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Computational Music Biofeedback for Stress Relief

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ENTITLED

Computational Music Biofeedback for Stress Relief

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

DEGREE OF

BACHELOR OF SCIENCE IN COMPUTER SCIENCE AND ENGINEERING

THESIS ADVISOR

DEPARTMENT CHAIR

COMPUTATIONAL MUSIC BIOFEEDBACK FOR STRESS RELIEF

by

Jason Capili, Mark Hattori, and Maile Naito

SENIOR DESIGN PROJECT REPORT

Submitted in partial fulfillment of the requirements
for the degree of
Bachelor of Science in Computer Science and Engineering
School of Engineering
Santa Clara University

Santa Clara, California

June 13, 2018

SANTA CLARA UNIVERSITY
DEPARTMENT OF COMPUTER ENGINEERING
SOFTWARE ENGINEERING

Computational Music Biofeedback for Stress Relief

by

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Mark Hattori
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Santa Clara, California
June 13, 2018

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Computational Music Biofeedback for Stress Relief

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ABSTRACT

The purpose of our project is to use EEG technology to combat stress in our daily lives. One of the most accessible EEG technologies that targets this challenge is the Muse headband, a wearable device that pairs with a phone application to help users train their brains to relax. The applications main goal is to help users train their brain to be more relaxed by monitoring and reporting their levels of stress. However, one of the shortcomings we noticed is that the constant notifications of how stressed we are actually adds to the level of stress as opposed to helping train our brains towards a more relaxed state.

In order to improve this solution, our program uses the live brain waves transmitted by the Muse headband and feedforward techniques to not only track brain users activity, but also help the user move towards a more relaxed state using music and binaural beats. While we werent able to test the system on an unbiased population due to time constraints, preliminary exploration on ourselves on both short term and longer term sessions shows that longer uses of our system led to more a relaxed state.

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1 Introduction

In today's fast-paced modern world, stress is an increasingly persistent part of life. According to the American Psychological Association, 75 percent of adults reported experiencing moderate to high levels of stress in the past month and nearly half reported that their stress has increased in the past year.[1] Now more than ever, effectively dealing with stress is crucial in order to regain control of our concentration, attention, and energy.

Currently, one tool for combating the epidemic of stress is Muse, a headband that detects brainwaves and pairs with an application that trains the user to meditate and relax by providing feedback based on their brainwaves. The Muse application detects the user's brainwave activity and uses this data to determine the user's state of mind: Active, Neutral, or Calm. The goal of the application is to have the user learn to focus their mind and calm it down if their mind is in an active state.

While the Muse offers a revolutionary approach to battling stress and anxiety, there are major flaws with the current approach. The application's primary methodology is to alert users of their current mindset, which is redundant and can actually exacerbate stress in a stressful state. Additionally, although it is useful to train users to calm themselves, the application itself only provides feedback on the user's brain activity. In other words, it is up to the user to move towards a state of relaxation and concentration; Muse is simply there to keep track of their progress.

While having an accessible way to read brain waves is revolutionary, we want to create an entirely new application using more effective technology to battle stress. Our proposed solution allows for users to not only be aware of their state of mind, but to also move towards a more relaxed state. As such, we want to integrate feedforward methodology into an otherwise purely feedback-based approach. When the headset detects brain activity from the user that indicates stress, the application will provide stimuli that will assist the user in moving towards the desired mental state. In order to achieve this goal, we will use computer-generated music and binaural beats to calm the user down until the the headset detects calmer brain activity. The application will also utilize machine learning to personalize the experience by determining what patterns of sound or binaural beats are the most effective at calming each user down. We expect that the combination of feedback and feedforward will lead to greater stress reduction than the application of feedback alone.

The integration of feedback and feedforward will increase the personalization of each users experience, helping them reach a more relaxed state more effectively. This novel combination of individualization and feedforward will make stress relief easier and more accessible than ever before.

[1] http://www.gostress.com/stress-facts/, 3 October 2017

2 Background

2.1 Brain Waves

Brainwaves are "electrical activities which are produced by the firing of neurons in the brain"[2]. Brainwaves are classified by their frequency, with higher frequency waves being associated with anxiety and stress. Beta waves generally fall within a range of 14 - 30 Hz, and are associated with stress, anxiety, and fear. Alpha waves are between 8 - 13.9 Hz and are associated with light meditation and relaxed focus. Theta waves are between 4 - 7.9 Hz and are associated with deep meditation. Delta waves fall between 1 - 3.9 Hz and are associated with deep sleep. For this project, we focused on the tracking of alpha waves relative to the other brain waves, in order to determine the level of the user's relaxed state.

2.2 Current Solutions

2.2.1 Biofeedback Therapy

Biofeedback is the process of monitoring the activity of various physiological functions in order for one to learn how to better control these functions. Functions such as heart rate, blood pressure, and brain wave states are tracked by means of non-invasive sensors on the human body. The sensors provide immediate results to the user, who must then learn how to control these functions[3]. A current popular method of biofeedback therapy is the use of wearable meditation headsets. These headsets are available on the market to consumers, with prices ranging from below $100 to nearly $1000 [4]. These headsets are designed to be cheaper than traditional brainwave tracking equipment in science laboratories, and easy-to-use for an everyday consumer. These products aim to give the consumer the ability to interact with their bodies by producing real time feedback of their various brain waves via software or a mobile application.

Current headbands on the market include the Thync, Versus, NeuroSky MindWave, and the Muse headband. The Thync headband is currently the cheapest option at $79, but has adhesive strips that attach to the forehead and can quickly wear out and be uncomfortable. The Versus headband is the most expensive option at $799, and has the best software for brain training. But the device's spike sensors need to be firmly attached to the scalp to have consistent brain wave readings. The NeuroSky MindWave is $199, but has a sensor that clips to the ear. Some customers have reported with just 30 minutes of use, the headband caused headaches [5].

[2] Gupta, Anushka, et al. Significance of Alpha Brainwaves in Meditation Examined from the Study of Binaural Beats. 2016 International Conference on Signal Processing and Communication (ICSC), 2016, doi:10.1109/icspcom.2016.7980629.

[3] Ratanasiripong, Paul, et al. "Setting up the next generation biofeedback program for stress and anxiety management for college students: A simple and cost-effective approach." College Student Journal 44.1 (2010): 97-100.

[4] Brinson, Sam. Hacking Your Brain Waves: A Guide To Wearable Meditation Headsets. DIY Genius, 29 Dec. 2017, www.diygenius.com/hacking-your-brain-waves/.

[5] Ibid.

2.2.2 Muse Headband

For this project, we used the Muse headband because of its balance between affordability and performance. The Muse is currently the most popular headband on the market at $199 and has a sleek and simple design, making it very user friendly. As for the Muse's accompanying mobile application, it utilizes a feedback methodology. Based on the user's brainwave signal, the application produces audio feedback to let the user know if they are reaching a more relaxed state. For example, if the meditation scene is a beach, the sound of crashing waves is produced if the user's brainwaves show a high level of stress.

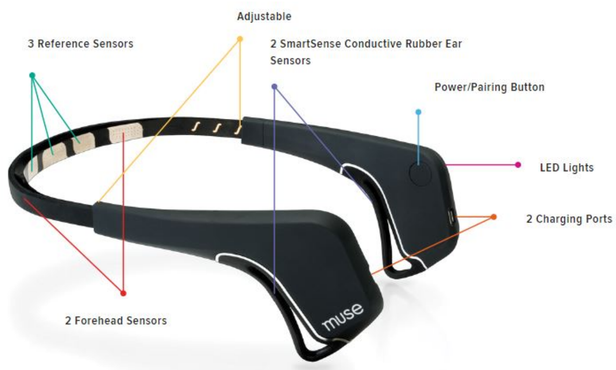

Figure 1: A diagram of the Muse headband and its sensors.

2.3 Biofeedback Anxiety

While various sources and studies state that biofeedback training helped individuals with their stress, anxiety, depression, and other symptoms, we found through our own testing of an EEG device we experienced what can be described as "biofeedback anxiety". While instantaneous feedback is helpful for a user to understand their current state, it can also lead to difficulty to improve their current state.

For example, if a user is to see that their brain waves reflect high stress levels, the user will attempt to relax. After attempting to relax, the user may see that their stress level has not changed. While the feedback is helpful for the user to understand what their current state is, the feedback may further contribute to further stress if the user is aware that their efforts are not changing the physiological function levels to a desired state.

In this project, we use a feedforward methodology instead of a feedback methodology in order to avoid biofeedback anxiety that may deter the user from reaching a relaxed state. Feedforward methodology involves utilizing the users past data to generate new sounds to guide them towards a relaxed state, instead of only reflecting their current state.

2.4 Binaural Beats

Binaural beats are an auditory illusion where slightly offset tones are played in each ear of the listener. The difference in frequency of the tones is interpreted by the listeners brain as a third tone. For example, if a binaural beat composed of a 200 Hz tone in one ear and a 210 Hz wave in the other, the listeners brain will also hear a 10 Hz wave. This allows the listener to interact with tones that are below the threshold of human hearing as well as what most headphones or speakers can produce. Binaural beats are known to have an emotional effect on a person and have a positive effect on people suffering from anxiety and tension.[6] In a 2017 study in the British Journal of Oral & Maxillofacial Surgery, patients who listened to binaural beats before dental surgery were found to be less stressed than the control group of patients who did not listen to binaural beats.[7] Because of this information gathered from this experiment, we decided to use binaural beats layered on top of ambient music designed for meditation to help guide the user to a state of restfulness, rather than training the user to calm themselves.

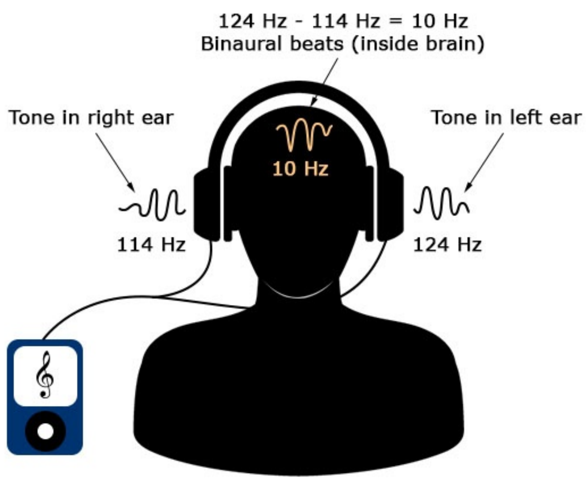

Figure 2: An example of binaural beats.

[6]Isik, B.K., et al. "Effectiveness of Binaural Beats in Reducing Preoperative Dental Anxiety." British Journal of Oral & Maxillofacial Surgery, vol. 55, 01 July 2017, pp. 571-574. EBSCOhost, doi:10.1016/j.bjoms.2017.02.014.

[7]Ibid.

3 Requirements

Listed below are the functional requirements, non-functional requirements, and design constraints that describes the scope of the project. Functional requirements describe exactly what the system will accomplish, non-functional requirements describe the manner in which the functional requirements must be achieved, and the design constraints describe the limitations of the system's operations.

3.1 Functional Requirements

The system:

- tracks the user's brain activity and provides feedback about the users state of mind via a graph.
- generates alpha binaural beats for a certain time period followed by theta binaural beats. Based on the user's state of mind, the system then plays whichever binaural beat was more relaxing.
- allows users to view their brain activity at the end of each session and generate a CSV file with all of the raw data.

3.2 Non-Functional Requirements

The system will:

- accurately records data and generates music based on that data in real time.
- accurately measures the user's brainwaves.

3.3 Design Constraints

- Our app runs on Apple laptops through Terminal.

4 Use Cases

Our application has one main actor, the user. They can connect the application with the Muse headband, start a session in which the application generates music, and view the brainwave data that the Muse records.

Use Case Diagram

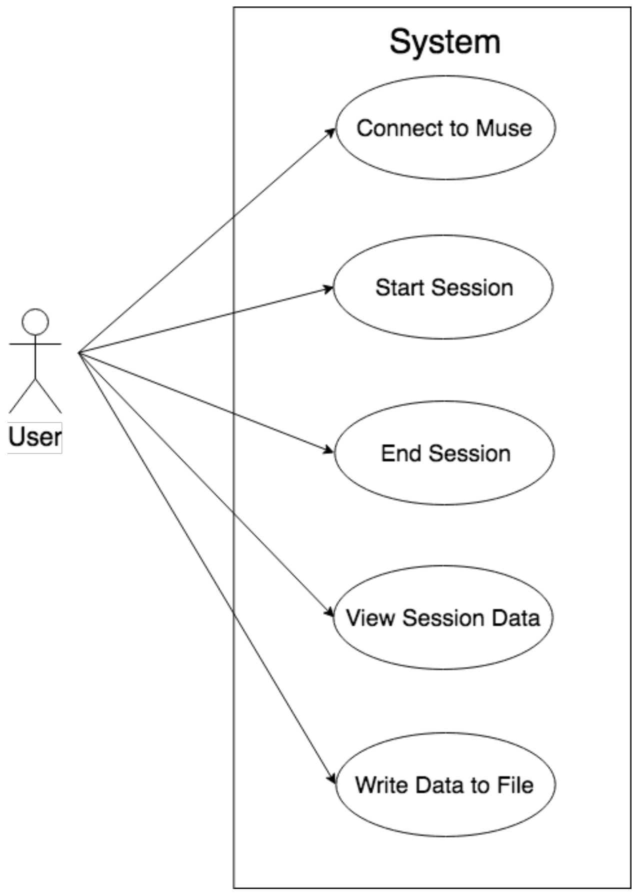

Figure 3: Use case for the application user.

4.1 User

- **Connect to Muse**
  Goal: User can pair the Muse Headband with their laptop via Bluetooth so that the application can receive information for the session.
  Actors: User
  Preconditions: Muse headband and laptop are on
  Postconditions: User is notified of the connection status and can start a new session once connected.
  Exceptions: None

- **Start Session**
  Goal: User can start a new session where the application will play music and generate binaural beats to help calm the user.
  Actors: User
  Preconditions: Muse headband and laptop are paired.
  Postconditions: The user's brain activity for the current session is recorded and music is generated based on the user's incoming brain waves.
  Exceptions: None

- **End Session**
  Goal: User can end the Muse Session which stops the music and brain wave recording for the current session.
  Actors: User
  Preconditions: Muse is connected and there is an ongoing session.
  Postconditions: Session Data stops being recorded and music generation ceases.
  Exceptions: None

- **View Session Data**
  Goal: User can view data gathered from the completed session.
  Actors: User
  Preconditions: User just finished a session.
  Postconditions: User interface includes graph of brainwave levels recorded during session
  Exceptions: None

- **Write Data to File**
  Goal: User can create a CSV file of the data gathered from the session.
  Actors: User
  Preconditions: Session data exists.
  Postconditions: CSV file of session data is saved to the local host computer.
  Exceptions: None

5 Activity Diagrams

The following activity diagram describes the flow of user interaction with the system. The diagram provides a clear visualization of the order in which a user performs major tasks.

User Activity Diagram

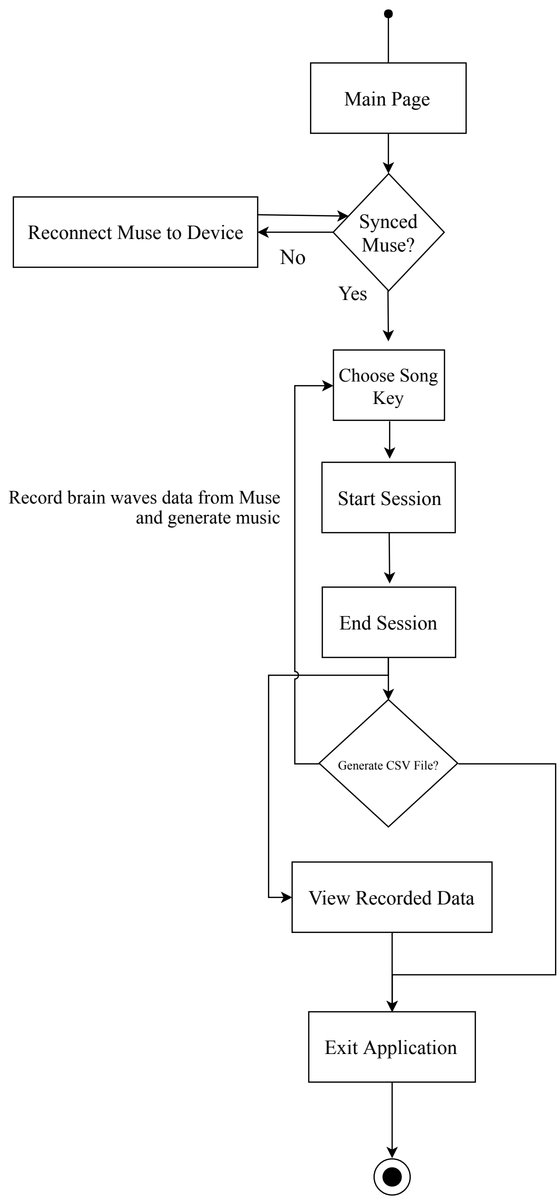

Figure 4: Activity diagram demonstrating student user's flow of the system.

6 User Interface

The following sections describe what a user sees while using the system.

6.1 Connecting the Muse and Starting a Session

Once the Muse is connected to the user's laptop via Bluetooth, the Terminal window will display a page similar to Figure 5 that shows information about the specific Muse device connected, such as the rate of data transmission, the amount of battery life, the number of dropped samples, and the noise levels at each sensor. Figure 6 shows the first page the user sees when the program is opened. This page allows the user to select the key of the song they would like to listen to, which also corresponds to the key of the binaural beat that will be overlaid on the music.

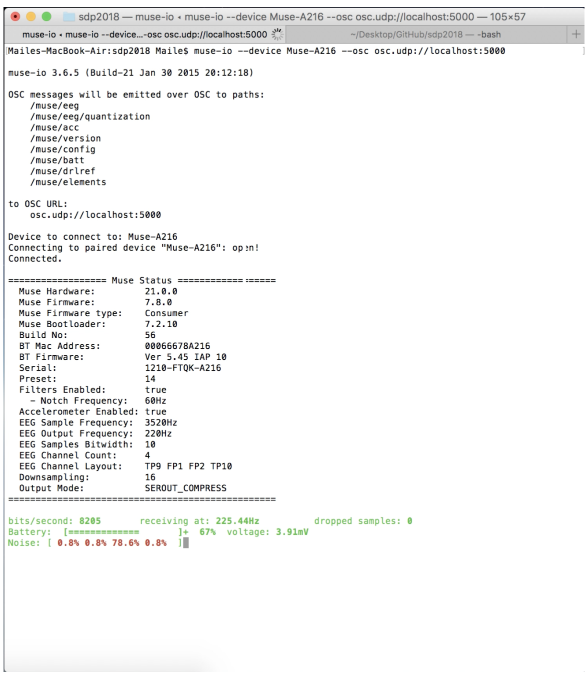

Figure 5: Status of Muse in Terminal Window.

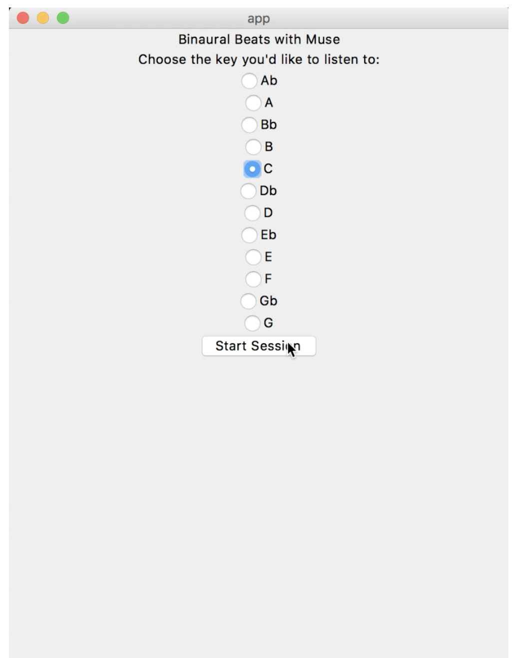

Figure 6: Song Selection Page.

6.2 User Session

Figure 7 depicts a sample of the graph that of the data gathered during the session in real-time. The red lines and the labels above the graph are not visible during the session; they have been added to the figure to mark the different sound generation sections of the session. The first phase of the session is just music, meaning that only ambient music is played without binaural beats. This is simply to establish a baseline for the user and to predispose a user to a more relaxed state. The second phase is playing alpha binaural beats. The introduction of the binaural beats is very subtle and is the same key as the chosen song. The third phase involves playing theta binaural beats, which are detected in deep relaxation and meditative states. We chose to play the theta waves after the alpha waves so that if a user is going to experience those deeper levels of relaxation, the alpha phase already predisposed them to be in a relaxed state. The fourth phase is where the feedforward portion of the session occurs. Once the program reaches 3/4 of the way through the session, it will calculate the average amount of alpha waves relative to the other brainwaves from each of the previous phases and plays whichever binaural beat was more relaxing for the user. This way, the program is attempting to relax the user based on the user's previous behavior as opposed to generalizations about each of the binaural beats.

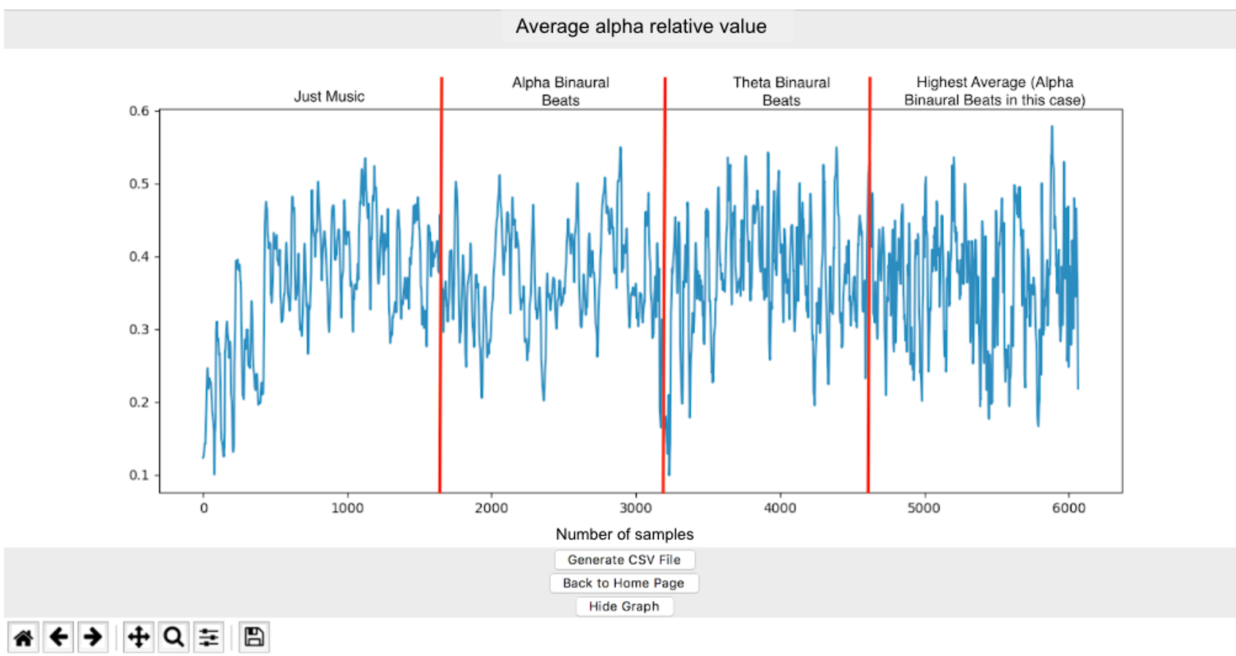

Figure 7: Sample In-Session Data.

6.3 Generate CSV File

Finally, Figure 8 shows a sample of the CSV file that can be generated at the end of each session so that the user has access to the raw brainwave data from their session. The numbers in the A column correspond to the user's alpha relative value at that point in time. The X-axis on the corresponding graph is the number of sample that corresponds with that piece of data, it does not correspond to the time.

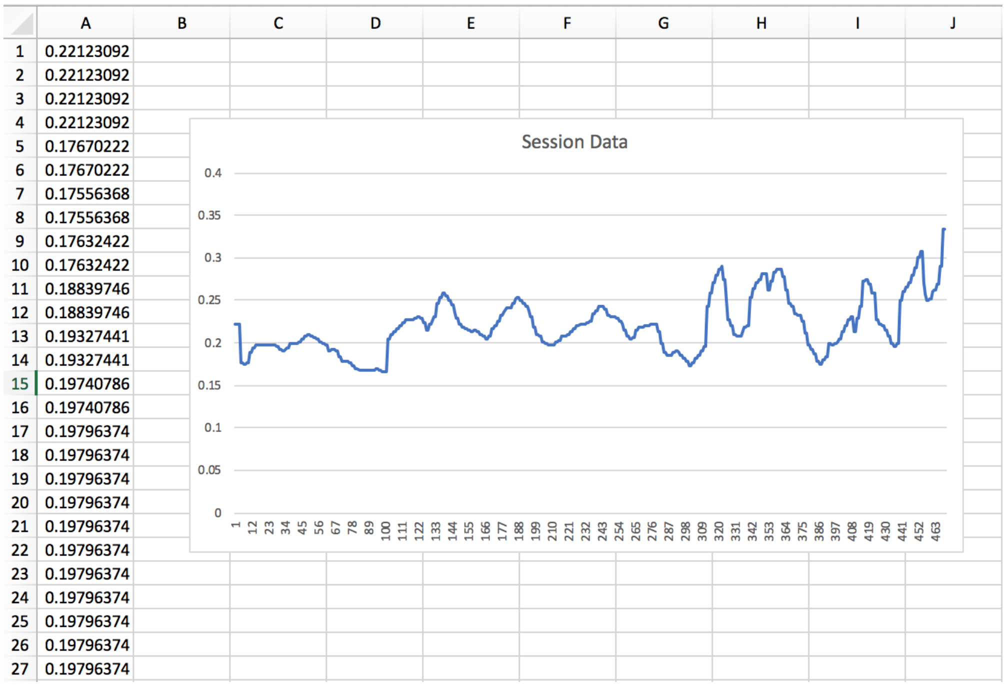

Figure 8: Sample Data Generated from CSV File.

7 Technologies Used

Our solution utilizes various software tools in order to create the application.

7.1 Software

- Muse SDK Developer Tools

  Software provided by Muse with various API's that includes pairing the Muse Headband with devices and real-time EEG brain activity data flow.

- Python

  A programming language that has sound generation libraries as well as graphical user interface packages for creating the graph in real time.

7.2 Hardware

- Muse Headband

  An external device that reads user's brainwaves and connects to the application via Bluetooth.

- Macbook

  An Apple device used to run the application.

8 Architectural Diagram

The architecture for this system is a data-flow architecture. The Muse headband is continuously reading in brain waves to the application, where the data is then be recorded and processed. The processed data is used to determine what kind of binaural beat will be generated. This data processing procedure continues until the user decides to end the current session. The Muse headband is connected to the laptop via Bluetooth.

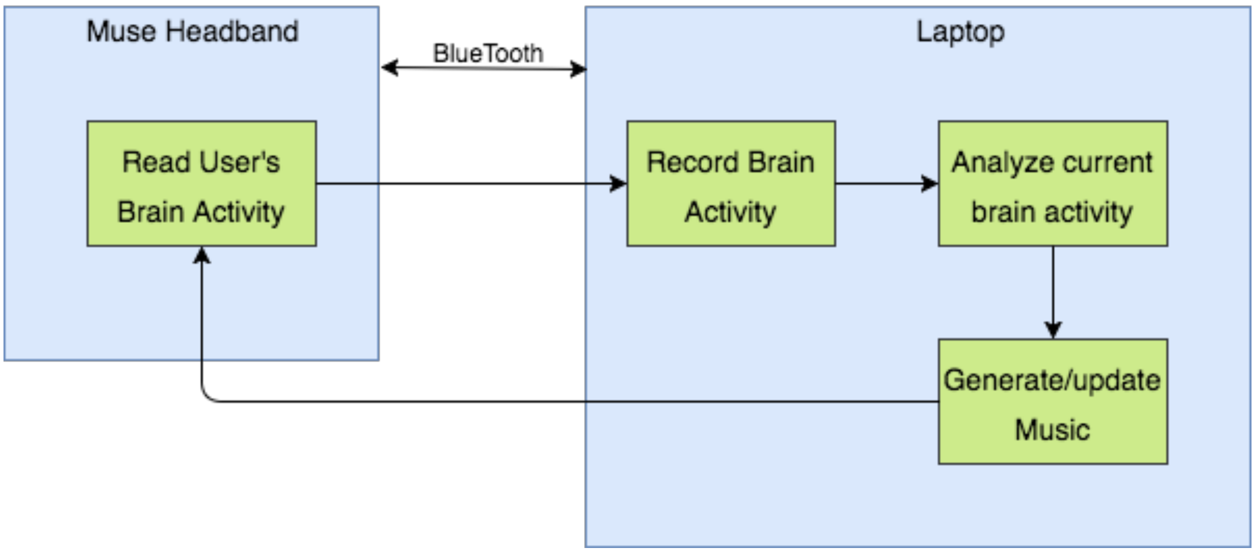

Figure 9: Architectural Diagram of the System.

9 Design Rationale

The reasoning behind the choices for the use of technologies to build our system.

9.1 Rationale for Technologies Used

- Muse Headband

  We are using the Muse Headband to read the user's brainwaves. We chose to use the Muse headband because the Muse company provides resources to help developers create their own applications that utilize the Muse Headbands.

- Macbook

  We chose to build an application on the Mac Operating System since everyone in the group has an Macbook. Additionally, we are much more familiar with the Apple's user interface.

- Muse Developer SDK

  Since we are using the Muse Headband, we plan to use the Muse Developer SDK tools since they help connect the Muse Headband to software.

- Python

  In order to generate music, we used the Python programming language by utilizing the pydub library. This will allow us to import and play mp3 files in real time. We also used the packages TKinter and mathplotlib for the GUI. We also chose Python because we had experience coding in that language.

10 Testing

In order to validate and verify our solution, we structured various testing procedures in order to test the functional and non-functional requirements of the project.

10.1 Validation Testing

- Accurate Communication with Muse Headband

  The first part of our testing procedure was making sure that the Muse headband was communicating properly with our laptops. This included making sure the transmitted data was in a manageable format, watching for erroneous data points, and experimenting with the different types of data that was available to us through the OSC transmission.

- Audio Generation Based on Brain Waves

  The second part of our testing involved experimenting with sound generation. Since we were generating binaural beats from scratch and not from audio files, we had to make sure that the beats blended well with one another and that they could stop when we wanted. We used multi-threading in order to layer multiple sounds over each other without overloading our computers or slowing our program down.

  After the sound generation was fine-tuned, the next part of testing was making sure that the generated sounds were actually responding to the brain wave data. This involved constantly calculating the parameters under which we wanted the sounds to change and doing live testing.

10.2 Research-Oriented Testing

- Effectiveness

  The main focus of this phase of research had to do with effectiveness over short term and long term usage. However, since we arrived at a functional prototype at such a late stage and because we did not apply to test on people other than ourselves, we were not able to test on a truly unbiased population.

  Despite this, the tests we carried out on ourselves confirmed that we got more and more relaxed throughout the sessions based on the data. We noticed an upward trend in alpha waves relative to other brainwaves as the session went on. This suggests that the feedforward methodology was able to increase the alpha waves produced by the user. We did tests with 5-minute sessions and 15-minute sessions, and we became more relaxed during both of the sessions. Any future work on this project should include long-term testing and usage over an extended period of time.

11 Risk Analysis

The following table is a list of potential risks that we initially thought would lead to the delayed completion of the project. The probabilities are based on a 0-to-1 scale, 0 being impossible and 1 being inevitable. Similarly, the severity of each case is on a 10-point scale, and the impact is the product of the two. Each of the risks is listed in order of impact, from the largest to the smallest.

Risk	**Consequences**	**Probability**	**Severity**	**Impact**	**Mitigation Strategies**
Scheduling conflicts, illnesses, or unforeseen events delay completion time.	Project doesn't get completed by the end of the year.	0.2	10	2.0	Effective time management among group members, transparency between group members and advisor, realistic goals for completion.
Difficulty with implementation only allows for implementation on one kind of iOS device.	Usability of app is greatly lessened.	0.4	5	2.0	Use Swift programming tutorials to make the app compatible with different kinds of devices.
Devices break and a complete device replacement is too expensive and the parts delivery is too long	Testing is delayed, not as many features can confidently be implemented.	0.3	6	1.8	Handle devices carefully, use proper casing for storage and transportation.

12 Development Timeline

The following table outlines the tasks of the project and when they were to be completed.

	Fall '17 Week 10	Winter Break	Winter Quarter '18	Spring Break '18	Beginning of Spring Quarter '18 until Senior Design Conference	Senior Design Conference until the end of Spring Quarter '18
User Interface (App flow, visuals during each session)						
Music Generation						
Muse Pairing						
Design Document						
Backend (Log in, statistics, subconscious musical preference, database, framework)						
Presentation						
Final Report						
Jason						
Mark						
Mark & Jason						
Maile & Jason						
All Team Members						

Table 1: Development Timeline displaying tentative work schedule during the project.

13 Societal Issues

13.1 Ethical

One ethical issue that was brought up during the course of our project was the fact that our application collects data from user's bodily functions. Currently the data is localized on the computer that is running the application, but if our application expands to a commercial product, the privacy and security of user's data would be a large concern.

13.2 Societal

We realized that having extra costs could limit the scope of our proposed solution, as some people may not have the disposable income available to purchase their own headband. However, we did not want this to suggest that stress relief was a luxury for people who could afford it. Since our product was initially designed to be therapeutic, we did bring up the idea that richer people would be less stressed since they would have more access to stress relieving technology. While the Muse Headband does seem marketed towards early adopters who have the disposable income for wearable technology, we chose to use it over cheaper alternatives for our project because of the extra resources available that the Muse Development community provides.

13.3 Political

Our product doesn't really have any inherent political implications. However, our research into stress revealed that the majority of the population feels stress about the United States' current political situation, so hopefully our program can address that help address that issue.

13.4 Economic

We were able to develop our project for free since we were able to code using resources we already owned. Though muse headbands currently retail for $199, we were able to borrow headbands from our advisor to use for the duration of our project. We were also able to benefit from the generosity of the muse developers who provide free, open source development tools so we did not have to pay a licensing fee.

13.5 Health & Safety

Due to the research-oriented nature of our project, we did not test on human subjects besides ourselves. While tracking brain waves is not harmful, as the sensors on the Muse headband are non-invasive, the use of binaural beats to manipulate one's brainwaves only has empirical evidence of affecting a user's brainwaves. While our project aims to help users reach a relaxed state of mind, were the frequency calculations of the binaural beats to be miscalculated, or emit the wrong frequencies, the beats could lead to the user being guided towards an unintended brain wave state. This could lead to the user becoming more stressed or anxious from using our system. Since this project is in its rudimentary phase, it did not make sense to begin testing on human subjects before having done thorough research and having a stable prototype.

13.6 Manufacturability

Our program can easily be distributed since it is mainly a computer implementation and all of our code is publicly available on GitHub. Because the hardware that we used belongs to a third party, manufacturability of the actual Muse headset is still up to them. However, if this product is further developed into an intuitive and user-friendly experience, it could be sold or inherited by the Muse company and distributed with their hardware.

13.7 Lifelong Learning

This project was truly a learning experience for everyone involved because we had to make a product much in the same way that we would have to make a product at our jobs in the real world. Making this product was a lesson in learning what we don't already know in order to achieve what we wanted to achieve. For instance, we weren't too familiar with the functionality of binaural beats and how they affected the brain, so we as a group had to learn about the science of binaural beats and how/why they are used. This project was also an example of how interdisciplinary computer engineering projects can be. Not only did we hone our computer engineering skills, but we also learned about the biological side of how binaural beats affect our brains physiologically. In short, this project enabled us to learn about subjects that aren't directly or obviously related to computer engineering.

13.8 Usability

The current version of our product is catered more towards the computer scientist who is interested in doing research with binaural beats and brain waves. In order to use the program, the user needs to have a basic knowledge of what Terminal is and how to run Python programs with it, so it's not the most accessible implementation. But it would be very accessible for a computer engineer to get started with. One of the future improvements we'd like to make is further accessibility.

13.9 Compassion

Stress is something that impacts people from all different walks of life. We wanted to create an application that would help relieve people of the negative effects of stress. Part of our goal was to create an application that would be intuitive for the user. Additionally, we wanted to create an experience through the use of music and binaural beats that would be more passive and therapeutic for the user, instead of an active training session.

14 Conclusion

14.1 Lessons Learned

- Prototype Quickly

  As with any new project, this project had a steep learning curve for us in terms of getting acquainted with the Muse developer tools and the Python TKinter package that we used for the GUI. Therefore, one of the most important things we learned during the project development process was the importance of prototyping quickly. There were so many unforeseen problems that could only be dealt with as we discovered them, and it's always better to build what you can and deal with the problems quickly so you can get to the next set of unforeseen problems.

- Increased Productivity

  At the beginning of this project, we had a system where we would meet with our advisor weekly and delegate tasks to each group member to work on before our next weekly meeting. However, we quickly discovered that the times we were able to work in the same room at the same time were the most productive. The communication was much quicker and problems got solved almost immediately because we were all in the same room to deal with them at the same time. In hindsight this was an obvious solution, but we are all busy students, so group coding sessions weren't always an option give our packed schedules. However, next time we will make sure to carve out a specific time for us to work altogether for increased productivity.

- Project Scope

  Lastly, we learned to limit the scope of our project given the time we have to complete it and the other responsibilities we have to deal with. Initially, we wanted to accomplish so much more with this project before Senior Design presentations, like a database for users, a more visually pleasing user interface, as well as machine learning principles for efficient feedforward methodologies. However, we didn't anticipate the steep learning curve as well as our other class projects, so we were only able to come up with a research prototype.

14.2 Advantages and Disadvantages

The obvious advantage of our system over the current Muse system is that our program helps move the user towards a state of deeper relaxation, whereas the Muse program just monitors the current state. However, an equally obvious disadvantage to both our program and the Muse solution is that it requires a piece of hardware that not many users already have. Therefore, our solutions would only be available to those who can afford the Muse headset.

14.3 Future Work

- Improved GUI and Accessibility

  While our current design has all of the basic functionality we wanted to implement, the design is very simplistic. We would like to make it more user friendly and more intuitive as to improve the flow of the software and make it easier for a wider audience to use.

- Create Executable Program to Connect Muse

  Our current implementation involves opening two Terminal windows, one to connect the Muse to the laptop and the second to run our actual program. We would like to compile all of the initial commands into one executable program or application to make the system more user friendly.

- Improve Data Analytics

  Despite our multiple smoothing techniques, the live data was still pretty noisy. Future improvements include reducing the noise even further and making sure anomalies in the data don't drastically affect the feedforward techniques. Speaking of feedforward, we'd like to experiment with multiple feedforward techniques. Currently, the only feedforward technique we use is taking the average of each session and choosing the one with the highest average, but there are so many machine learning techniques that can be applied to the data to make our system even more effective.

- Create User Profiles

  The implementation of user profiles would allow for easier customization of the system per user. Additionally, users would be able to save CSV files per session and be able to track their progress. With all this personalized data, we would also be able to implement more machine learning techniques to further optimize the system per user.

- Add More Options for Music

  While there are multiple song options for the user to choose from, the structure of each song is very similar. The only difference is the root chord that the song is based on. We'd like to implement different genres of music for each user so that we don't limit our system to a specific audience that is particularly relaxed by the current music we use. We want our system to be accessible and customizable to as large of an audience as we can reach.

15 References

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Appendices

A User Manual

A.1 Introduction

This user manual describes the different features of our system. The only actor is the user.

A.2 User

The user is anyone who wants to use our system, whether for relaxation or research purposes.

Song Selection

When the system is deployed, the user will be prompted to choose a key of the song that is to be played. The same key will be played until the session is over, at which point the user can choose a different song key. The key of the binaural beats generated also depends on this selection.

In-Session Options

During the session, the user should have their eyes closed for maximum relaxation and concentration, and to reduce noise from eye blinks. Otherwise, a user has the option to hide the graph at any point to reduce feedback anxiety. The graph can also be unhidden at any point during the session. The session can be stopped at any point.

Ending the Session

Once the music stops playing, the session is over. Otherwise, the user can stop the session at any point by pressing the ”Stop Session” button. At this point, the user can choose to save the session data as a CSV file for the raw brain wave data. The final option is to restart the session and choose a different key.

B Installation Guide

This section will give an in-depth guide on how to install and run our program, and how to connect the Muse to your computer.

Installing the Necessary Libraries

1. Install the following libraries if you don't already have them: python3, matplotlib, pydub, numpy, and pyaudio. Install them using the following Terminal command:

```
$ sudo pip3 install <package_name>
```

Connecting the Muse via Bluetooth

1. Make sure the Bluetooth on your laptop is turned on.
2. Run the following command in a Terminal window. Replace the XXXX the letter-number combination that corresponds to your Muse (you should be able to see these when you view the Bluetooth details)

```
$ muse-io --device Muse-XXX --osc osc.udp://localhost:5000
```

3. Once you see the "Connection Successful!" message, open up a second Terminal tab and navigate to the downloaded sdp2018 folder. Type the following command to run our program:

```
$ python3 server.py
```

4. The program may take a while to compile and run, but you should eventually be shown the song selection screen.