

Binaural Beat Effect on Brainwaves, Stress Management and Its Applications

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Abstract

The brain is made up of billions of brain cells called neurons, which communicate with each other via electric impulses. Neurochemical processes in human brain are measured by wave function which is nothing but Brain Waves. These waves can be detected by a sensitive machine called electroencephalograph (EEG) machine, which are indirect means of assessing the mind consciousness. These are categorized into four frequency band depending upon consciousness levels. The frequency band include; beta, alpha, theta, and delta waves, which depends on activeness of mind. These waves are the outcome of binaural beat phenomenon which is the auditory brainstem where responses originate in the superior Olivary nucleus of each hemisphere. This technique can also be applied to brainwave entrainment, where binaural beat can be changed through audio binaural beat resonant entrainment techniques by applying sonic frequency through stereo headphone. The experiment to verify the effect of binaural beats on brainwaves was carried out with the following apparatus: An Electroencephalogram Machine (Phoenix Digital EEG Machine), Binaural Beat Audio (10Hz), Stereo headphones. Binaural beat was used to entrain the brainwaves of 10 human subjects for 30 minutes using the electroencephalogram (Phoenix Digital EEG) machine to monitor the changes in brainwaves. The entrained brainwaves were recorded at every 10-minute interval for each subject under study. The data provides evidence that all subjects experienced some level of relaxation as evidenced in the significant change in their brainwaves from low beta (13 Hz) to high theta (7 Hz) and even as low as 6 Hz in one subject. Base on this work, one can deduced, binaural beats could be used to entrain brainwaves, and could be applied to stress management by inducing relaxation through reduction in the brainwaves.

Keywords: Brainwave, Binaural Beat, Beta, Alpha, Electroencephalograph, Stereo Headphone.

Introduction

Wave functions, for example photon, sound, color and energy emission can be explain by any occurring phenomena and existence. Likewise, neurochemical processes of human consciousness in our very thoughts ring with their own distinct wave patterns (Margaret, 2021). Brain is an electrochemical organ, which generates electrical waves called brain waves, measured by Electroencephalograph (EEG) machine. These reflects different

consciousness of human mind (Atwater, 1988). Research has shown that the human brain operates at a wide range of frequencies, but generally stays in four major levels of awareness known as beta (13 to 30 cps), alpha (8 to 12 cps), theta (5 to 7 cps), and delta (1 to 4 cps) depending upon activeness of mind (Empson, 2019). The consciousness is the result of electrochemical, neurological activity (Banquet, 2022). The brain is made up of billions of brain cells called neurons, which communicate with each other using electrical signal. All of these neurons sending signals at once produce a large amount of electrical activity commonly called a Brainwave pattern (Blundell, 2022). EEG measurements of Brainwave are an indirect means of assessing the mind-consciousness, interface with neurological structure of the brain (Glaser, 1963). There are four categories of these brainwaves, ranging from the most activity to the least activity, reflecting consciousness of human mind.

Research Questions

- i. Does binaural beat affect human brainwaves?
- ii. Does entrainment affect humans' mood?

Objectives of the Research

- i. To carry out experiments on human subjects so as to verify the correlational relationship between binaural beats and brainwaves
- ii. To measure the level and degree of entrainment so as to establish the therapeutic effect of binaural beats.

Literature Review

Human's daily activities can induce stress in the body such as distractions, noisy environment, hectic schedule, and even psychological disorders. To some extent, people can control the environmental factors that make it difficult to relax. However, what about internal factors such as perception or state of mind? Can people reduce stress levels by increasing their ability to relax deeply?

One invention that prompted research into how internal factors, such as state of mind or brainwaves, affect the average person's ability to relax was the encephalography. In 1924, Hans Berger was the first to record human encephalogram and the discoverer of Alpha waves rhythm also known as "Berger" waves. He successfully showed that the brain's electrical activities called brainwaves could be measured.

Another remarkable contribution to the field of brainwave entrainment was the work of Gerald Oster, who in 1973 published his findings and titled it 'Auditory Beats in the Brain'. In this research paper, Oster offered insightful laboratory findings on binaural beats and suggested that it could be applied in cognitive and neurological research.

Robert Monroe took the study of brainwave entrainment further by thoroughly investigating the application of binaural beats to consciousness. He achieved world-wide

recognition for his painstaking research into the use of binaural beats to enhance human capabilities. For example, he showed that certain frequency combination enhances alertness, others induce sleep and still others evoke relaxation effect.

Further studies on the exploration of consciousness were carried out by several other researchers such as the remarkable findings of Dr. Hutchinson (2003) which he compiled in his landmark book "Megabrain", outlining the many possible uses of entrainment from meditation to super-learning.

Studies continued into the 90s with Dr. Russell's, Dr. Carter's and others exploring the application of entrainment to the management of Attention Deficit Disorder (ADD) and learning disorders. Several researches have also been carried out to explore the use of entrainment to manage Post Traumatic Stress Disorder (PTSD), depression, hypertension, etc. Steady researches continued till date into the possibilities with the use of binaural beats.

However, there is almost no existing research in Nigeria on this interesting field of study. Therefore, this research work is to explore the possible effect of binaural beats on human brainwaves and its application to stress management in human.

Brain Waves

Beta Wave

When the brain is aroused and actively engaged in mental activities, it generates beta waves. Beta brainwaves are considered "fast brain wave" activity. These beta waves are of relatively low amplitude and high frequency among the four different brainwaves (Glaser, 1963). Beta brainwaves are brainwaves that cycle within the range of 12 – 38 Hz and are usually generated in the brain's left-hemisphere. Beta waves are characteristics of a strongly engaged mind. A person in active conversation would be in beta. A debater would be in high beta. A person making a speech, or a teacher, or a talk show host would all be in beta wave when they are engaged in their work (Martindale, 1978).

Alpha Wave

The next brainwave category in order of frequency is alpha, where beta represented arousal, alpha represents non-arousal (Glaser, 1963). Alpha brainwaves are having lower frequency and higher in amplitude. Alpha brain waves are considered relaxed brainwave activity. Alpha brainwaves are brainwaves that cycle within the range of 8 – 12 Hz and are usually generated in the brain's right hemisphere or in a synchronized pattern between both right and left hemispheres. Alpha waves kick in when our mind and body are completely relaxed and free of stress. Alpha is considered the "normal" brainwave pattern and is dominant when people close their eyes. Children tend to have much higher levels of alpha brainwaves than adults (Holmes, 1997).

Theta Wave

The next state, theta brainwaves, is typically of even greater amplitude and slower frequency. Theta brainwaves are considered extremely relaxing brainwave activity that is commonly associated with sleep and dreaming. Theta brainwaves are high in amplitude and cycle within the range of 4 – 8 Hz and are usually generated in the brain's right hemisphere. Theta waves kick in when we feel emotional, relaxed, day dreamy, unfocused, or asleep. Theta brainwaves are generally thought of as the brainwaves that are dominant in people with high levels of relaxation, high levels of creativity, and random thinking. The theta brainwave is considered the brainwave pattern that is dominant in deeply relaxed, dreamy and sleepy individuals (Holmes, 1997).

Delta Wave

Delta brainwaves are considered the most relaxing brainwave frequency range. Delta brainwaves are commonly associated with the deepest sleep and a state of unconsciousness. Delta brainwaves are the lowest in brainwave frequency: ranging from 0 - 4 Hz, but are the highest in amplitude. They never go down to zero because that would mean a brain's dead state. But deep dreamless sleep would take one down to the lowest frequency, typically, 2 to 3 cycles a second (Glaser, 1963). Delta brainwaves, like other slower brainwave patterns, are generated in the brain's right hemisphere, though they may be observed in widespread patterns throughout various parts of the brain.

When we go to bed and read for a few minutes before attempting to sleep, we are likely to be in low beta. When we put the book down, turn off the lights and close our eyes, our brainwaves will descend from beta, to alpha, to theta and finally, when we fall asleep, to delta (Holmes, 1997).

It is a well-known fact that humans dream in 90 minute cycles. When the delta brainwave frequencies increase into the frequency of theta brainwaves, active dreaming takes place and often becomes more experiential to the person. Typically, when this occurs there is rapid eye movement, which is characteristic of active dreaming. This is called **REM**, and is a well-known phenomenon (Banquet, 2022).

When an individual awakes from deep sleep in preparation for getting up, their brainwave frequencies will increase through the different specific stages of brainwave activity. That is, they will increase from delta to theta and then to alpha and finally, when the alarm goes off, into beta (Glaser, 1963). The same four brainwave states are common to the human species. Men, women and children of all ages experience the same characteristics brainwaves (Empson, 1986).

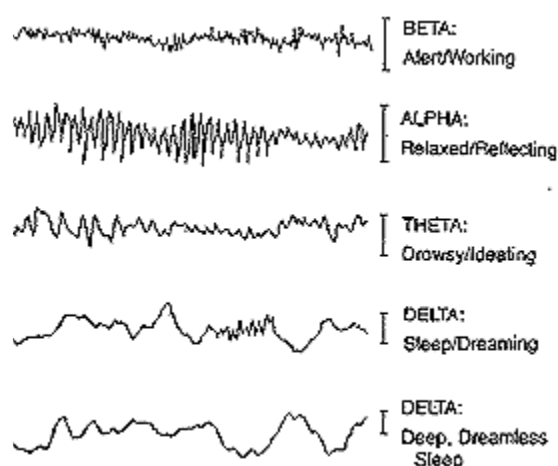


Figure 1.1: The Different Brainwave Patterns (Holmes, 1997)

Binaural Beats

Binaural beats are auditory brainstem responses which originate in the superior olivary nucleus of each hemisphere. They result from the interaction of two different auditory impulses, originating in opposite ears, below 1000 Hz, which differ in frequency between one and 30 Hz (Oster, 1973). For example, if a pure tone of 400 Hz is presented to the right ear and a pure tone of 410 Hz is presented simultaneously to the left ear, an amplitude modulated standing wave of 10 Hz, the difference between the two tones, is experienced as the two wave forms mesh in and out of phase within the superior olivary nuclei (Holmes, 1997). This binaural beat is not heard in the ordinary sense of the word (the human range of hearing is from 20-20,000 Hz). It is perceived as an auditory beat and theoretically can be used to entrain specific neural rhythms through the frequency-following response (FFR)--the tendency for cortical potentials to entrain to or resonate at the frequency of an external stimulus. Thus, it is theoretically possible to utilize a specific binaural-beat frequency as a consciousness management technique to entrain a specific cortical rhythm (Sadigh, 2021).

Brainwave Entrainment

Brainwave Entrainment refers to the brain's electrical response to rhythmic sensory stimulation, such as pulses of sound or light (Solso & Johnson, 2022). Brainwaves Entrainment occurs when the natural brainwave frequency of the brain establishes resonance with this perceived binaural beat. For example, if we present a 410 Hz sine wave to the left ear and another 403 Hz sine wave to the right ear, a binaural beat of 7 Hz (actually the difference between the two tones) is created in the brain which causes the brainwaves to be entrained to 7Hz frequency. Several researches have shown how a person's brainwaves change under different situations namely: fear, love, stress, alertness, sleep, dream, relaxation, etc.

Brainwaves and Stress

Stress is a term in psychology and biology, borrowed from physics and engineering. It was first used in the biological context in the 1930s, which has in more recent decades become commonly used in popular parlance. It refers to the consequence of the failure of an organism — human or other animal — to respond adequately to mental, emotional, or physical demands, whether actual or imagined (Hutchison, 1994). A stressed person's brainwaves are incoherent and erratic.

Materials and Methods

The experiment to verify the effect of binaural beats on brainwaves was carried out with the following apparatus: An Electroencephalogram Machine (Phoenix Digital EEG Machine), Binaural Beat Audio (10Hz), Stereo headphones

Each subject was presented with a consent form in compliance with procedure for research with human subjects, with instructions to completely read the consent form, including the description of the experiment, before signing and proceeding with their participation in the study. It was explained to the subjects that the purpose of the experiment was to determine the effect of binaural beats on brain waves. The subjects were also informed that if they were interested in the results of the study, it would be available to them after the completion of the study. Each subject was instructed to ask any question before signing the consent form if they were still interested in participating in the study.

Experimentation

The actual experiment was the same for each subject. The procedure is as follows:

- i. The bio data of the subject was collected.
- ii. Subject was made to sit comfortably in an arm chair.
- iii. Methylated spirit was used to clean the head of the subject to remove dust and oil.
- iv. The circumference of the head was measured so as to know the size of neurocap to use.
- v. The neurocap was worn on the head of the subject.
- vi. Electro gel was injected into each of the electrodes to aid conductivity.
- vii. The neurocap was connected to the brain box.
- viii. The "reference electrode" was clipped on the left ear.
- ix. Then the software was launched on the computer.
- x. Montage I was opened to check if all the electrodes are in the right places and making right contacts with the scalp.
- xi. Montage II was opened after "x" above was confirmed positive. Montage II was used for the recording because it covers most part of the brain.
- xii. The sensitivity calibration was adjusted to the standard of 100 microvolt/cm.

- xiii. The High Frequency Filter (HFF) was set at 15Hz, which means any frequency higher than 15Hz should be ignored. And the Low Frequency Filter (LFF) was set at the standard 0Hz.
- xiv. The subject was told to close the eyes and the recording of the baseline brainwaves commenced.
- xv. After about 7 to 10 minutes, the binaural beat audio was played to the subject via stereo earphones and recording continued for another 30 or more minutes.
- xvi. Recording was stopped after about 40 minutes of total recording time.
- xvii. The subject was disconnected from the machine and cleaned up.
- xviii. The subject was asked to explain his/her experiences during the time of the experiment.

Results and Discussion

Results

Table 3.1: Brainwaves of 10 subjects over a 40-minute period

S/N	SUBJECTS	BASELINE (Hz)	10 MIN (Hz)	20 MIN (Hz)	30 MIN (Hz)
1	A1	13.473	8.533	8.698	7.286
2	A2	9.006	10.211	9.399	7.915
3	A3	10.192	9.108	8.692	7.721
4	A4	9.671	8.325	6.661	6.289
5	A5	9.682	8.518	7.117	8.111
6	A6	12.343	10.324	8.753	7.967
7	A7	13.500	9.767	7.675	7.894
8	A8	12.346	10.406	9.746	8.333
9	A9	11.345	11.004	10.328	7.875
10	A10	10.769	9.745	9.765	8.654

Discussion

The data collected from each subject was processed the same way to arrive at the Table 1 of values obtained herein. The procedure of processing includes:

- i. The columns on the brainwave chart printed above represent time in seconds and we considered 7 columns which means 7 seconds.
- ii. The number of cycles per second or per column represents the brainwave obtained for that second, i.e. if there were 10 cycles or troughs or crests per second implies 10Hz for that second.
- iii. The number of channels on the charts below represent the sources of the brainwaves and in montage 2, there are 16 channels
- iv. To get the average brainwave per channel, we summed the cycles in each second/column and divided by 7(the number of seconds/columns for one channel)

- v. To get the average brainwave for the entire channels, the step above (iv) was repeated for all the channels and they were summed up and divided by 16 or any number of channels counted

Hence, we were able to obtain the average brainwaves for any instant of time say 10, 20 or 30 minutes after which the binaural beat audio was introduced.

A look at the Table 3.1 shows a steady decline in brainwaves over time. The baseline (background) brainwaves of most of subjects were within the alpha range (9 to 10 Hz) and a few more in the lower beta brainwaves (12 to 13 Hz). Ten (10) minutes after the binaural beat audio was introduced, there was a decline in the brainwaves. The decline increased after twenty (20) minutes of the introduction of the binaural beat audio. The lowest brainwaves were observed during the 30th minute of the introduction of the binaural beat audio. Subjects A₁, A₃, A₄, A₆, A₇, A₈, A₉ and A₁₀ showed a steady decline in brainwaves from initial time to the final time. However, subjects A₂ and A₅ did not show a regularly decreasing trend in brainwaves over time. This deviation may be due to emotional state of the subjects before the experiment. About 70% of the subjects did not like the humming sound of the audio.

Conclusion

The data provides evidence that all subjects experienced some level of relaxation as evidenced in the significant change in their brainwaves from low beta (13 Hz) to high theta (7 Hz) and even as low as 6 Hz in one subject(A₄). Subjects demonstrated increase in subjective experience of both mental and physical relaxation resulting from the treatment procedures. Four of the subjects acknowledged falling asleep intermittently during the time of the experiment.

The conclusions that can be drawn from this study include: Binaural beats could be used to entrain brainwaves. Alpha-frequency binaural beat stimulation would increase subjective experience of both mental and physical relaxation. Binaural beats could be applied to stress management by inducing relaxation through reduction in the brainwaves.

Recommendations

- i. Other works needs to be carried out in all parts of Nigeria and compared with this work.
- ii. Binaural beats could be applied to stress management by inducing relaxation through reduction in the brainwaves.

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