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Specialized Beta wave Binaural Auditory Beats for Reducing Attention Deficit Disorder

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Abstract*: 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. A new technology of brainwave entrainment is coming up recently for reducing attentional disorders. Some of the modern researches appeared in the past few years show that binaural beats entrainment actually produces changes that can be measured. Children with Autism & Attention Deficit Disorder have difficulty in paying attention during cognitive tasks specifically reading and understanding. 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.*

Key Word*: Binaural beats, electro encephalographic signal, auditory impulses, frequency following response, Cortical Evoked Response.*

I.THE HUMAN BRAIN AND BRAINWAVES

The human brain is extremely sophisticated and stays the least understood organ in the human body. Even as we evolve with wonderful advances in fields such as aerospace science, neuroscientists still do now not fully recognize the human brain. The measurement of electrical components of the intelligence is referred to as electroencephalography or EEG. There are a number of sensor electrodes applied to report brain signals along the scalp. Each of the electrodes analyses the weighted sum of all neurons voltage from the areas around that particular electrode, so placement of electrodes at specific scalp points is important for extra accuracy.

Active nerves in brain generate electrical current, which produces magnetic and electric voltages in microvolts at scalp. According to paper by **Singh, Yogendra Narain et al., (2012),** these can be calculated and recorded as Electroencephalography (EEG) signals. Electroencephalography helps us to look at intelligence of human brain even in a lower price as an alternative than different measurement methods. The brain contains almost one hundred billion nerve cells or neurons. If we think about a neuron as an ON-OFF switch, we can say that it is OFF whilst resting and ON while sending electrical signal. This signal is despatched using a wire referred to as axon in which the membrane carries ions such as sodium (Na+), potassium (K+), chloride (Cl−), and calcium (Ca_2+). Each of axons of these billion neurons generate a very small electrical charge, which helps the neurons to transmit records via electrical and chemical signals. Neurons can connect with each other to form neural networks.

Figure 1.1 explains signal propagation through a neuron and its transmission to the next neuron. As explained, a neuron produces electro-chemical indicators when transmitting information. These neurons' activities are measured in microvolts (μV) and frequency spectrums in Hertz. The amplitude of the EEG is about 100 μV when measured from the scalp, and about 1-2 mV when measured on the base of the brain.

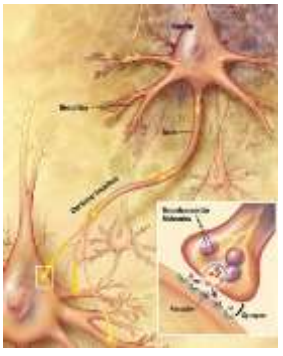

Figure 1.1 A signal from a neuron[https://www.medicalnewstoday.com/articles/320289 Retrieved date: 06/10/2021]

The bandwidth of this signal is from around 1 Hz to about 50 Hz, as established in Figure 1.2. The pattern is generally

called a brainwave pattern, because of its random, cyclic and wave-like nature. Brainwaves are produced by means of synchronized electrical pulses from loads of neurons communicating through impulses with each other. Brainwaves can be divided into smaller bandwidth intervals or different brainwave types. Depending on what a man or woman is doing, brainwaves changes and frequency range shifts from one kind to another.

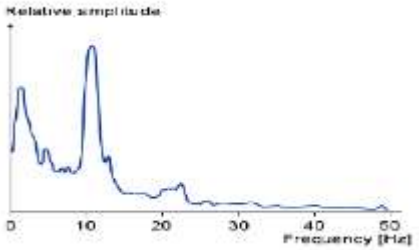

Figure 1.2: Magnitude spectrum EEG signal[5485243_Human-Machine_interfaces_base_on_EMG_and_EEG_applied_to_robotic_systems Retrieved date: 17/09/2021]

According to paper by **Fernando, Luiset al., (2012),** EEG is the perfect and most used signal processing technique for inspecting brainwaves due to the high temporal resolution, safety, and ease of use. In clinical contexts, EEG refers to the recording of the brain's random electrical activity measured in microvolts over a short duration of time, commonly 7-8 minutes, as recorded from various electrodes placed on the scalp as shown in Figure 1.3.

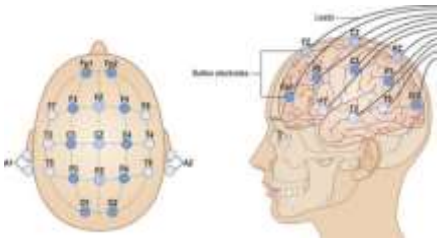

Figure 1.3: Electrode positions at scalp [https://clinicalgate.com/electroencephalography/ Retrieved date: 06/11/2020]

The EEG reveals not only the mind thought process, but indicates the context in which thinking occurs---state of arousal, extent of attention and alertness, etc. A predominant characteristic of the nondeterministic EEG signal is rhythmic activity, or periodicity. These rhythms are quite complicated in nature and are generated by using complex cortical, sub-cortical, and cortico-subcortical dynamics.

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 a 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. A common EEG signal is as shown in Figure 1.4.

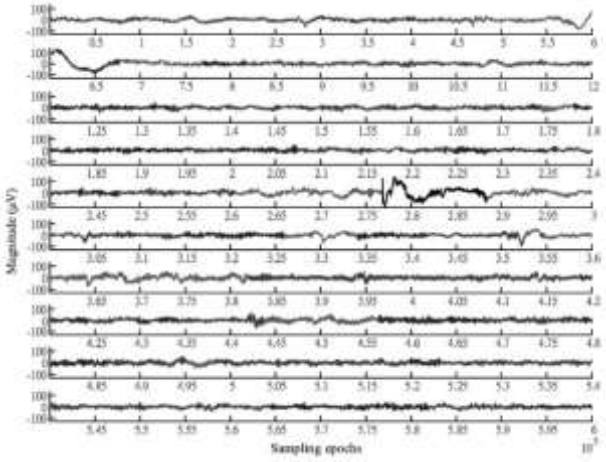

Figure 1.4: Typical EEG signal [www.researchgate.net/publication/228668233_Design_and_implementation_of_wireless_multi-channel_EEG_recording_system_and_study_of_EEG_clustering_method Retrieved date: 06/08/2021]

However, it is not viable to get sure statistics from brainwave indicators immediately in the time domain just by watching them. They are basically non-linear and non-stationary in nature. Significant features can be extracted for the evaluation by the use of superior signal processing techniques.

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.

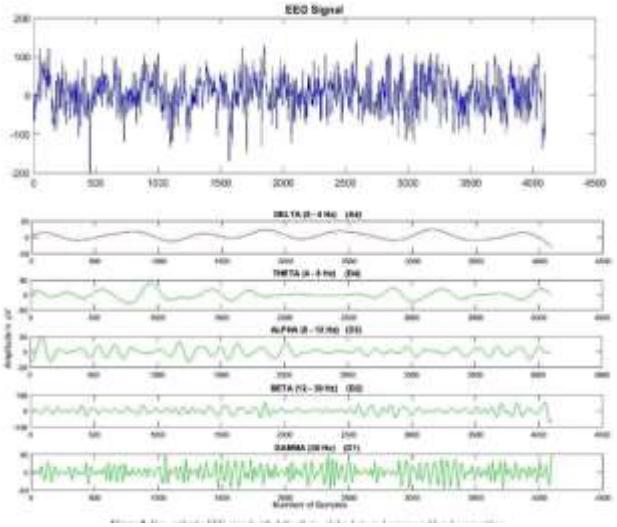

Figure 1.5: Brainwaves in different frequency ranges after filtering[www.semanticscholar.org/paper/Selection-of-Feature-for-Epilepsy-Seizer-Detection-Chandani-Kumar/ Retrieved date: 07/11/2021]

Alpha waves (α), 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 (β), 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 (θ), 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 (γ), 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.

II.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.

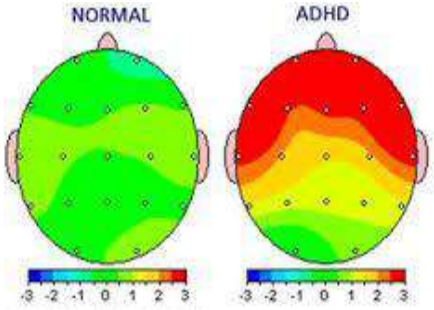

Figure 1.6 Topography maps comparison of ADHD and Normal Brain[https://www.centreforbraintraining.com.au/addadhd/ Retrieved date: 07/11/2019]

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.

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.

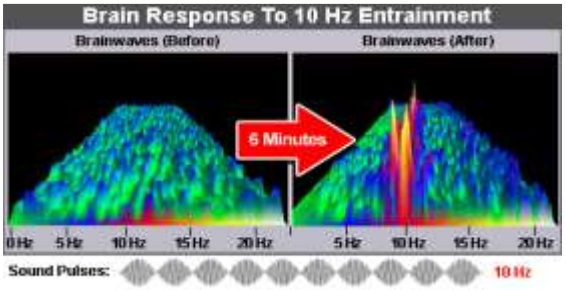

Figure 1.7: Brain response to entrainment[https://restorebehavioralhealth.com/treatment/neurophysiological-interventions/Retrieved date: 08/06/2020]

Treatment of mentally disabled patients, slow learners and moderate learners through sound therapy have been undertaken by various special educators, psychotherapists and counsellors in last few years. This treatment process has obtained wide-spread results including improvements in IQ, performance, concentration, recklessness, hyperactivity, nervousness, depression and reading level.

III.BINAURAL BEATS SOUND THERAPY

Sound may have profound effects on humans. Despite the fact that sounds appear to be a personal enjoyment, comparable studies are made to study the positive effects of sounds since last few decades. The sound of chirping birds in a wooded area produces even harmonics and can be more relaxing than the sounds from a factory, now not simply due to the associations people make with sounds of nature as opposed to factories, but additionally because of the harmonic content material. Professional musicians nowadays buy vacuum-tube pre-amplifiers because vacuum-tube amps generate even-harmonic distortion that is fun to concentrate to, whereas transistors generate unusual-harmonic distortion, which often "gets on the nerves." Spooky sounds can make people experience hectic and scared, whereas up-tempo sounds could make people sense active positivity. Special tunes have been shown to lessen an autistic kid's hyperactivity and improve its capability to pay attention.

For children, being attentive to classical music even while doing homework can assist better and increase performance sometimes. It's also named as the Mozart impact. Essentially, those who pay attention to Mozart's music are more inclined to attain better on cognitive checks and show better intellectual performance stages. Binaural beats, a brainwave entrainment technology in itself has the identical impact.

Figure 1.8: Brainwaves and sound Therapy [https://sciencenordic.com/creativity-denmark-depression/can-electric-pulses-to-the-brain-boost-your-creativity/1439339 Retrieved date: 27/02/2020]

Binaural beats was generated firstly by a physicist named Henry Wilhelm Dove in 1839. He determined that when a signal at one frequency is heard in one of our ears and another signal at a different frequency is heard in our other ear, our brain hears the frequency difference. Our brain compensates the difference in frequencies, producing a difference frequency. For example, if we hear a sound in our left ear that is 295 Hz and a sound in our right ear that is 305 Hz, our brain hears a sound that is 10 Hz. This distinction and generation of third frequency we hear is what is known as a binaural beat. The figure 1.9 shows Creation of 10 Hz Binaural Beats.

Through work done later in 1973 by biophysicist Gerald Oster at Mount Sinai Hospital, it has been established with proofs that listening to a binaural beat can force the brain to resonate in tune with it. This effect is known as the Frequency Following Response. Oster's findings had been published in Scientific American and they have paved the way for in addition improvement in the effect of auditory stimulation. There are now a range of specific MP3s and CDs available with binaural beats. Depending on the kind of frequency the binaural beats produce, they can be used to help people sleep, relieve stress and anxiety, meditate, focus better, and more. Some people combine this with something like Blessed CBD oil to help them increase their effects. Frequency Following Response induces mind recreation and can quickly and without problems translates the mind into any desired state.

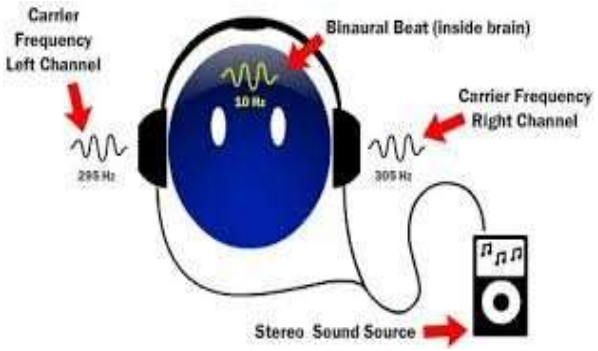

Figure 1.9: Generation of Binaural Beats [https://hearinghealthmatters.org/hearinginternational/2015/binaural-beats/Retrieved date: 19/11/2019]

If we try to explain binaural beats mathematically, tones sounding concurrent are superimposed. If a graph is drawn to expose the function similar to the full sound of two strings, it can be visible that maxima and minima are not consistent. When the two waves are nearly 180 degrees out of phase the maxima of one wave cancel the minima of the other, whereas when they are nearly in phase their maxima sum up, raising the perceived volume. It may be verified with the assist of a sum-to-product trigonometric identity that the envelope of the maxima and minima shape a wave whose frequency is half the distinction between the frequencies of the two authentic waves.

If the two unique frequencies are quite near, the frequency of the cosine of the right side of the expression above, that is f1 − f2/2, is often too low to be perceived as an audible tone or pitch. As an alternative, it is perceived as a periodic version in the amplitude of the primary term inside the expression above. It can be stated that the lower frequency cosine term is an envelope that is its amplitude is modulated. The frequency of the modulation is f1 + f2/2, that is, the average of the two frequencies. It is able to be mentioned that every second burst in the modulation sample is inverted. However, because the human ear isn't always sensitive to the phase of a valid, handiest it's amplitude or intensity, most effective the value of the envelope is heard. Therefore, subjectively, the frequency of the envelope appears to have two times the frequency of the modulating cosine, this means that the audible beat frequency is

$$f_{beat} = f_1 - f_2$$

A physical interpretation is that when the waves are in phase they interfere constructively. When it's out of phase intervene destructively. Beats arise also in greater complicated sounds, or in sounds of various volumes, though calculating them mathematically is not so easy. For a human ear to hear beat phenomena, the ratio of frequencies have to be less than 7/6, in any other case the mind perceives them as exclusive frequencies.

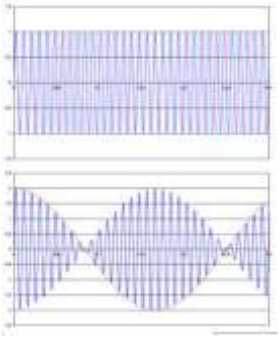

Figure 1.10: Binaural beats waveform [https://en.wikipedia.org/wiki/Beat_(acoustics)#Binaural_beats Retrieved date: 15/12/2019]

This can be seen with the figure 1.10 which shows a 110 Hz A sine wave (magenta; first 2 seconds), a 104 Hz sine wave (cyan; following 2 seconds), their sum (blue; final 2 seconds) and the corresponding envelope (red) as binaural beats. If children are made to listen to the alpha wave sounds for half an hour and then begin their homework, they are able to concentrate better. Child can also increase alertness by binaural beats at some stage in the day and sleep better at night time using auditory beats. Humans with ADHD have a hard time producing alpha and beta brainwaves. As discussed earlier, listening to Alpha and beta binaural beats is best recommended for treatment of ADHD, ASD, ADD and slow learners. Listening to binaural beats cannot treat these disorders completely but binaural beats may be taken as a device to assist these sufferers. It can reduce problems in focusing for the day and restlessness at night, commonly faced by individuals with these types of disorders.

IV.BRAINWAVE ENTRAINMENT WITH BINAURAL BEATS

While a person concentrates to binaural beats, the brain's electrical activity and energy becomes extra enormous and the mind develops new neural pathways. The new dendritic growth effects in smoother and quicker neural verbal exchange. Every time our mind learns something new, like learning a new musical tool as an instance, new dendritic boom takes place from our brain being stimulated in a brand new and distinctive manner. As we get older, some of our dendritic connections can end up inactive and use up according to **Buell S.J. et al., (1979).** The intention of using binaural beats is to continuously stimulate dendritic increase, which would permit our mind to perform at its complete potential.

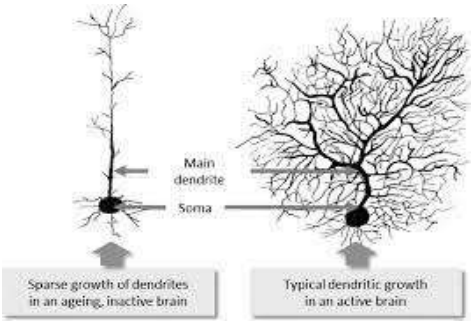

*Figure 1.11: Dendritic growth in brain [Dendritic growth in the aged human brain and failure of growth in senile dementia PMID: **493989** Retrieved date: 27/07/2020]*

Research has shown that our brains are able to generate new neural paths and connections at all stages in our life. Just like we can train our muscles in our arms, we can entrain our brain "muscle." Through the use of binaural beats, our brains will eventually learn to achieve more powerful states of performance all on its own according to **Jirakittayakorn N et al., (2015)**. This is called hemispheric synchronization as shown in figure 1.12. Studies have shown that persons with balanced brain waves tend to be more cheerful, confident, and emotionally stable.

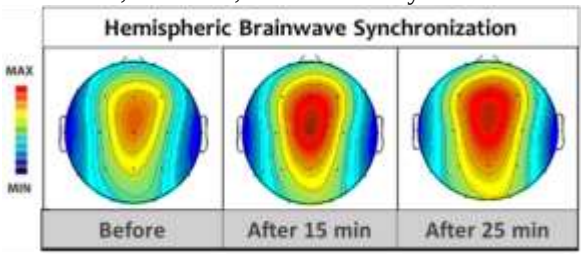

Figure 1.12 Left-Right hemisphere synchronization after a binaural beat
[Brain Responses to a 6-Hz Binaural Beat: Effects on General Theta Rhythm and Frontal Midline Theta Activity 10.3389/fnins.2017.00365 Retrieved date: 23/12/2020*]*

When the brain receives an outside auditory stimulus, it emits an electrical signal in response that's referred to as a cortical evoked response as shown in figure 1.13. These electrical responses flow at some point of the mind to show into what a person sees and hears. The outside stimuli can cause neurons within the mind to fire synchronously with the frequency of binaural beat and thus converting the brainwaves and its state. This activity can be properly measured with sensitive electrodes attached to the scalp by means of EEG signals.

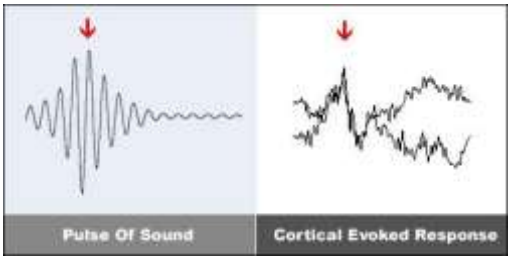

Figure 1.13: Cortical Evoked Response[https://www.activemindsglobal.com/how-it-works/corticalevokedresponse/ Retrieved date: 11/09/2019]

The idea that these can create therapeutic effects through certain complex brain wave states can only be determined from the real medical EEG signals recorded for subjects. A lot of studies have established the occurrence of a frequency-following response to audio stimuli in normal adults, measured through EEG at the vertex of the human brain that is top of the head. An auditory beat can be used to entrain unique neural rhythms by means of the frequency-following response as proven in figure 1.14. It allows the cortical potentials to entrain to or echo on the frequency of the given outside stimulus. Consequently, it's workable to apply a particular binaural-beat frequency as a cognizance managing technique to entrain the brain.

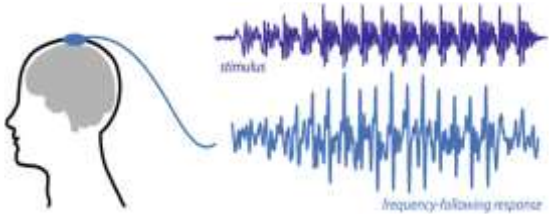

Figure 1.14 Frequency Following Response
[The Frequency-Following Response: A Window into Human Communication 2017 Retrieved date: 17/08/2021]

These binaural beats or auditory stimulus can create healing outcomes via certain complex mind wave states can be decided from the actual medical EEG scans on subjects. Brain wave entrainment and hemispheric synchronization are technically understood through various research papers. In this research the occurrence of a frequency-following response to audio stimuli given to subjects for a period of 3-5 months has been measured through recording of EEG signal and analyzed to establish the results. This research aims at using binaural beats or Audio Entrainment technology in the treatment of ADD/ASD/ADHD sufferers. Audio Visual Entrainment can be 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.

In this research, a trial has been done for a group of children suffering with Autism and ADHD by exposing them to beta and alpha binaural beats, specifically designed on the basis of their scalp EEG signal analysis. It is expected that as their brain starts to produce the desired brainwaves automatically and naturally using Brainwave Entrainment Technology, they will eventually become more focussed and attentional disorder will reduce to a measurable extent. This can be a new treatment method for mental disorder sufferers without medication.

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