Effectiveness of Music Frequencies on Mitigating the Symptoms Attention Deficit Hyperactivity Disorder
Grant Proposal

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Abstract (RQ) or Executive Summary:

Using binaural beats, this study aims to determine what genre of music is the most effective in mitigating the symptoms of Attention Deficit Hyperactivity Disorder (ADHD) patients. Due to its known properties in helping students focus while studying, classical music was hypothesized to be more effective than other genres of music in decreasing the symptoms of ADHD. ADHD is a disorder in which a patient has periods of heightened hyperactivity. This is caused by an imbalance of theta and beta brain waves in the brain's prefrontal cortex. Binaural beats are a method of changing brain waves using different frequencies playing simultaneously. However, music, despite having multiple frequencies, has not been used as a method for inducing binaural beats, which is what this study tested. There was a control group consisting of subjects not diagnosed with the disorder and an experimental group of patients diagnosed with ADHD in the experiment. They listened to different genres of music that exhibited binaural beats for 8 minutes, with an EEG to measure changes in brainwaves. Since x% of the participants express a reduction in symptoms after listening to classical music, it is clear that listening to classical music can be used to help ADHD patients mitigate their symptoms and help them focus on work while also providing them with a cost-effective way to do so in comparison to methods that aren't as effective and costly. This research demonstrates how music can be used to mitigate symptoms of mental disorders and furthers the research in binaural beats.

Keywords:

Brainwaves, ADHD, Music Genres, Binaural Beats, EEG

Impact of Music Frequencies on Attention Deficit Hyperactivity Disorder

The overall aim of this project is to determine the effectiveness of genres of music in reducing the symptoms of Attention Deficit Hyperactivity Disorder (ADHD). Binaural beats will be used as a method of neurofeedback with different genres of music to test which genres are better at reducing the symptoms of patients with ADHD.

ADHD is a significant problem in which the user has difficulty paying attention, excessive amounts of hyperactivity, and impulsive behavior (*Adult Attention-Deficit/Hyperactivity Disorder (ADHD) - Symptoms and Causes*, 2023). There are current medicines used to treat the disorder, as well as several ways to decrease symptoms of hyperactivity, such as fidget toys. ADHD is known to decrease with age; however, 29% of people diagnosed with the disease in childhood had symptoms as adults; and 81% of those adults had at least one other psychiatric condition (Low, 2022).

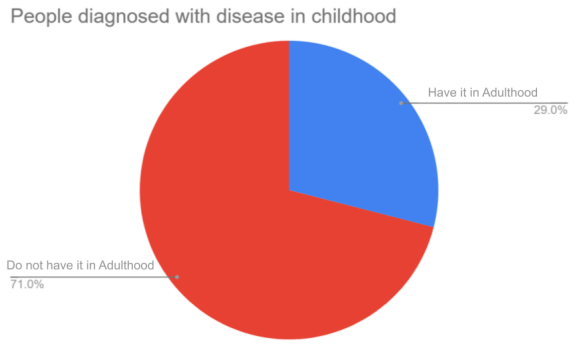

Figure 1. People diagnosed with ADHD as children, and the percentages of those who do have it in Adulthood and the percentages of those who dont. (Low, 2022)

Brainwaves are combinations of electrical signals sent by neurons in the brain (Editorial, 2016). These brainwaves have different types with correlative frequencies, which determine different behaviors. One of these wavelengths, theta waves, have frequencies of 3 Hz to 8 Hz and are known to reduce anxiety, stress, and mental fatigue. Beta waves have frequencies of 12 Hz to 27 Hz, and are responsible for improved concentration, alertness, logic, reasoning, and critical thinking.

Nuerofeedback is a practice used to adjust a person's brain waves (Bakhshayesh et al., 2011). Binaural beats is a method used to do this, in which the user hears two different frequencies (one on each ear), and in correspondence, their brain waves conform to this and reflect the difference in frequencies (Bakhshayesh et al., 2011). Binaural beats have been found to affect specific Electroencephalography (EEG) frequency bands, such as cognitive processings, affective states, mood, pain perception, meditation and relaxation, mind wandering, or creativity (Ingendoh et al., 2023).

Binaural beats have been used in previous studies to impact theta and beta to decrease ADHD symptoms. In ADHD, there are an increased amount of theta waves and a lack of beta waves (Nunez-Jarmillo et al., 2021), which is a significant marker of the disorder.

Previous studies that have implemented the idea of using binaural beats and frequencies to decrease symptoms of ADHD overall have been unexplored in the neurology field. These studies have tried manipulating the gamma brain waves (Rakhshan et al., 2022) or theta, beta, and gamma brainwaves (Ingendoh et al., 2023). While these studies did prove to be partially successful, drawbacks of the studies include the testing strategy and how they failed to implement binaural beats for a sufficient period, as well as the EEG technology used. Using music frequencies, instead of regular frequencies, could provide an approachable and easily accessible way to mitigate symptoms.

Frequencies of music that reflect theta and beta waves with the difference in binaural beats are projected to cause the most reduction in ADHD symptoms in this study. Audio software, such as Audacity, will be used to find the frequencies in the most popular genres of music, with 3 random songs from each. This study could further the research in decreasing ADHD symptoms, and lead the way in using binaural beats as a way to do this.

EEG technology will be used to study and examine the brainwaves of individuals, which is a core part of this study,

Section II: Specific Aims

The main objective of this project is to decrease the abnormal brain waves of ADHD patients using music as a direct method for binaural beats. The final product will define a specific genre of music to listen to to cause a change in brainwaves. The reasoning behind this is as follows:

Specific Aims 1: Find a correlation between music and binaural beats, with music being a compatible input in binaural beats.

Specific Aims 2: Define and execute a method of testing the effectiveness of binaural beats on ADHD patients, in an efficient and standard method.

Specific Aims 3: Find and measure the effectiveness of a genre of music that best decreases the beta and increases theta waves of ADHD patients and compare this to other methods of mitigating symptoms.

Section III: Project Goals and Methodology

Relevance/Significance

The methods for reduction of ADHD symptoms, such as fidget toys or medication, often have costly effects, whether it is in terms of money, or health related to the medication. The medication consists of side effects such as decreased appetite, difficulty sleeping, headaches, and stomach aches (*ADHD Medications Can Cause These Side Effects*, 2019) The average adult spends about $14,000 on medication (McKenna, 2023.).At a social level, the price to pay for having the disorder costs $122.8 billion, with excess unemployment and loss of productivity as

a result of the symptoms associated with the disorder (McKenna, 2023.). With this study, the objective is that a correlation between music and changing the brainwaves, specifically of ADHD patients, is found and measured to find the optimal genre of music to listen to act as a way of mitigating symptoms. By using music to mitigate symptoms, the intention is that a cost-effective solution is found. This would overall help decrease the average amount of money ADHD patients have to spend on mitigating their symptoms, making treatments of the disorder more accessible.

Binaural beats have been done solely with focused frequencies and the impact on ADHD has been studied solely; however, using music to do this induces more of a progression in terms of how binaural beats can be applied and its impact on everyday life.

This overall study can also be applied to music therapy, and help enforce various methods to help the brain relax or calm down.

Innovation

There are various methods to treating ADHD symptoms, such as medication and fidget toys, however music has not been used or prioritized as a main treatment for the disorder. This study serves as a way to present a certain genre of music that the patient can listen to to mitigate their symptoms. In correlation to this, binaural beats is the method used to determine how music will have an impact on the symptoms of ADHD patients by manipulating their brainwaves.

In the past, studies have used focused frequencies as a way to use binaural beats; however, this study prepares to use music (containing multiple frequencies at a time) for

binaural beats (Bakhshayesh et al., 2011). This method progresses the research and course of study for binaural beats.

Methodology

The experiment consists of two groups, one that does have ADHD (experimental group), and one that does not (control group). Both groups will take a survey before and after the experiment consisting of questions related to ADHD symptoms. They will also have their brain waves tested directly before the experiment is done. During the experiment, EEG technology will be used to test their brain waves as they are listening to a song from a specific genre of music, using binaural beats to simulate this. There will be 5 trials done for each subject, with about 8 minute sessions of listening to a specific genre of music. Their brainwaves, specifically the ones known to cause ADHD (beta and theta waves, though gamma waves will also be measured), will be analyzed before and after the experiment to conclude any impacts the music may have made. Since ADHD is more prevalent or has the majority of its symptoms affected in the prefrontal cortex of the brain, this area will be prioritized and focused on during studying to determine the impact on ADHD (Browdey, 2023). The survey will also be used to conclude this:

1. IDV: Frequencies in genres of music-song played
2. DV: Brain waves of individuals being tested
3. Control: Trails (and time) run per subject, technology used, standard frequencies used
4. Experimental: Individuals with ADHD
5. Control groups: Individuals without ADHD
6. Iterations: 5 10 minute trials per person

Specific Aim #1:

Find a correlation between music and binaural beats, with music being a compatible input in binaural beats.

Justification and Feasibility. Previous studies have used focused frequencies (one specific frequency on playing on one ear and a different frequency playing on the other ear (Bakhshayesh et al., 2011). The differences between these specific frequencies agreement produced as a brain frequency, which then correlates to a brain wave produced). However, how music fits into binaural beats is still unknown. At its core, music is made up of a series of frequencies, playing at once (Hz, 2020). There have been studies conducted that have explored the different variations of frequencies or inputs that can be used in binaural beats, testing its effectiveness in intelligence tests (Klichowski et al., 2023). These tests consisted of Raven's Progressive Matrices (RPM) and Matrix Reasoning Item Bank (MRIB) and were used to measure the effectiveness of the binaural beats. The participants of the study were randomized and split into three groups, which determined the binaural beat exposed to.

The first group listened to focused frequencies of binaural beats (kept constant in all groups), the second group listened to neutral sounds, and the third group listened to binaural beat frequencies with nature sounds (stimulating sounds) in the background. The third group is used to simulate the effectiveness of binaural beats if there are other multiple frequencies playing at the same time. The results of the study consisted of the binaural beats indeed having an overall impact on the score of the two intelligence tests, demonstrating their significance in changing the brain waves to impact the results of cognitive functions. However, as shown on the figure below, when exposed to neutral and stimulating sounds, there was a greater impact

negatively on the scores when compared to that of the average score (all participants took the intelligence tests before the experiment) and the focused frequency of the binaural beat. This overall demonstrates the possibility that using binaural beats, while listening to other frequencies at the same time, can weaken cognitive activities (Klichowski et al., 2023) Due to the fact that music is still made up of frequencies, which is what binaural beats used to overall change the brain waves of a subject, we can still use music and the difference between certain frequencies playing at one point in the music.

Summary of Preliminary Data. The patient was subject to binaural beats for 8 minutes. The patient was subject to 220 Hz and 198 Hz for 8 minutes, with a 240 Hz control. The goal of this test was to ensure that frequencies could be used to induce beta waves and therefore induce concentration. The nodes 1 and 2, which align with the prefrontal cortex of the brain, were studied. It was found that beta waves were produced, demonstrating how frequencies can be used to induce binaural beats and concentration.

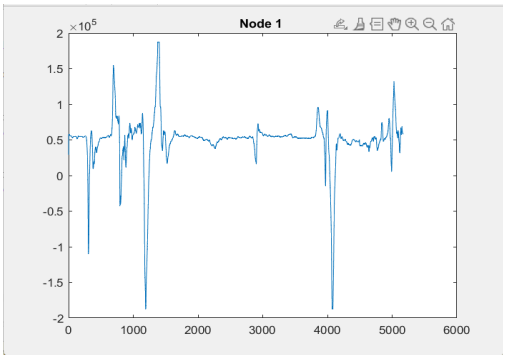

Figure 5. Results of preliminary data depict beta waves in the prefrontal cortex of the patient's brain after being exposed to binaural beat frequencies.

Expected Outcomes. The overall outcome for this aim is to ensure that music can be used as a method for binaural beats. This is predicted to be true. This knowledge will be used to

then test different genres of music with binaural beats and determine the genre that generates the greatest change/desirable change in brain waves for ADHD patients.

Potential Pitfalls and Alternative Strategies. Expected pitfalls consist of the differences between the two different groups of frequencies being hard to distinguish. An alternative strategy would be to test two specific frequencies from the music at one point. However, this comes with the pitfall of the other frequencies, making it harder for the participant to properly distinguish the two frequencies that will be subject to binaural beats, as shown in the study mentioned in the section above by Klichowski et al., unless more prominent frequencies that can be heard are used. As shown in the study, using binaural beats while also having multiple frequencies playing at once, caused a decrease in cognitive activities, which is a problem since our goal is to increase cognitive activities overall in order to help the student enhance better. Though, as a solution, we can focus the effect of the binaural beats on one region of the brain that has heightened beta and theta brain waves in order to overall decrease ADHD symptoms.

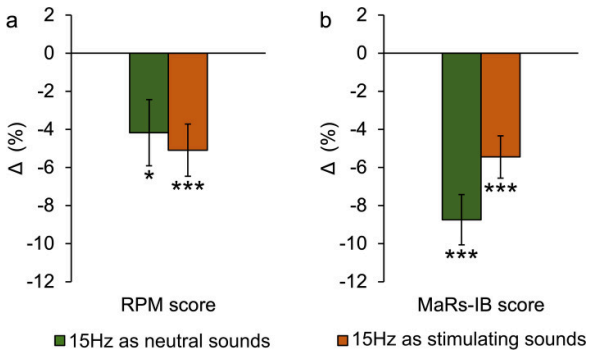

Figure 2. Change in average test results after one group was exposed to binaural beats with stimulating sounds and another group was exposed to binaural beats with neutral sounds. (Klichowski et al., 2023)

Specific Aim #2:

Define and execute a method of testing the effectiveness of binaural beats on ADHD patients, in an efficient and standard method.

Justification and Feasibility. Binaural beats is a method of neurofeedback used to change brain waves of a participant. While there are a lot of tests using the method, there are several different testing strategies. Each testing strategy of binaural beats comes with differences in how long the participant was subject to the binaural beat frequency, at which point during the study was the EEG used (during or after binaural beats), and the frequencies of binaural beats used. This can lead to discrepancies in the impact binaural beats have on the brain. To find the standard test that should be conducted, a study was done (Ingendoh et al., 2023) in which data of the studies on binaural beats was sorted through to find the number of studies that had successful results and the average testing strategy among them. The successful studies all consisted of having 5-minute or longer periods of binaural beat usage, with a specific range of frequencies tested and the EEG being used after the usage of binaural beats (Ingendoh et al., 2023). Another study proving a similar topic concludes that exposing the subject to the binaural beats before, and during the task produces better results overall and that higher time is optimal. This helps us define the testing strategy and show how certain methods for testing are most optimal. (Appendix 1. Data on Specific Aim #2)

Summary of Preliminary Data. The patient was subject to binaural beats for 8 minutes. The patient was subject to 220 Hz and 198 Hz for 8 minutes, with a 240 Hz control. The goal of this test was to ensure that the testing strategy was able to properly project the expected result, which consisted of beta waves in this case, under a specific amount of time.

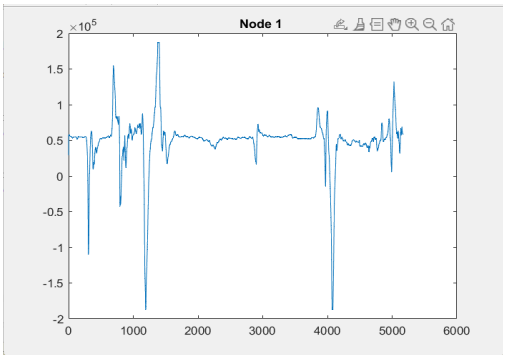

Figure 6. Results of preliminary data depict beta waves in the prefrontal cortex of the patient's brain after being exposed to binaural beat frequencies.

Expected Outcomes. The overall outcome of this aim is for the testing strategy defined to be similar or within the range of other testing strategies used, and overall be successful in terms of using binaural beats to demonstrate its impact on ADHD (all using frequencies as a basis for studying its impact). This would later be used as a control to compare its impacts to that of genres of music when using binaural beats to change the brain waves of ADHD patients.

Potential Pitfalls and Alternative Strategies. Some of the overall pitfalls include lots of variables that can each determine the effectiveness of the test and binaural beats in general. To mitigate this, an analysis of the most important variables will be taken into account with first priority, meaning we would be optimizing their usage in the testing strategy without focusing on the smaller variables to get the most optimal result.

Specific Aim #3:

Find and measure the effectiveness of a genre of music that best decreases the beta and increases theta waves of ADHD patients, and compare this to other methods of mitigating symptoms.

Justification and Feasibility. As stated previously, binaural beats is a method of neurofeedback in which the brain waves of the user are altered according to the differences in frequencies presented. While the participant is subject to binaural beats, we can focus on one region of the brain to study, in which the prefrontal cortex would be studied due to its impact on ADHD (*Adult Attention-Deficit/Hyperactivity Disorder (ADHD) - Symptoms and Causes*, 2023). Other studies have used binaural beats (focused frequencies) to mitigate the symptoms of

ADHD patients in the past. One specific study has used meta-analysis to find the effective studies that test the impacts of binaural beats on memory, attention, anxiety and, analgesia (inability to feel pain) (Garcia-Argibay et al., 2019). These all consist of some of the symptoms of ADHD. The study concludes that 22 studies met the inclusion criteria. The authors concluded that exposing the subject to the binaural beats before and during the task produces better results overall and that higher time was optimal. The study states that binaural beats, with certain criteria already mentioned above, is an effective way to impact cognition, reducing anxiety levels, and inducing analgesia, with its magnitude being determined by the outlined criteria. These studies provide justification as to why ADHD can overall be impacted by binaural beats, as long as it is the specific criteria outlined in the testing strategy when the user is exposed to binaural beats. We can then test different genres of music, which all consist of different frequencies that allow each to have their different sound, and test their impactfulness on mitigating ADHD symptoms. (Garcia-Argibay et al., 2019)

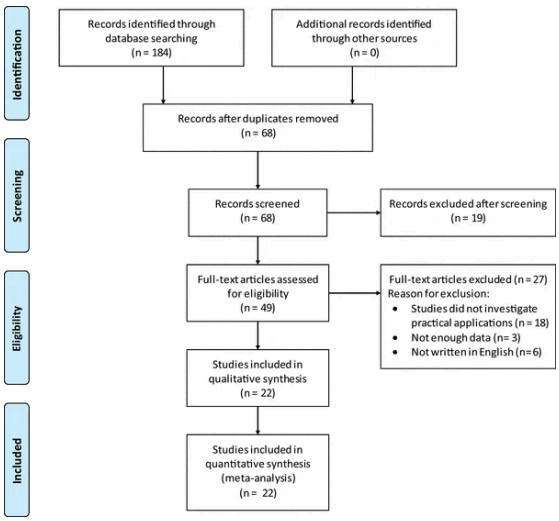

Figure 4. Flowchart of literature search in the meta-analysis (Garcia-Argibay et al., 2019)

Summary of Preliminary Data. The patient was subject to binaural beats for 8 minutes. The patient was subject to 220 Hz and 198 Hz for 8 minutes, with a 240 Hz control. The goal of this

test was to ensure that concentration increased and a lack of focus would be decreased (ADHD symptom) by inducing beta waves in the brain. This was in fact successful, and beta waves were produced after this test.

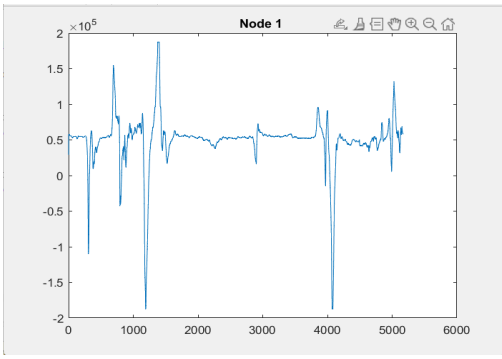

Figure 8. Results of preliminary data depict beta waves in the prefrontal cortex of the patient's brain after being exposed to binaural beat frequencies.

Expected Outcomes. The overall aim of this specific aim is to define the impact and compare the impact genres of music have on mitigating ADHD symptoms. It uses the previous specific aims to test and measure the changes in brain waves determined by the EEG once the user is exposed to the genres of music.

Potential Pitfalls and Alternative Strategies. This comes with the specific pitfall of trying to focus on trying to measure the decreases in multiple ADHD symptoms. To reduce confusion and mitigate this, we could focus on how the user responds overtime using the questionnaire, and try to focus on one specific symptom at a time.

Section IV: Resources/ Equipment

There are various resources that will be used to fully achieve this project, all of which are detailed below:

1. OpenBCI 8-channel Cyton Biosensing Board
2. Auditory Listening Device that can achieve binaural beats
3. Audio software that is able to use specific frequencies

Section V: Ethical Concerns

Since we are testing on human beings, there is a risk in the health and safety of these individuals. The EEG technology we will be using consists of a OpenBCI 8-channel Cyton Biosensing Board. It is designed with a PCB capture program. The voltage regulation for this board is 3.3V, +2.5V, -2.5V, with an input range of +2.5 to -2.5V, and a voltage resolution of 0.298 microvolt/bit (5V/16777216) (Cyton Specs: OpenBCI Documentation., 2023). This voltage is known to cause no harm to participants. EEG technology is a safe procedure which does not produce sensation, there is no risk of getting an electrical shock with the device. (Electroencephalogram (EEG), 2021)

Section VI: Timeline

1. 12/6/23-Preliminary data will be tested
2. 12/8/23-Specific Aim 1# will be analyzed and achieved
3. 12/22/23-Specific Aim 2# will begin
4. 1/07/23-Specific Aim 1# will be analyzed and started on
5. 2/9/24-All data will be received
6. 2/13/24-All conclusions will be made

Section: VII: Appendix

Ingendoh, R. M., Posny, E. S., & Heine, A. (2023). Binaural beats to entrain the brain? A systematic review of the effects of binaural beat stimulation on brain oscillatory activity, and the implications for psychological research and intervention. *PLOS ONE*, *18*(5), e0286023. —Table - PMC (nih.gov)

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