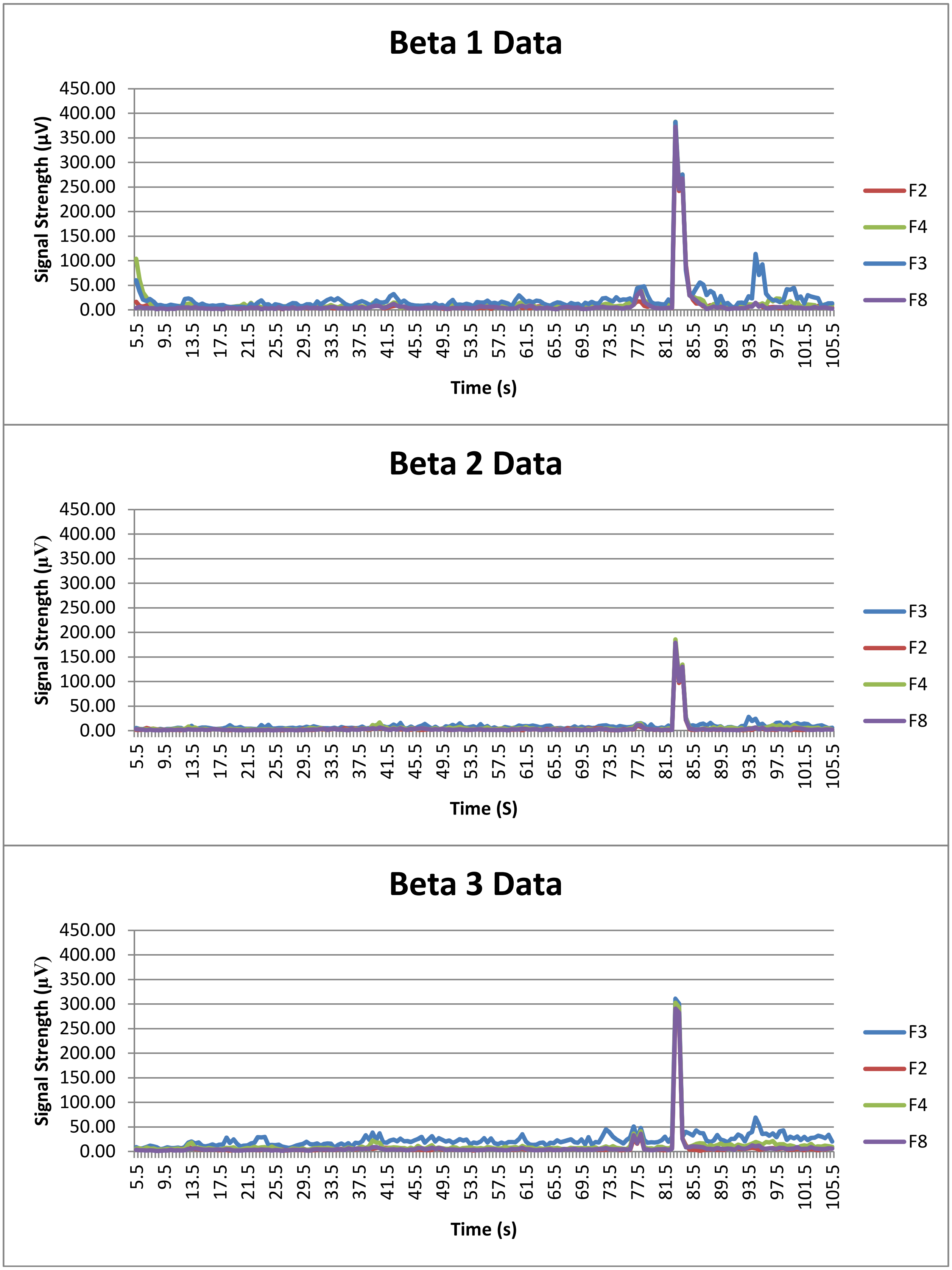

Figure 6: Spectral Analysis Data from the F2, F4, F3, and F8 Nodes. They correlate close to the Motor Cortex brain region that controls bodily movements.

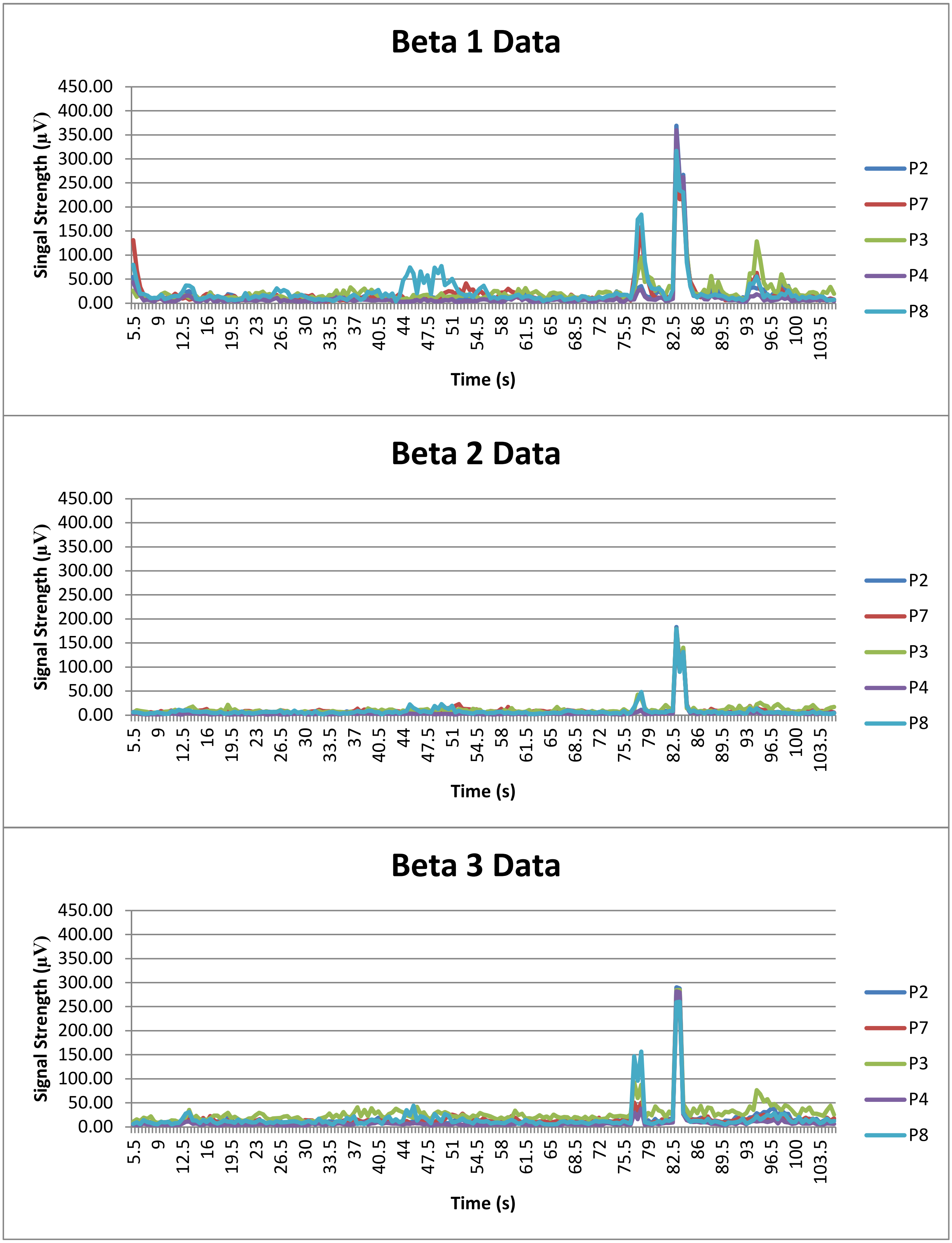

Figure 7: Spectral Analysis Data from the P2, P7, P3, P4, and P8 Nodes. They correlate with the Parietal lobe, responsible for processing information through the senses.

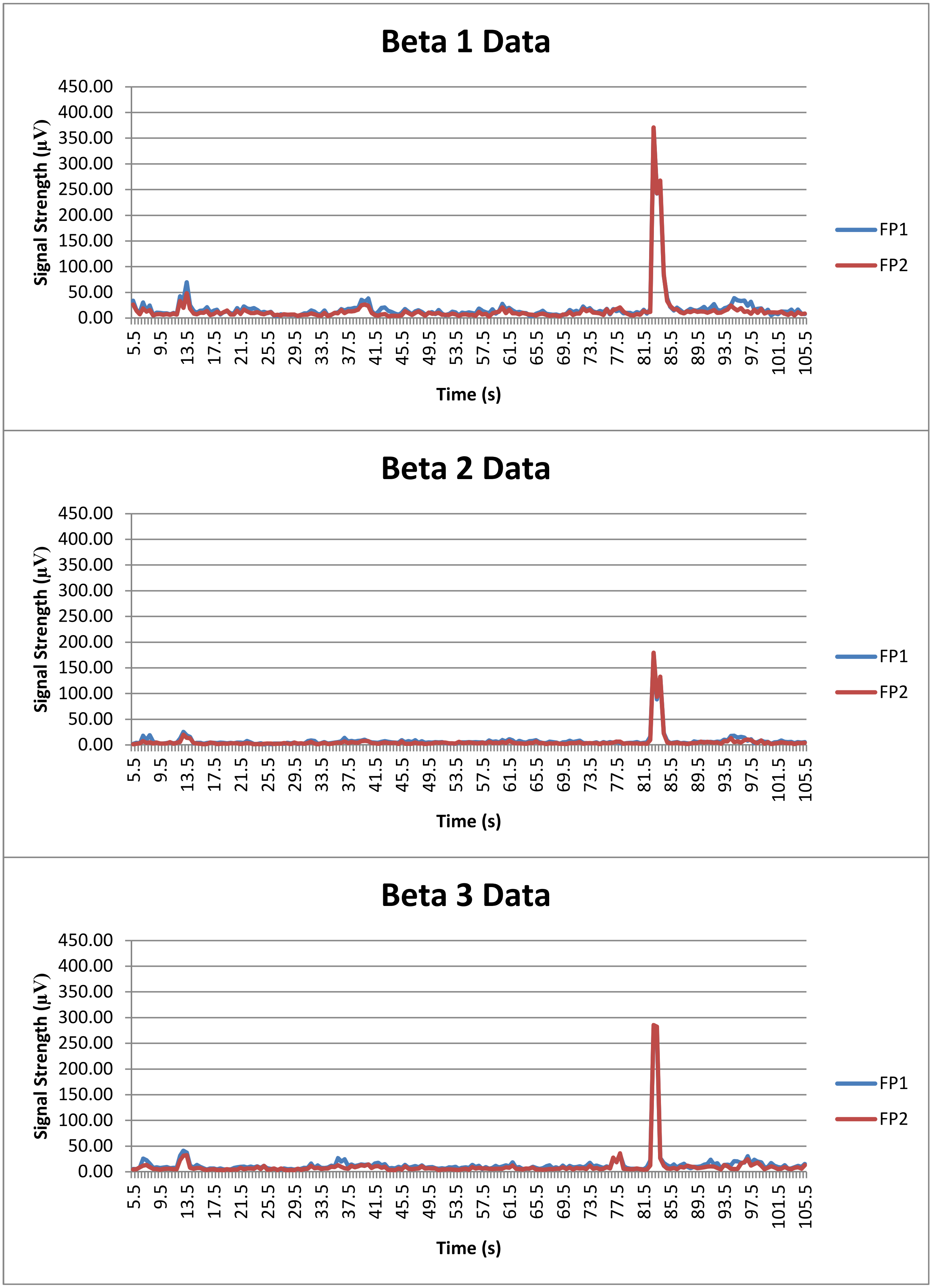

Figure 8:: Spectral Analysis Data from the FP2 and FP1 Nodes. They correlate to the Frontal Lobe, the region that controls logical thought processes.

Results

The charts and data section displays the Beta 1, 2, and 3 over time graphs from the Frontal Lobe, Motor Cortex, and the Parietal Lobe of the brain during the virtual reality horror simulation. The Mu rhythm data and the data from the screen simulation were corrupted and could not be processed. However, critical data can be pulled from the Beta wave graphs for the Virtual Reality simulation. The Beta 1 graphs derive the spectrum analysis data from frequencies 13 Hz to 15.5 Hz. The Beta 2 graphs derive the spectrum analysis data from frequencies 17 Hz to 19.5 Hz. The Beta 3 graphs derive the spectrum analysis data from frequencies 21 Hz to 27 Hz. This was done to observe any differences within the wide frequency range that the Beta waves cover.

The first noticeable characteristic that all the Beta wave graphs possess is the large spike at 83 seconds. In the Motor Cortex the average highest voltage for Beta 1 was 373.7 µV, Beta 2 was 180.5 µV, and Beta 3 was 296.5 µV. In the Parietal Lobe the average highest voltage for Beta 1 was 339.4 µV, Beta 2 was 178.2 µV, and Beta 3 was 273.2 µV. Finally for the Frontal Lobe the average highest voltage for Beta 1 was 370.0 µV, Beta 2 was 179 µV, and Beta 3 was 282 µV. The time of the spike correlates with the time of the major jump scare within the simulation.

In the Parietal lobe graphs for Beta waves, there is also a second smaller spike before the jump scare spike, at 77 seconds. The average highest voltage during that spike for Beta 1 was 38.5 µV, Beta 2 was 46.1 µV, and Beta 3 was 47.4 µV. The maximum measured voltage for Beta 1 was 184 µV, Beta 2 was 48.1 µV, and Beta 3 was 156 µV. During this time in the simulation a doll on the shelf fell down, creating a large noise, which could have led to this bump.

A pattern arises between the different Beta graphs which could lead to different results coming from the different Beta wave graphs. The Beta 1 graph, which has a frequency closer to that of Mu rhythms, has the strongest spike. Beta 2 waves have a much weaker voltage spike than Beta 1 and 3. And Beta 3’s waves, which are closer to Gamma wave frequency, are closest in strength to that of Beta 1 graph. This suggests that the Beta waves do not respond as strongly to these simulation compared to wave types around the Beta wave such as Alpha or Gamma waves.

Discussion

Beta waves are associated with the state of being awake, and most humans have a strong Beta wave signal throughout the day waking hours. The lack of Beta waves is often leads to mental and emotional disorders. Beta waves can further be separated into Beta 1, 2 and 3. Beta 1 is associated with fast idle wakefulness; Beta 2 is associated with high engagement; and Beta 3 is associated with complex thoughts, new experiences, high anxiety or excitement. Just below the Beta frequency range are the alpha waves, which are associated with mental coordination, calmness, and alertness, which shadows the theme of tranquility from Beta 1 waves. Above the Beta frequency range is the Gamma waves which is associated with interactions between different brain regions, which also correlates with the Beta 3's high level thinking characteristic.

This phenomenon where the implications of Beta 1 and 3 mimic the qualities of Alpha and Gamma waves, respectively, can be an indication of what horror simulations more strongly stimulate. The data collected at all three regions studied—Motor Cortex, Frontal Lobe, and Occipital Lobe—followed the same pattern between Beta 1, 2 and 3. The average voltage values for Beta 2 values were significantly lower than that of Beta 1 and 3. This suggests that Alpha waves and Gamma waves may respond to the stimuli stronger than Beta 2. This theory is further reinforced by the method used to filter the data, Butterworth, which causes a bleed effect from surrounding frequencies, namely Alpha into Beta 1 and Gamma into Beta 3. Furthermore, Beta 2 voltage data is surprisingly low considering the bleed from Beta 1 and 3 was also factored into the average value for the Beta 2 voltage. This suggests that compared to Gamma and Alpha waves, Beta waves do not react as strongly to the horror simulation stimuli. This possible indicates that the brain will be in a greater alerted state, other brain activities will take precedence.

Separate from the major spike there are three other voltage spikes, the larger of which being at 77 seconds. The spike before the main voltage spike can be found in the Beta 1 and 3 graphs from the Motor Cortex, all three Beta graphs from the Parietal Lobe, and the Beta 3 graph of the Frontal Lobe. This time also coincides with a doll on a shelf falling and creating a large sound. Once again, there is a lack of response to the stimuli from the Beta 2 graphs supporting the idea that the brain is not significantly stimulated in the beta wave frequency compared to Alpha or Gamma waves.

The second smaller spike occurred at 94 seconds. However, it did not correlate with any specific stimuli in the simulation. There were, however, several smaller stimuli throughout the simulation, specifically, the thunder and lightning. The lightning was blindingly bright and that may have been the cause of the sudden spike in the Parietal Lobe. The Parietal Lobe is responsible for receiving and processing sensory information, such as taste and touch. This explanation would clarify why the voltage spike occurred; however, there were multiple lightning strikes throughout the simulation and the expected result would have the same spike occur multiple times. That lightning strike was also the first major strike after the main horror stimuli, so it is also possible that the reaction was greatest because of this.

The third smallest spike occurred at 13 seconds, and correlates to the door opening by itself in the simulation along with the first lightning strike. Only the Frontal Lobe data presents a greater than average spike at this time, indicating that the brain was involved in logical thinking, trying to analyze the situation.

It would be expected for the data from the Motor Cortex to create larger, stronger voltage readings, but in relation to other regions of the brain it does not. A possible answer to this problem is the fact that the movements made during these stimuli are more reactionary than intentional. This would indicate that these are out of the Central Nervous System's powers and fall into the Peripheral Nervous System's power. However, this does not completely create a solution, because the only sense that is immersed in virtual reality is sight, which is connected directly to the brainstem, and would therefore be a part of the Central Nervous System.

Unfortunately, there were problems throughout this research. For future projects, it is suggested that more time be taken for data collection with a larger group of individuals. This helps ensure the integrity of data collection and helps create a buffer period between simulations testing of the subjects. A control sample should also be taken to gauge the data more accurately. In addition, care should be taken when placing the VR headset on the EEG Cap. The VR headset can have a tendency to remove or loosen the electrodes. During the testing, the subject should be in an isolated environment: no exterior sounds, sight of other individuals, etc. The use earphones are also strongly suggested, because it can not only help create the most immersed experience but also mitigate exterior sound interference. The OpenViBE system should also be thoroughly tested, so that it can be confirmed that no data is corrupted. The corruption of data can also be minimized through the use of a larger sample size. When using the larger sample size however, the subject must only be compared to data from the same subject. This is because different subjects will respond differently to the same experience: some people may enjoy horror simulation while some people will not. Another source of interference is the Gear VR plus phone itself. Due to its close proximity to the electrodes they may influence the voltage readings from the electrodes. While filtering out 60 Hz generally solves this problem, the proximity may play a role as well and instantiate the problem.

References

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