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## **Binaural Auditory Beats for Reducing Attention Deficit Disorder**

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### **ABSTRACT**

Audio Visual Entrainment is an operational and affordable treatment of special-needs children. The objective of this research project is to establish Brain Wave Entrainment as a remedial curing method for ADHD/ autistic children in society. It will be done by performing detailed analysis of EEG signals of same subject before and after listening to specially designed 14 Hz Binaural Beats. It is desired to technically prove that Beta wave brainwave entrainment provide real potential to really change psychological outcomes in case of ADHD/Autism patients. It will be done by the help of mathematical analysis using MATLAB software. A variety of problems, such as uneasiness and gloominess are often combined with attentional disorder, therefore creating an increase in complications in treatment methods. Brainwave Entrainment is a pharmaceutical-free way to manage symptoms of ADD/ADHD and improve attention and learning. This technology may be used later by doctors and psychotherapists as a treatment method for ADHD patients

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### **1.Introduction**

The human brain is extremely sophisticated and remains the least understood organ in the human body. Even as we evolve with great advances in fields such as aerospace science, neuroscientists still do not fully understand the human brain. Across a few thousand years of human civilization, ancient great philosophers and current scientists shared a general view that music therapy can help the human brain to attain desired states of relaxation, happiness and enhance brain functions.

The emergence of binaural beats entrainment as a field of study in the nineteenth century opened a new frontier of research into EEG (electroencephalography) and the use of rhythmic brain entrainment with low frequencies comparable to brain waves to influence and elevate the function of human brains. Traditional music therapy, binaural waves and TMS are mainstream techniques used in the mental wellness industry today.

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#### **1.1 Attentional Disorder and AVE Technology**

Attention Deficit Disorder (ADD) is exceptional attentional disorder which mainly involve slow frontal brain wave action and hypo-perfusion of cerebral blood flow in the frontal regions, particularly in tasks such as reading. A variety of problems, such as uneasiness and gloominess are often combined with ADD, therefore creating an increase in complications in treatment methods .Since learning incapability and attentional disorders are found in 10-15 percentage of the school-age population, such a prevalent condition may not be a “disorder” as we typically understand it, but rather an explanation of those individuals who struggle with certain forms of continuous attention.

Since, several studies estimated the prevalence of ADHD, in USA 4-8%, Korea 7.6% to 9.5%, India 20%, and Emirates 29.7% in United Arab emirates. Every 3 out of 5 children in the world are affected by this syndrome. The Chhattisgarh State today is witnessing many young children suffering from Autism/ ADHD Disorder. More than 10,00,000 children in the age group of 3-16 years of age are found to be suffering from Attentional Deficit Disorder by statistics.

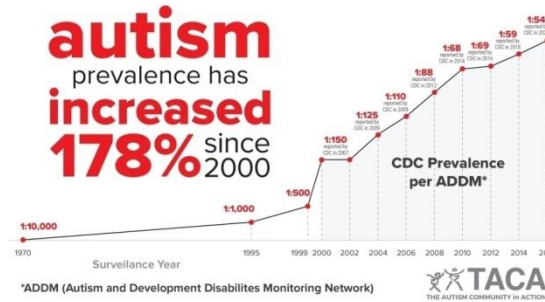


Figure 1: Statistics of Autism worldwide

Audio-Visual Entrainment has been shown to produce intense increases in cerebral blood flow. Several studies using the use of AVE in the treatment of attention deficit disorders and its related disorders like slow learners and moderate learners have been undertaken. This treatment process has obtained wide-spread results including improvements in IQ, performance, concentration, recklessness, hyperactivity, nervousness, depression and reading level.

Sound-based therapies have shown optimistic results by decreasing sensory defensiveness and increasing self-regulation in patients worldwide. Sound-based therapies use an individual's acoustic processes to make changes possible in functional performance and actions.[3] In 2008, Neuro Code Research Centre proposed the Neuro Soundwave technology combining music therapy with brain entrainment by directly stimulating neuronal elements with rhythmic stimulation protocols to provide therapeutic effects and brain improvement results. Extensive research and clinical trials were conducted, methods and techniques were then reviewed and refined to produce the desired outcomes. [1]

## 1.2 EEG signals & Brainwave Entrainment

In relation with the EEG signals, according to paper by Light, G.A. et al., (2010), major work has been carried out to find the substantial parameters in brainwaves by way of using different special signal processing techniques. A standard EEG tracing of brain is an unexpectedly changing composite or aggregate of distinct frequencies—waves shifting up and down at extraordinary rates—some slow, some fast. During ordinary waking alert state of mind, EEG patterns are complex, scattered and disorderly.

The difficulties regarding EEG techniques are that most of the EEG techniques used in research are not standardised sufficiently for clinical use, and many ERP studies do not explain all of the necessary processing procedure for data collection and reduction. Research on mental brain disabilities, such as Auditory Processing Disorder (APD), Attention Deficit Disorder (ADD), Autism Spectrum Disorder (ASD) or Attentional Deficit Hyperactivity Disorder (ADHD), are becoming more common and EEGs are used as diagnostic and treatment tools. After performing filtering operations by the use of matlab and eeglab software, wave extraction from the EEG signal can be achieved for unique frequency ranges. Signal processing toolbox from matlab can be used for further analysis of EEG signal.

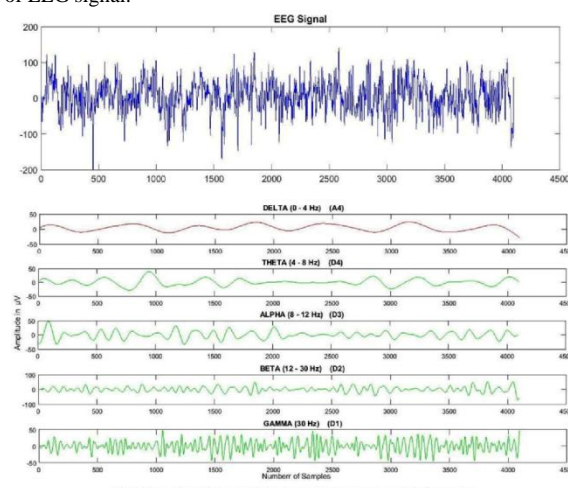


Figure 2: Brainwaves in different frequency ranges after filtering

Alpha waves ( $\alpha$ ), are in the frequency vary from 7.5 Hz to 12 Hz. These kinds of waves originate from occipital lobe. Alpha waves dominate in satisfied and calm mental states while being awake. They have greater amplitude compared with other waves.

Beta waves ( $\beta$ ), ranging from 13 to 30 Hz, are associated to deep thinking, high concentration level and anxious state. They have higher frequency band in contrast with others. Beta waves originate from central area of the mind and the front side of head.

Theta waves ( $\theta$ ), are in the frequency vary from 3.5 to 7.5 Hz. They originate from central, temporal and parietal components of head. High degree of theta waves normally takes place in abnormal adults, generally one with ADHD or ASD.

Gamma waves ( $\gamma$ ), are the waves which lies in the frequency vary of 30 Hz and above. Motor functions, simultaneous work and different multi-tasking appear in this range of frequency.

Delta waves, are in the frequency vary from 0.5 to 3.5 Hz. They are the slowest waves compared to others. Delta waves commonly occur in deep sleep.

The process of binaural beats entrainment was discovered in 1839 by the German researcher Heinrich Wilhelm Dove and checked using encephalograph by the American biologist and physicist Gerald Oster in the year 1973 at Mount Sinai School of Medicine in New York. The amount of the brain's cortical provocation considerably affects how well a particular function can be performed.

At the 1991 AAPB ,Association of Applied Psychophysiology and Biofeedback Annual Meeting in Dallas, Texas, Harold Russell, Ph.D. reported on new research that showed that L/S at beta frequencies at 18 -21 Hz improved the cognitive ability of special needs children. Russell found out that perhaps the L/S stimulation could be joint with EEG biofeedback

Binaural beats are aural responses of the brain starting in the bigger olivary nucleus of both the hemispheres. They result from the interface of two different auditory impulses, applied in opposite ears, below 1000 Hz and which differ in frequency up to 1-30 Hz. It is supposed as an auditory beat and tentatively can be used to entrain particular neural rhythms by the frequency-following response (FFR). It allows the cortical potentials to entrain to or echo at the frequency of the given external stimulus. Therefore, it is quite achievable to use a particular binaural-beat frequency as a consciousness managing method to entrain the brain.

When the brain receives an external auditory stimulus, it emits an electrical charge in response which is called a Cortical Evoked Response as shown in figure. These electrical responses move all through the brain to turn into what a person sees and hears. The external stimuli can cause neurons in the brain to fire synchronously with the frequency of binaural beat and thus changing the brain activity and its state. This activity can be accurately measured with sensitive electrodes attached to the scalp by means of EEG signals.

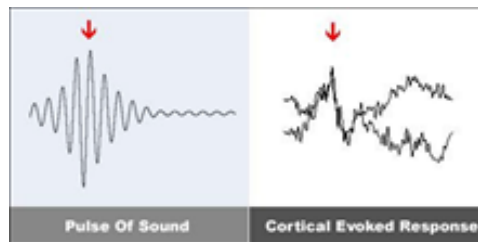


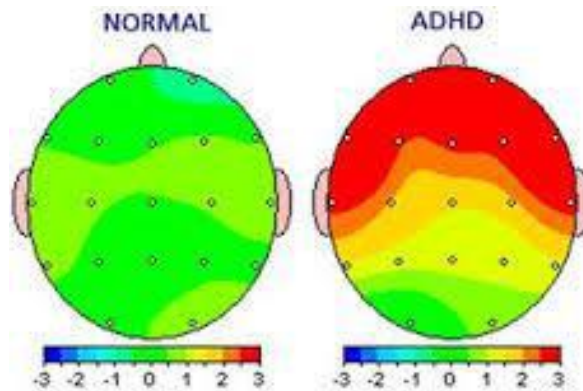
Figure 3: Cortical Evoked Response

A lot of studies have established the occurrence of a frequency-following response to audio stimuli, measured at the vertex of the human brain that is top of the head. This EEG action is called the "frequency-following response".

### 1.3 Brainwaves of ADHD patients and treatment methods

Attention Deficit Disorder (ADD) is acute attentional disease which mainly includes sluggish frontal wave action and hypo-perfusion of cerebral blood flow in the frontal regions of brain, particularly in cognitive tasks such as reading and learning. A range of problems, such as uneasiness or gloominess are frequently blended with ADD, therefore developing an obstacle in cure methods. The Autistic humans or persons diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) have major disabilities and more hyperactivity issues. This is the reason why such adolescents can't be handled like normal children. According to paper by **Lenartowicz, Agatha et al., (2014)**, the utility of EEG in the analysis of ADHD was determined and it was discovered that intellectual disability of any form is related with elevation of theta to beta power ratio in EEG signals.

Several evaluation carried out by various researchers indicate that, ADHD subjects show high neuronal activities in the eyes closed position, whereas normally people tend to suppress their neuronal activity in this position. This is the reason that many ADHD sufferers have problems in sound sleep. Generally, alpha and beta waves are more prominent in case of a healthy person i.e., at electrode positions O1, O2, P3 and P4. Here, the ADHD cases exhibit very low alpha and beta electricity levels in posterior vicinity of the brain. This brain disorder is called attentional disorder because of same reason. ADHD victims generally have an elevated Theta to Beta Ratio in terms of electric impulses of brainwaves. In the motor activity, theta waves are dominantly viewed in ADHD cases, which indicates the abnormality as per the neurologists. According to literature survey, previous researches obtain the accuracy of 90% in distinguishing between ADHD and normal; and 95% accuracy in distinguishing between the subtypes using the diagnostic parameter of theta to beta ratio. It additionally proves that, EEG signals as input, if analyzed perfectly using advanced signal processing methods, can be used to distinguish between ADHD and ordinary subjects.



**Figure 4: Topography maps comparison of ADHD and Normal Brain**

Across a few thousand years of human civilization, historical outstanding philosophers and cutting-edge scientists shared a widely wide-spread view that musical therapies can assist the human brain to acquire desired states of relaxation, happiness and enhance intelligence functions. This insists at using sound therapy to entrain the human brain to produce the desired frequencies.

Patients with learning disorders are unable to access the fast brainwave rhythm of Beta in order to think and process information. If beta waves are large in quantity, they help with mental processing, thinking, and figuring things out.

Individuals with neurological disorders have certain problem in shifting their pre-frontal lobes into gear during thinking tasks specifically passive, spatial tasks such as reading and learning. In the paper by Dave Siever, it has been shown that external stimulation through audi-visual aids improves attention and decrease hyperactivity [13]

Albouy et al. found out that training of brain oscillations with recurring stimulation can precisely improve auditory operational memory performance and modulate brain activity and connectivity patterns. Using EEG, it was showed that theta rhythms in the dorsal stream predict participants' operation abilities during memory holding in a task requiring the comparison of two patterns differing in temporal order.[8]

It was discovered by authors Anna-Katharina et. al that longer stimulation resulted in a phase shift of a participant's neural phaserelative to the stimulus phase. It was concluded by authors that the brain attunes to externally induced rhythmic stimulation by adjusting the brain's internal depiction of incoming environmental stimuli.[10]

In a paper by Tirdad Seifi Alaa et al it has been suggested that binaural beats can improve the power and connectivity of the brain and broadening the stimuli, interchangeably with pink noise, also changes the outcomes. [12]

It was verified that in the process of binaural-beat stimuli, reductions in the percentages of occipital alpha were prominent by the author F. Holmes Atwater. During these recording periods, decrease in the percentages of central delta were also significant.[14]

The aims of the research by Holger Gevensleben et al were to assess the impact of different NF protocols on the resting EEG and the association between distinct EEG measuresand behavioral improvements. Distinct EEG patterns for theta/beta and SCP training provide further evidence that distinct neuronal mechanisms may contribute to similar behavioral improvements in children with ADHD.[18]

The emergence of binaural beats entrainment as a discipline of study in the nineteenth century opened a new frontier of research into EEG (electroencephalography) and the use of rhythmic entrainment of brain with low frequencies comparable to mind waves to influence and raise the function of human brains.

According to a paper by **Yamsa-ard, Traisak et al., (2015)**, Traditional song therapy, binaural waves and TMS are mainstream techniques used in the intellectual well being industry nowadays. Across a few thousand years of human civilization, ancient great philosophers and current scientists shared a general view that music therapy can help the human brain to attain desired states of relaxation, happiness and enhance brain functions. This project aims at using music therapy to entrain the human brain to produce the desired frequencies.

Audio-Visual Entrainment as shown in figure 1.7 can produce intense increases in cerebral blood flow. Several papers by Gupta, A. et al., (2016) and many other authors have been studied and concluded that Audio entrainment can be used for the treatment of attention deficit disorders and its related disorders.This treatment process has obtained wide-spread results including improvements in IQ, performance, concentration, recklessness, hyperactivity, nervousness, depression and reading level.

The Beta wave binaural beats are generated using Gnaural Binaural Beat Sound Generator and compiled using Audacity Software. The difference frequency is maintained around 14 Hz. To easily follow the beat of the pulses, in the sound track OM sound is also added.

It has been suggested that the carrier frequency is has to be kept below 1 kHz for soothing sound. Since each ear has to listen to a slightly different

frequency for creation of binaural beats, binaural beats can be best practiced when the two audio signals are heard by using stereo headphones. The amplitude of beta rhythms when measured in reference to linked ears is less than 20  $\mu\text{V}$ .

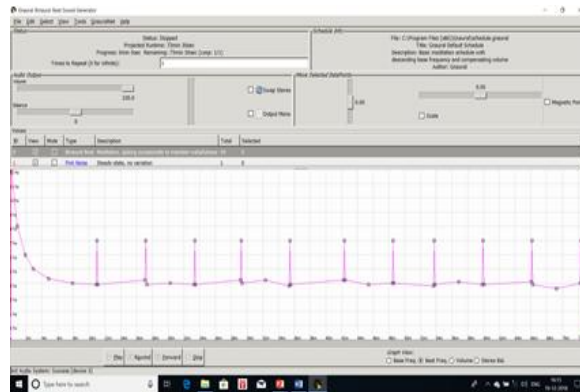


Figure 5: Creation of peaks using Gnaural Binaural Beat Sound Generator

For most of the participants in this study the difference frequency is maintained around 12-16 Hz. To get proper results, for every individual subject according to the patterns of EEG signals, small changes have been done to suit his/her compatibility. To easily follow the beat of the pulses, in the sound track extra sound is also added for individual subjects. The base frequency is maintained around 300 Hz.

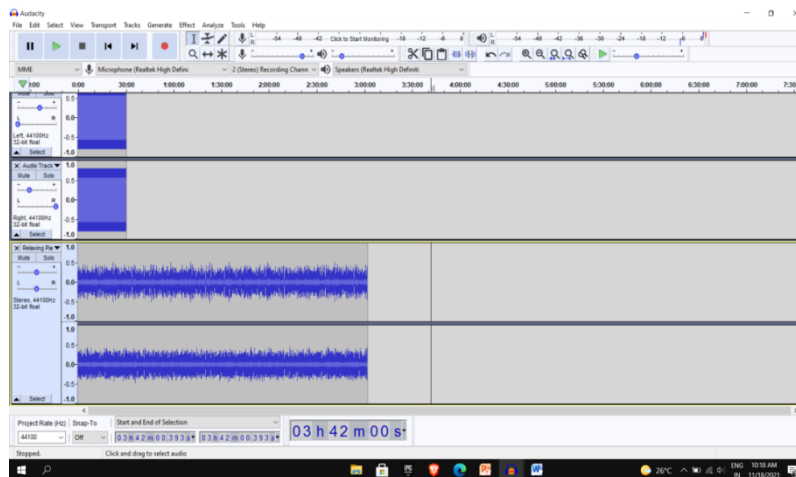


Figure 6: Creation of binaural beats in Audacity

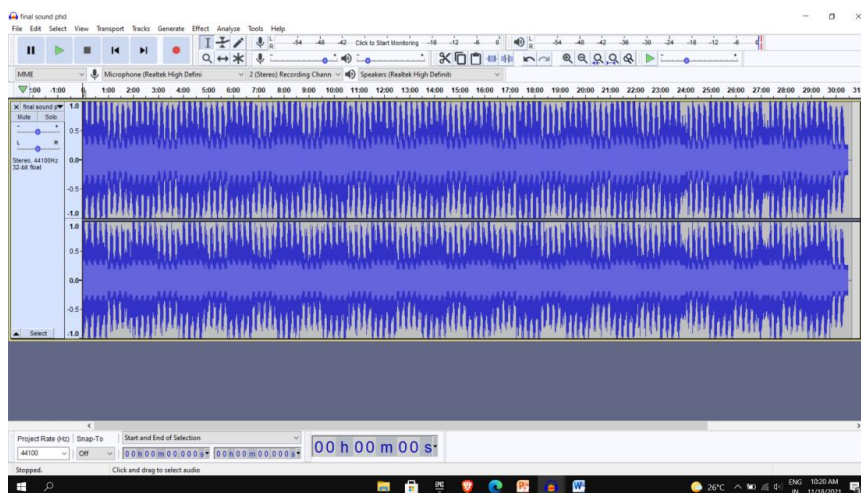


Figure 7: Final sound sample

The sound was extracted, converted to Mp3 using Audacity and given to the parents of the participants. The Participants listened to the binaural beats for 1 hr in morning at a fixed time for 3-5 months The figure 3.31 shows a final sound sample and figure 3.32 and figure 3.33 show participants listening to the binaural beats.





**Figure 8 ADHD patient listening to beats**



**Figure 9: Autistic patient listening to beats**

The subjects which were able to complete the Entrainment Process successfully for at least three continuous months were selected for the study. Their EEG signal is recorded again and using same algorithm in EEGLAB differences are established between the power ratio of Theta to Beta waves (TBR).

Most of the special children show not only decreased beta activity in the resting state, they also are unable to synchronize frontal beta activity in response to the task load. Healthy subjects synchronize frontal beta activity in response to Cue, GO, NOGO, and Novel stimuli, that is, to all stimuli associated with activation of the frontal lobes, but not children with attentional disorders

Fifteen subjects are selected effected with autism or other learning and attentional disorders. Some of them are slow learners also. Their mental age is approximately 5+-2 years. Analysis of the effects of 14 Hz binaural beats on the power spectrum (absolute and relative) of EEG signals will be investigated. For further analyses, we will also explore functional brain connectivity to see how brain synchronization will be affected by this stimulation. It is expected that by continuous application of Binaural beats of a specific frequency for a period of 3 months noticeable improvements will be observed in EEG signals of the ADHD effected children. Brainwave entrainment is being used at many rehabilitation centers around the globe for treatment of mentally challenged children. It is presently in research stage.

## 1.4 Conclusion

It is summarized that brainwave entrainment provide real potential to really change psychological outcomes. However, supplementary and superior researches need to be made, using additional outcomes and outcomes by now examined. The essential background is given in this paper to motivate further research and collaboration in the field of brainwave entrainment. In particular, AVE has established itself to be an operational and affordable treatment of special-needs children. This research work has its own social importance and supports cognitive trainers to improvise the behaviour of

children with ADHD syndrome with this treatment method. This is done by periodically evaluating the improvements in kid's academic performance and day-to-day activities. The effects from this treatment would be permanent as treatment is based on internal rhythms of brain synchronizing naturally.

## 1.5 Acknowledgement

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