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Brainwave Music: A Scientific Review of Psychological Effects and Future Innovations

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Abstract

This literature review introduces brainwave music (BWM), a revolutionary type of music generated using digitally filtered brainwaves as displayed in electroencephalography (EEG) impulses. The review summarizes the previous studies on the applications of BWM in different fields and presents a vision for future innovative uses. The review also explains how EEG data is used to map mental state to music with similar arousal levels, and how BWM can be used in clinical or psychological settings. Additionally, the review discusses how brainwave music can have positive effects on various mental states such as anxiety, sleep, and more. The review also highlights the importance of portability and operability in future brainwave music applications, and the potential for incorporating visual elements such as video and flashes to enhance the experience. Overall, brainwave music combines neurology, science, and music therapy to improve focus, energy, stress, anxiety, pain, and sleep.

Keywords: Brainwave Music, Brainwave, Music Therapy, EEG Study, Disease

1. Introduction

For the past three years, the COVID-19 epidemic has continued to affect all aspects of the world. For the student population, the change in the learning environment from campus to home is certainly a challenge. It is an urgent need for students to be able to maintain the same state of learning at school and to avoid the limitations of online teaching (e.g., teachers are forced to reduce their supervision) that can affect their learning outcomes. It has been observed that during the COVID-19 epidemic's home study, prolonged internet usage for leisure and inadequate learning surroundings that caused constant interruptions were factors on students' learning. In response to this

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need, brainwave music lists and videos, which are claimed to be one of the approaches that are able to "promote concentration and improve learning efficiency", are popular among users. Compared to medication, it is non-invasive and does not have side effects. In contrast to exercise or nutrition, it often provides immediate effects. Brainwave music (BWM) is also more portable and versatile than traditional methods, such as study groups or tutors, as it can be used anytime, anywhere, and for multiple purposes. Overall, brainwave music offers a unique and effective solution for those seeking to enhance their cognitive abilities. This literature review will introduce brainwave music and summarize the applications of brainwave music in different fields based on previous studies. Finally, the paper will present a vision of future innovative applications of BWM.

2. Definition

BWM is a revolutionary type of music generated using digitally filtered brainwaves, as displayed in electroencephalography (EEG) impulses, in accordance with certain translation criteria. (Huang et al., 2016) The brainwave is described as an arhythmic electric potential between nerve cells, also known as neurons, and is expertly caught by EEG apparatus (Rodgers, 2011). EEG is the recording of electrical activity generated by the firing of neurons in the brain along the scalp. In clinical situations, EEG refers to the recording of the spontaneous electrical activity of the brain during a specified time period (Cohen, 1996).

3. History

In the second part of the 19th century, the physiologist Etienne-Jules Marey pioneered the graphic way of capturing diverse physiological data, ushering in the era of imaging methods. Hans Berger, a German psychiatrist, presented the first study on human EEG in 1929 by capturing scalp-layer electrical waves with a non-invasive probe.

Edgar Adrian, a renowned neurophysiologist and Nobel winner, duplicated the experimental results of Berger's rhythm in 1934 by translating EEG impulses to sound signals and playing them via a loudspeaker. What is its sound? Similar to audio signals, brain waves are frequency-varying sequences of time. Humans make sounds in the frequency range of 20 to 3000 Hz, primarily in the 100-300 Hz region, while the vast majority of musical instruments create hundreds of hertz notes. In contrast, scalp-collected EEG signals are mostly concentrated in the 1-100 Hz frequency range, and their power spectrum decays fast with increasing frequency. If the EEG signal is immediately played as an audio file, it sounds like an inconsequential low-frequency rumbling. In the beginning, due to the limits of signal processing technology, the EEG signal frequency could only be boosted by multiplying by a particular amount to make it audible to the human ear.

Beginning in the 1950s, developments in signal processing led to considerable improvements in the analysis of EEG data, establishing the groundwork for the production of brainwave music. The world's first brainwave music was made in 1965.

Music for the single performer, the world's first brainwave music, was launched in 1965 and performed throughout Europe and the United States. Edmond Dewan, a prominent physicist, and Alvin Lucier, an experimental musician, collaborated to build a system that employed alpha waves in the brain to control the sound of percussion instruments, which were produced and performed by Alvin Lucier's brain waves. The Musical Instrument Digital Interface (MIDI) was established in the 1980s in order to tackle the problem of communication between electro-acoustic instruments (Mangieri, 2022). Towards the close of the twentieth century, advancements in EEG and sound technology led to the construction of the Brain-Computer Music Interface (BCMI), which, for instance, controls the playing of complex instruments using EEG. By mapping the signal properties of EEG to pitch, timbre, and tone in music and recompiling them into MIDI format, brainwave music became more accessible and agreeable to the ear.

4. Current Theory

Scale-free BWM formed from EEG data according to the power law of both EEG and music has the features of both music and EEG and may contain physiological information that music alone may not (Wu et al., 2010, 2014; Lu et al., 2012).

As it has been reported that music with specific pitch or rhythm characteristics effectively promotes brain function (Adalarasu et al., 2011), perhaps in a manner similar to sound resonance, BWM created by relaxed-state EGG signals may also induce such activities in the brain and prompt specific brain function, resulting in an improved mental or emotional state (Fedotchev and Radchenko, 2013).

Table 1: Frequency Range - State of Mind

Beta 12Hz-38Hz	Wide awake state
Alpha 8Hz-12Hz	Awake but relaxed.
Theta 3Hz-8Hz	Light sleep or extreme relaxation.
Delta 0.2Hz-3Hz	Deep, dreamless sleep.

Table 1 describes different brain wave frequencies measured by EEG and the states of consciousness associated with them. Beta waves, which have a frequency range of 12Hz-38Hz, are associated with the wide awake state. Alpha waves, which have a frequency range of 8Hz-12Hz, are associated with being awake but relaxed. Theta waves, which have a frequency range of 3Hz-8Hz, are associated with light sleep or extreme relaxation. Delta waves, which have a frequency range of 0.2Hz-3Hz, are associated with deep, dreamless sleep.

The resonance of the head caused by the sound waves generated by music generates alpha brain waves that can loosen up the mood, have self-healing ability, have a high immune status, and slowly release morphine in the brain. These waves, which are referred to as healthy waves, are capable of promoting self-healing and have a high immune status. Pang Jun found in "Modern medical clinical non-pharmacological therapy of insomnia profile" based on studies and clinical performance that activation of lower frequencies, light, and rhythmic sound induces a calm state in human brain waves.

In "Overview of Clinical Non-pharmacological Treatment of Insomnia in Modern Medicine," it was concluded from the experimental and clinical performance that stimulation of low frequency, light, and rhythmic sound induces patients to reach a state of relaxation and eventually sleep (Pang, 2005). In "On the Psychotherapy Function of Music," it is said that music therapy has evolved from a tool for entertainment to a tool for enhancing mental state and quality of life with psycho-therapeutic functions (Ge, 2006).

5. General use

Brainwave Entrainment (BWE) is a technique that uses auditory tones, flashing lights, or a combination of both, in conjunction with isochronic, monaural, or binaural beats, to stimulate the brain at the correct frequency. Isochronic tones are evenly spaced tones that alternate between being on and off. Monaural and binaural beats are delivered as two tones with very similar frequencies, and the brain detects a beat corresponding to the pitch difference between the two tones. The pitches are delivered simultaneously with monaural beats, but each ear is supplied with binaural beats individually. Therefore, when listening to brainwave music containing binaural beats, it is recommended to wear headphones or similar music playing devices to achieve the best relaxation effect.

The process of creating music using BWE is illustrated in Figure 1, with the blue arrow representing the conceptual framework and the yellow arrow representing the actual implementation in this study. Using arousal as a bridge, EEG data is collected as a reflection of mental state and mapped to the parameters of music with similar arousal levels, according to a two-dimensional model of mood. The creation of music consists of five steps, as shown in Figure 2: 1) extracting EEG signal characteristics, 2) defining music segmentation (factors: main note, tone, and rhythm cadence) based on relevant EEG features, 3) building music bars (parameters: chord and note location) based on EEG features and song segment parameters, 4) setting properties of notes (timbre, scale, duration, and loudness) based on bar parameters, and 5) constructing the music melody using a program. The choice of feature extraction technique can affect the meaning of the resulting music, and any rule shared by brain function and music can serve as a suitable bridge between brainwaves and music. (Wu et al., 2010)

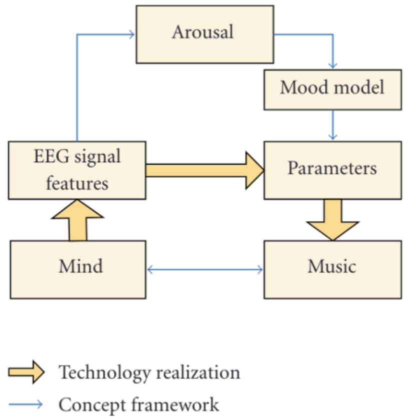

Figure 1: Overview of the brainwave music generation (Wu et al., 2010)

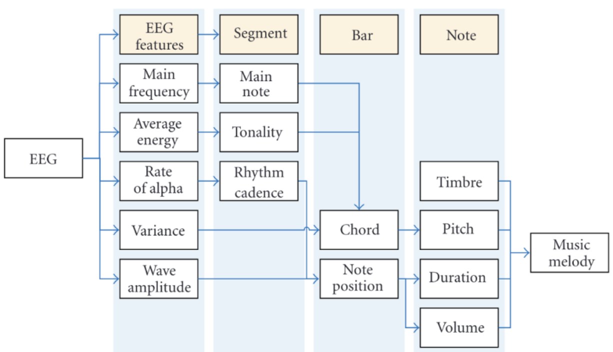

Figure 2: Mapping rules from EEG to music (Wu et al., 2010)

The technical level now attained in computer-assisted imaging elaboration as well as in the employment of novel methods of analysis has sparked significant fresh interest in both the theoretical analysis of the therapy and its clinical applications.

6. Methods

In order to conduct a thorough review of the existing literature on brainwave music, a comprehensive search strategy was employed, and total 50 works were eventually reviewed. A total of ten databases were utilized, including WorldCat, PubMed, Paddyfield, CampusWell, SageJournal, ESource, CNKI, Wanfang database, ScienceDirect, and Frontiers. The search was limited to articles published in English, with a few exceptions for articles written in Chinese and German. The search terms used included *brainwave music, music therapy, stress management, attention performance, neural entertainment, EEG analysis, music stimuli, emotion perception, musical emotion, neural plasticity, binaural beats, monaural beats, isochronic beats, isochronic tones, brainwave entertainment, brain stimulation, photic stimulation, audio-visual entertainment, AVE, brain AND entertainment, afferent sensory stimulation, sleep, and sleepiness.*

The selection criteria for the articles included in this review were as follows: (1) the article must address brainwave music or a related area of expertise; (2) the article must include an experimental study with a comparison group or a pre-test/post-test design; (3) the study must assess clinical or psychological outcomes using valid and adequate test techniques; (4) the study must provide enhanced statistical data, including descriptive statistics and analysis, as well as figures and tables to illustrate the outcomes.

In addition to the articles retrieved through the literature search, a song list of brainwave music provided on the network platform was also chosen to test the application of brainwave music at this stage. A total of 20 brainwave music playlists were selected from three audio-video platforms: QQ music, Netease cloud music, and

Youtube. After excluding the overlapped singles, ten complete playlists were compiled, with a total of 182 audio tracks.

The number of samples collected in the studies included in this review varied, and the filtration method used to narrow down the key resources adopted for the research was not specified in all of the studies. However, the selection criteria outlined above were used to ensure that only high-quality, relevant studies were included in this review.

7. Results

7.1 Cognitive

Multiple types of research have demonstrated that musical compositions and deep brain stimulation have a beneficial facilitative influence on people's cognitive behavior. The primary areas affected were attention, productivity, cognitive ability, and academic achievement. Five of the research were done on children and adults with attention deficit hyperactivity disorder (ADHD). At the same time, the remaining investigations were conducted on college students or persons employed in a particular field.

According to studies using modified visual oddball tasks (Kilmesch et al., 1998), desynchronization in the lower alpha band reflects attention, whereas desynchronization in the upper alpha band represents semantic memory performance. Theta band synchronization also reflects episodic memory and the encoding of new information (Buzsaki et al., 1994). Two studies examined the effect of photic stimulation with or without electrodermal stimulation (EDR) at various frequencies on general intelligence or grade point average (GPA). The research recruited youngsters with ADHD or college students with "academic problems" and found that stimulation of 14 Hz alternating with 22 Hz25 or 12 to 14 Hz over numerous sessions increased GPA or the Scholastic Achievement Wechsler Individual Achievement Test substantially.

In addition, research indicates that rhythmic classical music might reduce the tension associated with number crunching and lead to more reasonable customer decisions. (Feng et al., 2014). Math-averse consumers shun alternatives requiring pricing calculations. Intriguingly, these customers experience less arithmetic anxiety when classical music with a moderate pace is playing in the background. Nonetheless, in the absence of background music or when the speed of such music is rapid, people with high math anxiety avoided decisions involving pricing computations more.

The influence of background music on listeners' attention test scores increases with the intensity of listeners' perception of background music relative to the absence of background music, according to studies. (Huang & Shih, 2011) Therefore, lyrics and melodies that tend to attract the listener's attention should not be included in music used for work or study. Brainwave music, as pure music with a tranquil melody and strong rhythm, successfully circumvents the ban on working background sound and may play a more significant role in stimulating thought.

Evaluation of the influence of an external element, particularly music playing, on the execution of a task requiring significant concentration. (Mori, 2014) The result suggests that listening to the favorite music condition improves overall performance since it decreases the number of instances in which the subject is unable to locate the exceptional indication and takes an abnormally long time to complete the trial.

7.2 Stress and Anxiety

Brainwave music has substantial impacts on compulsiveness, interpersonal relationships, sadness, anxiety, anger, paranoia, and psychoticism. It was determined that there was no interaction between the gender factor and the effect of brainwave music; it was also determined that the effect of brainwave music on the emotional state of college students was significantly different in the music cultivation dimension; based on these results, it was determined that there was no interaction between the gender factor and the effect of brainwave music.

In the relaxation curve experiment, the brainwave music group demonstrated a progressive increase in the overlap. In contrast, in the control group (refers to the Youth Digest and French News group), there was no discernible trend of change. In conclusion, the regularity and consistency of the integrated relaxation curve in the brainwave music group suggests that brainwave music may induce a calm state in each experiment's individuals.

In addition, researchers have discovered that healthy persons may utilize music to reduce stress through music creation, drumming, and passive listening. It can also provide essential assistance for physical activity (Parambi & Prabhakar, n.d.).

The research on the extended length of brain functional cortex (FC) in response to music, network density, and the number of brain connections in the Music Listening Group revealed substantial changes not only in the general connectivity but also in specific frequency bands, such as the delta, alpha, and beta bands. This alteration implies an improvement in the subject's level of relaxation, attentiveness, mental exertion, and awareness. (Mahmood et al., 2022) Long-term research on the effect of music listening on the human brain reveals that the FC in the frontal and parietal lobes within the alpha and theta frequency bands significantly increases, while the FC in the frontal, temporal, and occipital lobes within the beta frequency band significantly decreases. This rise in alpha and drop in beta FC shows that the individual has been relaxed (Kim et al., 2014).

Brainwave entertainment employing binaural beats significantly reduced state anxiety and trait anxiety in 30 engineering research firm employees who listened to non-vocal music for four weeks, three times per week. Every session lasted around 20 minutes. This indicates that brain wave coordination through alpha and beta sounds in relation to stress condition and stage is effective and can be used as a non-invasive method for controlling and reducing stress among patients in clinics and treatment centers, by psychologists, counselors and psychiatrists. (Alipoor et al., 2014).

7.3 Pain

In 2016, researchers studied the impact of brainwave music on alleviating orthodontic discomfort. 36 individuals matching for age, gender, and anxiety/pain levels were randomly allocated to either the BWM (N=12), CBT (N=12), or control (N=12) groups (Huang et al., 2016). The BWM group's baseline resting EEG data were transformed into BWM. During the first week following orthodontic appliance insertion, EEG signals and pain perception (as measured by the Visual Analog Scale, VAS) were collected for each participant. Multiple methods were used to evaluate EEG data.

Ultimately, the BWM and cognitive behavioral therapy (CBT) groups had significantly reduced pain perception compared to the control group, demonstrating that BWM is beneficial in managing orthodontic pain, presumably by restoring functional connections and brain regularity impacted by pain (Huang et al., 2016).

In a different research, participants with bruxism and myofascial pain dysfunction syndrome were given isochronic tones of constant frequency and duration that were modified and chosen by the patient, as well as electromyographic (EMG) feedback (Manns et al., 1981). The subjects noticed much-reduced discomfort and muscle spasms in the temporal mandibular joint after three weeks.

7.4 Sleep

A 2020 study demonstrated that slow-wave sleep brain-wave music may have a good impact on sleep quality, whereas rapid eye movement (REM) brain-wave music or white noise may not (Gao et al., 2020). Reducing the power spectral density of the delta band of EEG and increasing the functional connection between the left frontal lobe and the left parietal lobe may also contribute to improved sleep quality. As a form of musical stimulation, researchers created two forms of scale-free brain-wave music, one from the REM stage and the other from the SWS stage. Deep sleep can predict sleep satisfaction and is a representative indicator of sleep quality (Riedel and Lichstein, 1998), so for EEG analysis, we primarily analyzed the power spectrum of EEG during deep sleep and investigated the neural mechanisms of this two brain-wave music on sleep promotion from an EEG standpoint.

Another 2014 study intends to determine if the sleep quality of elite athletes may be enhanced by auditory brainwave entertainment and if this leads to improvements in post-sleep psychophysical states (Abeln et al., 2014). In preliminary research, 15 teenage top soccer players slept with binaural beats between 2 and 8 Hz for eight weeks. Only the intervention group saw a substantial improvement in subjective assessments of sleep and waking quality, tiredness, and motivational mood, although this did not affect their reported physical condition. In conclusion, eight weeks of auditory stimulation with binaural beats increased athletes' perceived sleep quality and post-sleep condition. In contrast, the effect on the physical level is assumed to be delayed.

A 2019 study revealed that binaural beats paired with Autonomous Sensory Meridian Response (ASMR) and calibrated to the optimal frequency (6 Hz binaural beats and ASMR triggers) have the most significant sleep-inducing effects and send the user to a state of psychological relaxation the quickest. (Lee et al., 2019)

8. Limitation

The current body of research on the impact of brainwave music on cognitive function is constrained by a number of methodological considerations. One of the most significant limitations is the lack of standardization in the techniques employed to generate and administer brainwave music. Studies have employed a wide range of frequencies, amplitudes, and durations of stimulation, which makes it challenging to make cross-study comparisons. Furthermore, the sample sizes of many studies are relatively small, which can restrict the generalizability of their findings.

Another limitation is the absence of a widely accepted methodology for assessing the effects of brainwave music on the brain. Studies have employed a range of neuroimaging techniques, such as EEG, fMRI, and PET, which can make it difficult to compare results across studies.

Finally, a paucity of long-term studies exists on the effects of brainwave music on cognitive function. Most studies have focused on short-term effects, and it remains unclear how these effects may change over time.

Despite these limitations, the available literature suggests that brainwave music holds promise as a tool for modulating brain activity. However, further research is needed to more fully understand the effects of brainwave music on cognitive function and to develop effective protocols for its use.

9. Future Use

As a burgeoning field of study, brainwave music has future research depth and application potential. Currently, brainwave music is predominantly used in audio tracks produced on music platforms and videos released on video platforms (e.g., youtube). If brainwave music is expanded to offline or immersive experiences, it will contribute considerably to the fusion of art and science.

Thus far, research has investigated the visualization of alpha brainwave music (Yu, 2020). Several methods for enhancing the immersive presentation of alpha-brainwave music were suggested by the research.

Immersive experience refers to the total immersion of the person, giving them the impression that they are in the virtual world.

Virtual reality expression is characterized by the immersive experience; immersion is the process by which the brain is impacted. It achieves the audience's conscious acceptance of more emotional input to the current events by shortening the spatial distance between the viewer and the displayed body, which is a kind of total attention in a state of forgetfulness and mental engagement, from experiencing the course of development, change, and transition therein. Virtual reality subverts the adage "seeing is believing" and breaks the incoherence of the senses created by the conventional medium of information transmission. Virtual reality creates illusions of reality through technological techniques, activating the viewer's entire body organ perception.

In recent years, as new media art has evolved, an increasing number of artworks have utilized immersive experience exhibitions to bring the audience closer. The use of surround projection and L-shaped folding projection enhances the sense of immersion in the exhibition hall, and the atmosphere created by isolating the audience from the outside world causes them to forget their original identities and enter the scene space to participate in the experience. The genuine effect of the immersive displays "TeamLab Future Amusement Park," "Feeling is Real," "I Have a Dream," "Rain Room," "Datamatics," and "Leonardo da Vinci" is warmly appreciated by the audience. The visualization of alpha brainwave music and the immersive display are constructed in public spaces or art treatment facilities for persons under stress.

The objective of VR technology is to replicate a virtual environment in three dimensions on a computer. The user then enters the virtual realm using specialized sensing equipment to produce a novel perceptual experience. Users of VR devices may experience 3D space through visualization, 3D surround sound, and real-time interaction with the virtual world. Using this technology, an Alpha brainwave music visualization design can produce a personal immersion experience; portability and operability are more important than in the case of a physical immersion experience.

In addition to the use of brainwave music in public art facilities, which can play an anxiety-relieving and calming role, it is also possible to innovate on existing video and audio formats to create an "immersive" sense of the scene. After collecting "concentration aid" videos from different video platforms, it was found that not all videos with the term "brainwave music" in the title were using regular and effective brainwave music. In addition, the video images are relatively single, mostly illustrated animation or landscape pictures. In future use, the video images can be combined with more visual stimulation methods used in deep brain stimulation experiments, such as regular flashes, and with playback devices such as headphones, to achieve simple brain wave activation. The changing learning environment of home learning has led to a greater reliance on such artificial tools to aid concentration and sleep, so it is also important to take into account the freshness of the video format to avoid becoming immune to such stimuli through repeated use.

Using the principle of neurofeedback, a personal and unique induction learning environment is customized to help users regulate their mental state and promote learning effectiveness. For example, do cross-border commercial cooperation with time management and efficiency-enhancing APP applications to produce similar focus-inducing devices and promote them in the market so that concentration applications provide more than just white noise.

However, BWM faces some limitations and challenges in its implementation and widespread use. One of the main challenges is the technology required for EEG data recording and analysis, which can be expensive and difficult to use, making widespread implementation a challenge. Another challenge is the lack of standardization in the mapping of EEG data to music, making it difficult to compare results across different studies and applications. Additionally, while there have been some studies suggesting the potential benefits of brainwave music, more rigorous and extensive research is needed to establish its efficacy and determine the best methods for using it. Personalization is also a challenge, as EEG signals can vary greatly between individuals, making it difficult to create a one-size-fits-all solution for brainwave music. Furthermore, brainwave music is a relatively new and unconventional approach, and it may take time for it to be widely accepted and adopted. Overall, it is important to approach the development and implementation of brainwave music with caution and to carefully consider these limitations and challenges.

10. Conclusion

Brainwave music, as a scientific product that covers a variety of cognitive science, music therapy, neuroscience, and other fields of knowledge, will be a tool that cannot be ignored in the future to regulate both physical and mental states. It has been proven to prolong and improve concentration, enhance mental energy, reduce stress and anxiety, reduce pain, and induce sleep. Nearly fifty selected papers have conducted scientific and systematic experimental studies on brainwave music or various research areas related to it (e.g. music therapy) to confirm the relevance of these indicators. In the context of the increasing pursuit of virtual context in modern times, future applications of brainwave music may focus on creating a "sense of context" to serve the user in a way that constructs a comfortable space, either real or virtual. The future application of brainwave music will be in a wide range of situations, including classrooms, libraries, wards, offices, fitness centers, airplains, etc.

References

Abeln, V., Kleinert, J., Strüder, H. K., & Schneider, S. (2014). Brainwave entertainment for better sleep and post-sleep state of young elite soccer players – A pilot study. *European Journal of Sport*

Science, *14*(5), 393–402.

Adrian ED, & Matthews BH. (1934). The Berger rhythm: potential changes from the occipital lobes in man. Brain, 57(4), 355-385.

Alipoor, A., Oraki, M., & Sabet, M. Y. (2014). Efficiency of brainwave entertainment by binaural beats in reducing anxiety. *Journal of Kermanshah University of Medical Sciences*, *18*(1), Article 1.

Casciaro, F., Laterza, V., Conte, S., Pieralice, M., Federici, A., Todarello, O., Orsucci, F., & Conte, E. (2013). Alpha-rhythm stimulation using brain entertainment enhances heart rate variability in subjects with reduced HRV. *World Journal of Neuroscience*, *03*(04), 213–220.

Curtis, D. (2022). *BINAURAL BEATS, BRAIN WAVE entertainment AND THE HEMI-SYNC PROCESS*.

D. Cohen, The Secret Language of the Mind. London: Duncan Baird Publishers, 1996

Doherty, C. (n.d.). *A comparison of alpha brainwave entertainment, with and without musical accompaniment.* 44.

Feng, S., Suri, R., & Bell, M. (2014). Does Classical Music Relieve Math Anxiety? Role of Tempo on Price Computation Avoidance: MATH ANXIETY AND MUSIC TEMPO. *Psychology & Marketing*, *31*(7), 489–499.

Gao, D., Long, S., Yang, H., Cheng, Y., Guo, S., Yu, Y., Liu, T., Dong, L., Lu, J., & Yao, D. (2020). SWS Brain-Wave Music May Improve the Quality of Sleep: An EEG Study. *Frontiers in Neuroscience*, *14*, 67.

Geretsegger, M., Elefant, C., Mössler, K. A., & Gold, C. (2014). Music therapy for people with autism spectrum disorder. *Cochrane Database of Systematic Reviews*, *2016*(3).

Huang, R., et al., (2016). The effects of customised brainwave music on orofacial pain induced by orthodontic tooth movement. *Oral Diseases*, *22*(8), 766–774.

Huang, R.-H., & Shih, Y.-N. (2011). Effects of background music on concentration of workers. *Work*, *38*(4), 383–387.

Huang, T. L., & Charyton, C. (2008). A comprehensive review of the psychological effects of brainwave entertainment. *Alternative Therapies in Health and Medicine,* 14(5), 38-50

Jackson, N. A. (2003). A Survey of Music Therapy Methods and Their Role in the Treatment of Early Elementary School Children with ADHD. *Journal of Music Therapy*, *40*(4), 302–323.

Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: A review and analysis. *Brain Research Reviews*, *29*(2–3), 169–195.

Knapp, R. B., & Lusted, H. S. (1990). A Bioelectric Controller for Computer Music Applications. *Computer Music Journal*, *14*(1), 42.

Lee, M., Song, C.-B., Shin, G.-H., & Lee, S.-W. (2019). Possible Effect of Binaural Beat Combined With Autonomous Sensory Meridian Response for Inducing Sleep. *Frontiers in Human Neuroscience*, *13*, 425.

Mackenzie, M. (2021, November 10). How binaural beats, pink noise, and ASMR can help you sleep better. *CampusWell*.

Madjar, N. et al., (2020). Contrasting effects of music on reading comprehension in preadolescents with and without ADHD. *Psychiatry Research*, *291*, 113207.

Mahmood, D., Nisar, H., Yap, V. V., & Tsai, C.-Y. (2022). The Effect of Music Listening on EEG Functional Connectivity of Brain: A Short-Duration and Long-Duration Study. *Mathematics*, *10*(3), 349.

Mori, F. (2014). The Effect of Music on the Level of Mental Concentration and its Temporal Change: (2014). *Proceedings of the 6th International Conference on Computer Supported Education,* 34–42. https://doi.org/10.5220/0004791100340042

Okawa, H., Suefusa, K., & Tanaka, T. (2017). Neural entertainment to Auditory Imagery of Rhythms. *Frontiers in Human Neuroscience*, *11*, 493.

O'Reilly, R. C., & Munakata, Y. (2000). *Computational Explorations in Cognitive Neuroscience: Understanding the Mind by Simulating the Brain*. MIT Press.

Patrick, G. J. (1996). Improved Neuronal Regulation in ADHD: An Application of 15 Sessions of Photic-Driven EEG Neurotherapy. *Journal of Neurotherapy*, *1*(4), 27–36.

Schack, B., Klimesch, W., & Sauseng, P. (2005). Phase synchronization between theta and upper alpha oscillations in a working memory task. *International Journal of Psychophysiology*, *57*(2), 105–114.

Smith, C. A., & Morris, L. W. (1977). Differential Effects of Stimulative and Sedative Music on Anxiety, Concentration, and Performance. *Psychological Reports*, *41*(3_suppl), 1047–1053.

The Nobel Prize in Physiology or Medicine 1932. (n.d.). NobelPrize.Org. Retrieved June 18, 2022, from www.nobelprize.org/prizes/medicine/1932/adrian/lecture/

Wagner, M. J. (1975). Effect of Music and Biofeedback on Alpha Brainwave Rhythms and Attentiveness. *Journal of Research in Music Education*, *23*(1), 3–13.

Wu, D., Li, C., Yin, Y., Zhou, C., & Yao, D. (2010). Music Composition from the Brain Signal: Representing the Mental State by Music. *Computational Intelligence and Neuroscience*, *2010*, 1–6.

Yu S. Miao. Visualization of alpha brainwave music in stress-relieving music. (Doctoral dissertation, Dalian University of Technology).

Zhang, F., Liu, K., An, P., You, C., Teng, L., & Liu, Q. (2017). Music therapy for attention deficit hyperactivity disorder (ADHD) in children and adolescents. *Cochrane Database of Systematic Reviews*.

Zulkurnaini, N. A., Kadir, R. S. S. A., Murat, Z. H., & Isa, R. M. (2012). The Comparison between Listening to Al-Quran and Listening to Classical Music on the Brainwave Signal for the Alpha Band. *2012 Third International Conference on Intelligent Systems Modelling and Simulation*, 181–186.