Significance of Alpha Brainwaves in Meditation examined from the study of Binaural Beats

Anushka Gupta[1], Esther Ramdinmawii[2], and V. K. Mittal[3]
[1]Jaypee University of Information Technology, Waknaghat, Solan, Himachal Pradesh
[2,3] Indian Institute of Information Technology, Chittor, Sricity, A. P., India
ms.anushka.gupta@ieee.org[1], esther.rm@iiits.in[2] and vkmittal@iiits.in[3]

***Abstract*—Human brain contains of approximately 100 billion neurons. Each neuron communicates with few ten thousands of other neurons in order to carry messages in the brain. Significant electrical activity is produced in the brain over synaptic joints of such neurons sending signals at very low frequencies below (50 Hz), thereby forming the brainwave pattern. The brainwaves are categorized as delta, theta, alpha and beta, as per different frequency ranges. In this paper, the effect of binaural beats on human mind is presented. Alpha binaural beats of 10 Hz are produced by creating the auditory illusion of 10 Hz in the brain by playing the binaural beats of 370 Hz and 380 Hz for left and right ear respectively. Binaural beats are effective only when heard through an earphone. In order to examine the effects of binaural beats on human brain, 10 people are subjected to these beats for 3 minutes. Using Matlab, the attention level and meditation levels are measured by alpha brainwaves, and the comparison graphs are plotted. Relative comparison is carried out for each persons state while listening to the binaural beats. This study provides scientific evidences for the common perception that alpha binaural beats and thus music can help a person in achieving a relaxed state of mind i.e., meditative state in a better way.**

Keywords: brainwaves, alpha brainwaves, binaural beats, relaxation, meditation, attention, brain, electroencephalogram

I. Introduction

Brainwaves are electrical activities which are produced by the firing of neurons in the brain [1]. Each of these neurons contacts with 1 to 10 thousand other neurons [2]. Electric waves registered in the brain helped regulate the activities of the brain. These activities can be measured along the scalp using an Electroencephalogram (EEG) device attached to the scalp [3]. These electric waves emit electrochemical impulses of different frequencies which are then received by an Electroencephalogram [4]. The brainwaves, divided into five different categories, which range from the least to the most active, are shown in Table 1 [5].

Delta brainwaves (Fig. 2 (d)) have the greatest amplitude and the slowest frequencies. The brain is in the least active state. It usually occurs when a person is in deep dreamless sleep or is in a deeply meditative state of mind. Delta brainwaves are generally found in infants and advanced meditator. Delta brainwaves can provide the ability to read people's emotions and empathize greatly with people. Theta brainwaves (Fig. 2 (c)) are commonly found in people who dream in a very relaxed state or people struggling with Attention Deficit Disorder (ADD) or Attention Deficit Hyperactive Disorder (ADHD) [6]. A person who is deeply relaxed or sleeping but not in a deep sleep may be in theta state.

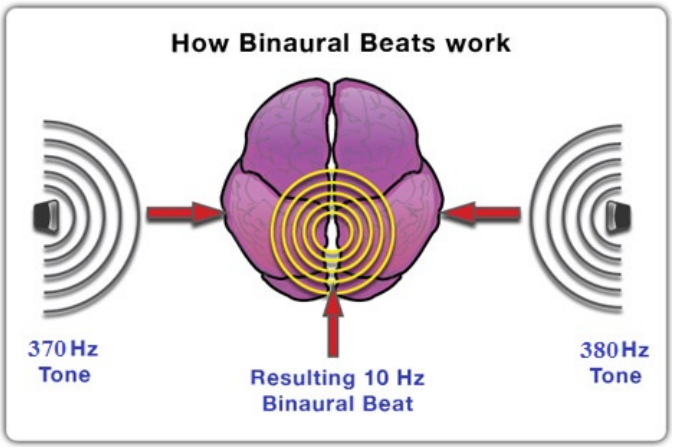

Fig. 1. Binaural Beats representation. To produce 10 Hz binaural beat, 380 Hz and 370 Hz are taken and presented to both side of the ears [25].

Alpha brainwaves (Fig. 2 (b)) state allows a person to be completely free of tension, nervousness, pain and discomfort. However, too much alpha activities lead to excessive daydreaming and escape from reality. Beta brainwaves (Fig. 2 (a)) are the fastest but amplitude is relatively lower than the previous categories. A person exhibits beta state when he thinks logically, is anxious, tries to solve problems or his mind is strongly engaged on some things such as debating or having an active conversation [7]. Gamma brainwaves are achieved when a person have ecstatic experiences and feeling of oneness, or is overjoyed. A person in gamma state may have higher mental activity and motor functions.

Binaural beats can be defined as the illusion that is perceived when dichotically presenting two or more tones of similar frequencies to the ear through stereo headphones [9]. Binaural beats are generally less than 1500 Hz [8]. For example, playing a pure sinusoidal tone with frequency of 370 Hz on the right ear and another with a frequency of 380 Hz on the left ear would create a perception of a third tone with 10 Hz, which is the binaural beat. This is illustrated in Fig. 1. The frequency difference of binaural beats is usually between 1 and 30 Hz [10]. Binaural beats are known to have an emotional effect on a person and have a positive effect on people suffering from

TABLE I
TYPES OF BRAINWAVES AND THEIR FREQUENCIES.

(a) Brainwave Type	*(b) Frequency*
Delta	$<$ 4 Hz
Theta	4 - 7 Hz
Alpha	8 - 12 Hz
Beta	12 - 36 Hz
Gamma	$>$ 36Hz

anxiety and tension [11]. As is mentioned previously, alpha state is when a person is in a tension free state, and playing binaural beats to the scenario helps in achieving this relaxed state of mind.

Several studies including brainwave controlled wheelchair, brainwave controlled robot, and the effect of music on the brainwaves and training a child's brain using music have been done in the past. These studies show positive results on what the brain does and how the right type of music have a positive effect on people. Brainwave controlled wheelchair was designed for better mobility and to aid patients in times of seizures and other medical emergencies [12].

For most brain-controlled robots, EEG, attention and eye-blinking signals were needed to be sent through a Brain-Computer Interface (BCI). The amount of blinks sent to the BCI equals a specific command which was carried out by the robot. To move the robot forward, the attention level was detected. Higher attention level resulted in faster movement. NeuroSky MindWave, which is a dry EEG device, was used for transmitting beta brainwave signals to the BCI. A brainwave controlled robots is also designed to aid people who are unable to move, to be mobile and be more independent of others [13], [14].

In the study of the influence of Mozart's music [15], it was speculated that Mozart's music helps in the activation of certain specific areas of the brain which are significant for spatio-temporal reasoning. It has also been seen that starting musical training at an early age can highly affect how the musical brain is organized [16]. This revealed a difference on the structure and function in the brains of people who play musical instruments and those who don't. Children who are trained musically from the age of 5 to 7 years old also have long-term enhancement of memory as compared to children who are not musically trained [17].

There are several researches about music like the study of production characteristics of music signal [18], [19], or separation of music and source [20]. In the study of characterizing temporal and spectral features of Indian music [18], features like Short-Time Fourier Transform (STFT), Autocorrelation, Linear Prediction (LP) Analysis and Short-Time Energy were analyzed upon the speech files of total 10 speakers. Another study [19] in music deals with classifying musical instruments from monophonic signals. In this study, 3 different instruments (guitar, violin and drums) were taken under observations. The

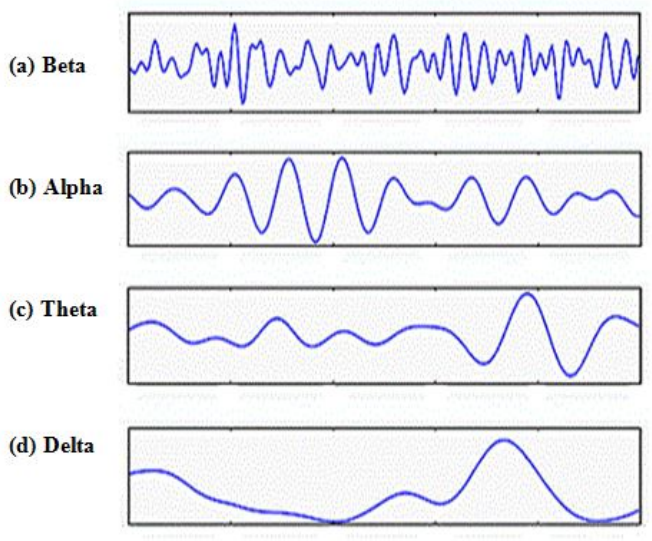

Fig. 2. *Brainwave patterns* for (a) Beta frequency, (b) Alpha frequency, (c) Theta frequency, and (d) Delta frequency [26].

characteristics and musical components of these instruments were analyzed by using the acoustic features, namely Mel Frequency Cepstral Coefficients (MFFCs), Spectral Centroid (SC), Zero-Crossing Rate (ZCR), and signal energy. Musical instruments were then classified depending on their components. Separation of music from its source signal has been studied upon by determining the best window selection [20]. Studies related to the detection of when a person is shouting (shouted speech) [21], Noh voices which are expressive voices [22], and even finding the characteristics of laugh and non-laugh speech signals have been analysed [23]. The Noh voice and laugh speech analysis of source characteristics have been done using modified Zero-Frequency Filtering (mZFF) method.

It is evident that there have been numerous studies related to music, be it monophonic, bi-phonic, or polyphonic. These studies, including the analysis production characteristics of the mentioned music signal, musical instruments, Noh voice etc., however, are solely analysed using speech signal processing, and not brainwave signals. It has also been seen that there is not enough study on binaural beats, and the effect of alpha binaural beats in generating alpha waves for deep meditation. In this paper, a study on brainwaves has been conducted on how binaural beats aid in achieving high level of meditation. The wave patterns of the first four categories are shown in Fig. 2. Experiments were performed on how the alpha brainwaves are significant to a person who is relaxing or meditating while simultaneously listening to alpha binaural beats at 10 Hz via earphone. The results we have seen from our experiments prove promising and could greatly help for future research.

The organization of this paper is as follows: Section II discusses the about the data, how it is obtained and used. Section III describes the methodology of this paper. It discuss in details about the hardware and software instruments used. This is followed by Section IV, in which details the

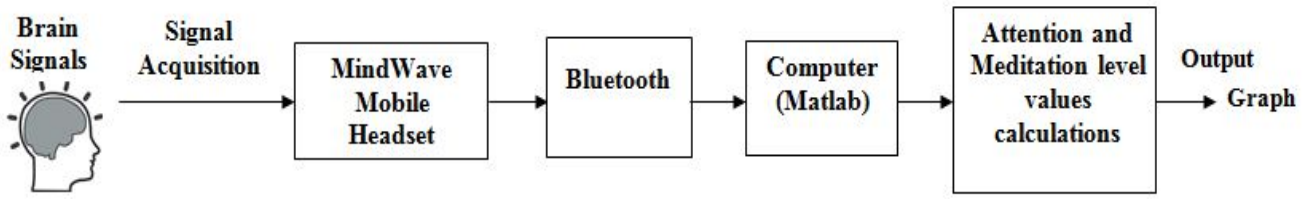

Fig. 3. *Methodology* of the experiment in this study.

Fig. 4. NeuroSky MindWave Mobile Headset description.

experiments performed in this paper are explained. Section V lays out the experiments performed in this paper. Section V lays out the observations from experiments performed in the previous section. Section VI is a discussion on the results obtained, which is followed by Summary and Conclusion of this paper.

II. DATA

To detect brainwaves pattern clearly, it is important to collect samples of binaural beats for proper experimentation on the subjects. With the help of Matlab, the alpha binaural beats have been created. The alpha binaural beats are sinusoidal waves of 370 Hz and 380 Hz for left and right ear respectively. The auditory illusion of 10 Hz will be created in the brain. So, in nutshell, alpha binaural beats of 10 Hz have been taken. The alpha beats were stored in wave file with '.wav' extension for playing these beats through earphones. This alpha binaural beats sample is created for 3 minutes duration.

The alpha frequency ranges from 8-12 Hz. So the median of the Alpha at 10 Hz have been taken. These alpha beats at 10 Hz will force the brainwaves to oscillate at this frequency thereby inducing a relaxed state in the brain [1]. These external alpha binaural beats are played for 3 minutes for the brain to gradually adapt to these beats and thus itself produce alpha waves in the brain.

The brainwaves data are captured through a Neurosky, MindWave Mobile Headset. The brainwaves data are stored in bit values for further processing of the data. 10 subjects were chosen to experiment upon. 5 males and 5 female were taken as the subjects. The age varies from 17-29. The average age of the subject was 24.

III. METHODOLOGY

For capturing the brainwaves, we have used Neurosky, MindWave Mobile Headset shown in Fig. 4. It has an EEG chip TGAM (Thinkgear AM) which collects the brainwaves in the form of electrical pulses. The electrical pulses are produced in head whenever two neurons communicate, i.e. whenever the brain is indulged in an activity. These activities occur at particular frequencies. These frequencies are captured by TGAM chip and the data is stored or processed. The methodology of this paper is illustrated in Fig. 3.

We have used version, R2013a Matlab as a tool for creating binaural beats and conducting experiments. The library files for the connection and use of Neurosky, MindWave Mobile Headset are available at the official site. The two files, "Thinkgear.h" and "Thinkgear.dll" are to be loaded at the starting of any code. On this platform, combined attention and meditation coding is executed. The attention reflects the emphasis on beta waves in the brain and meditation level emphasizes on the alpha brainwaves. The attention and meditation level can be seen on a graph as a real-time plotting.

In case, one does not wish to code then an open source software, NeuroExperimenter can be downloaded from the official site of Neurosky. It provides a graphical interface for attention and meditation level. MindWave Mobile has an inbuilt Bluetooth for pairing and data retrieval purposes. To utilize the Headset data, Bluetooth drivers must be updated before working on Matlab platform. Lastly, VLC media player have been used for playing the beats using a normal earphone.

IV. EXPERIMENTS AND OBSERVATIONS

The subjects were made to wear the MindWave Mobile Headset. They were observed for 5 minutes in total. For the first two (2) minutes, no beats were played and their normal state was observed. On the start of the 3rd minute, the alpha binaural beat was played for 3 minutes long and the subjects were told to close the eyes and relax. The beats were played through a normal earphone. The sound was kept at medium with 40% volume.

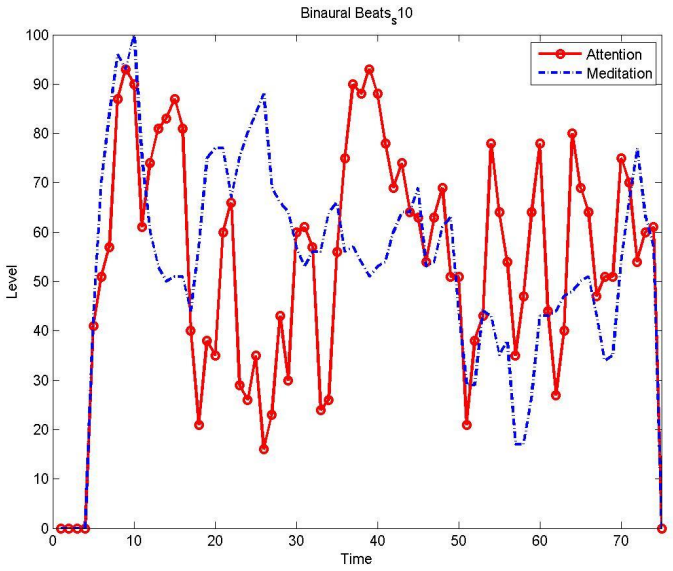

Fig. 5. Illustration of relative *attention* and *meditation* levels observed using alpha brainwaves, when the subject is in normal state.

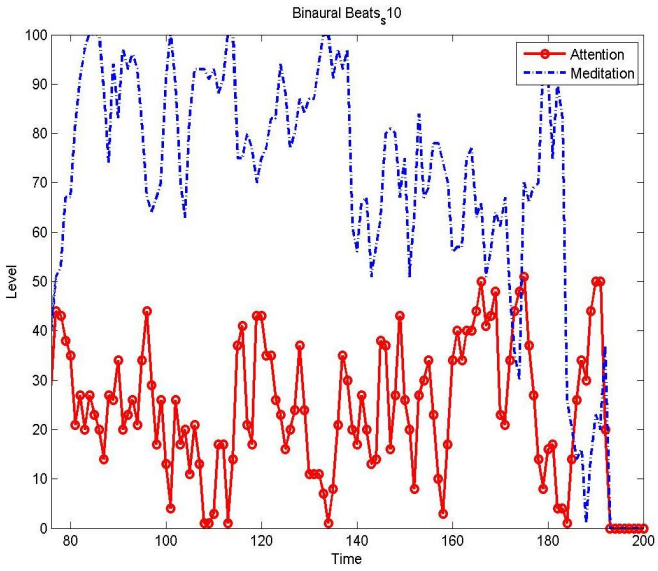

Fig. 6. Illustration of *attention* and *meditation* levels using alpha brainwaves, observed when the subject is hearing alpha binaural beats.

TABLE II
AVERAGE VALUES OF ATTENTION AND MEDITATION LEVELS OF 10 SUBJECTS: (A) THE SUBJECT (GENDER), (B) ATTENTION LEVEL AND (C) MEDITATION LEVEL OF A SUBJECT WITHOUT BEATS, AND (D) ATTENTION LEVEL AND (E) MEDITATION LEVEL WITH BEATS.

	Without Beats		*With Beats*	
(a) Subjects	*(b) Attention*	*(c) Meditation*	*(d) Attention*	*(e) Meditation*
S1 (F)	55.16	50.04	48.23	87.31
S2 (M)	47.17	50.73	41.18	57.57
S3 (F)	38.76	48.96	55.92	69.27
S4 (M)	45.65	45.74	53.38	52.53
S5 (F)	40.45	40.45	35.53	69.18
S11 (M)	61.28	50.34	48.10	65.00
S12 (M)	59.40	46.20	34.12	66.31
S13 (M)	36.00	33.32	45.78	61.77
S14 (F)	53.56	53.22	23.97	69.53
S15 (F)	37.71	37.47	20.21	73.47

TABLE III
SAMPLE DATA OF A SUBJECT FOR FIRST 10 ITERATIONS WHEN ALPHA BINAURAL BEATS ARE PLAYED FOR 3 MINUTES VIA EARPHONES. FIRST FOUR VALUES ARE 0S BECAUSE OF THE DELAY IN INTERPRETING THE SIGNALS SENT FROM SENSOR HEADSET, AND MEASURING THE LEVELS. HERE, (A) DENOTES THE ITERATION NUMBER, (B) THE ATTENTION LEVEL, AND (C) THE MEDITATION LEVEL.

(a) Iteration No.	*(b) Attention levels*	*(c) Meditation levels*
1	0	0
2	0	0
3	0	0
4	0	0
5	41	43
6	51	70
7	57	84
8	87	96
9	93	93
10	90	100

Real time plotting of the attention and meditation for the whole 5 minutes was done. The graphs for the meditation level and attention level were plotted, that is, the inclination towards alpha and beta was observed. The attention and meditation graphs were observed for two cases, "Without beat" as in Fig. 5 and "With beat" as in Fig. 6. All the values were stored in excel sheet for the duration of 5 minutes for the two cases. Average values of meditation and attention in both the cases were calculated as in Table II and graphs were plotted for further comparison.

From the graphs and diagrams, it is evident that for the first two seconds the attention level was higher than the meditation level. When the beats are played, the subject's meditation level gradually becomes higher than the attention level. The values of meditation level are generally higher than the attention level at almost all the points. The raw values were stored directly in excel file as done in Table III. In the first few iterations, the attention meditation levels are 0s (zeros) because the neural signals are first captured and input into the Thinkgear chip in the MindWave Headset. These signals are then sent via Bluetooth to the Brain-Computer Interface, i.e., Matlab in our case. The signals are then interpreted using the algorithm for attention and meditation, and are output in the plots. Hence there is a slight delay in plotting the values.

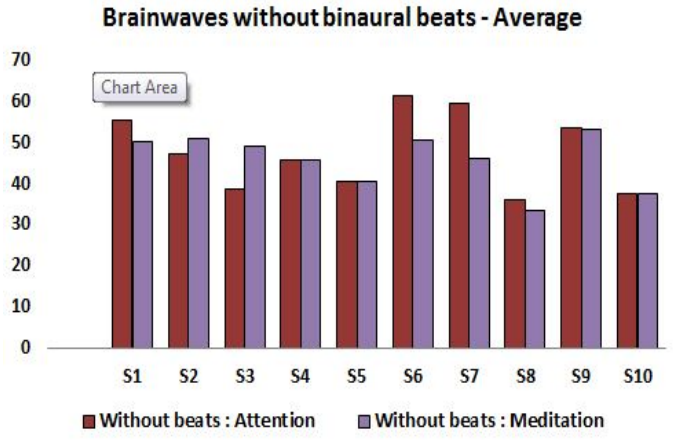

Fig. 7. Average values of *attention* and *meditation* levels for 10 subjects in the normal state that is *without binaural beats*.

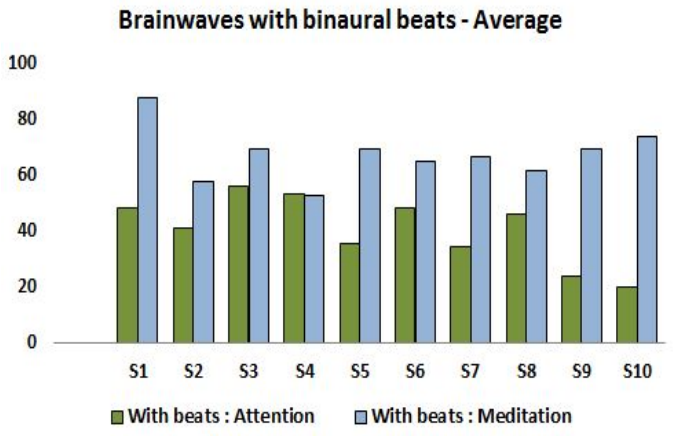

Fig. 9. Average values of *attention* and *meditation* levels for 10 subjects in the normal state that is *with binaural beats.*

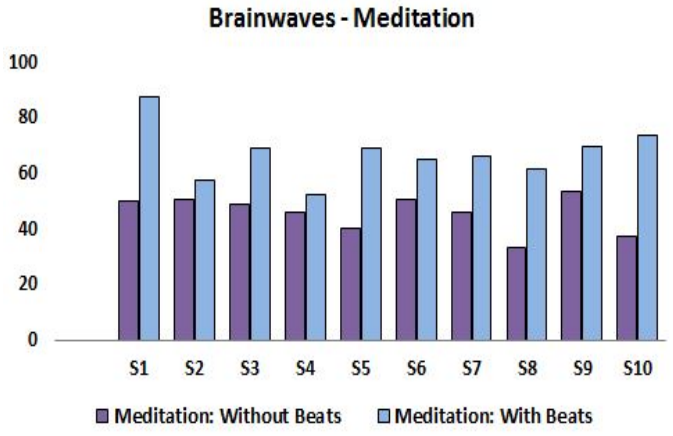

Fig. 8. Average values of *meditation* levels for 10 subjects *without the binaural beats* and *with the binaural beats* played.

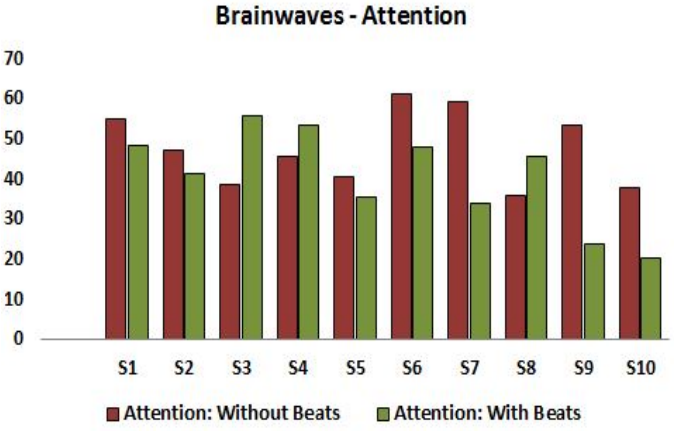

Fig. 10. Average values of *attention* levels for 10 subjects *without the binaural beats* and *with the binaural beats* played.

V. DISCUSSION ON RESULTS

Firstly, for two minutes, the subject is in normal state and is attentive to the surrounding. The subject can move, talk and do all the things that he does while wearing the headset. The brain is more active in this state. This attentiveness and activeness to the surrounding causes the individual to incline towards the beta waves which falls in the range of 13-30 Hz. This is why the attention levels and the meditation levels fluctuate in the normal state. The attention levels and meditation levels were noted for every iteration. The total number of iterations was 75 for normal state. So the iterations correspond to the number of brain wave samples taken from the MindWave Mobile. So in the Normal state attention level was higher than the meditation level.

Now, the alpha binaural beats were played via earphones to the subjects for almost 3 minutes. The no. of iteration was 125. The average of 125 samples was taken for each subject. Here, the subject's mind changes from the attentive state to the relaxed state. So when the beats are played, gradually the subject's brain starts oscillating with the external frequency of alpha waves. The frequency of occurrence of alpha waves in the brain gradually increases. The brain itself starts oscillating with the alpha frequency and starts producing alpha waves. The subject becomes calm and relaxed. Thus, the level of meditation becomes higher than the level of attention. It is also observed that the attention level decreases, when the binaural beats are played, in comparison to the previous state. This also proves the significance of alpha binaural beats in relaxing a human mind.

The comparison of attention and meditation levels in the normal state and the state when the beats are played to the subjects are shown in Fig. 7, Fig. 8, Fig. 9 and Fig. 10.

VI. SUMMARY AND CONCLUSIONS

This paper presents a study on the effect of the binaural beat on human mind. In this study, we conducted experiments on 10 subjects and recorded their brainwave through Neurosky, MindWave Mobile Headset. The data was acquired over Bluetooth on Matlab platform. The samples for the binaural beats were also created on Matlab version R2013a. Each sample

was 3 minutes long. The samples were binaural beats of 370 and 380 Hz for left and right ear respectively, that is, the sample was of alpha binaural beats of 10 Hz. These beats were played for 3 minutes on the subject after observing their normal mode for 2 minutes. The graphs for attention level and meditation level were plotted and the values were stored in the excel file. The average values for attention and meditation were calculated for both the case of 'without beats' and 'with beats'.

The paper presents the discussion on how the alpha wave dominates over the other 3 waves (i., beta, theta and delta brainwaves) when a person is in a relaxed state. When in normal state, an individual is more alert to the happenings in the surroundings, which is an indication that music definitely relaxes a person. The best way to observe is through the Binaural Beats which create an auditory illusion of lower frequency ranges in the brain (below 50 Hz). The brain has different experiences for different ranges of frequency. In the alpha range of frequency, an individual tends to be more relaxed and calm, in a light meditated state. The graphs are also plotted for the attention and meditation level in the two cases.

As an extension to this study, further experiments can to be done by observing the subjects under other ranges of external frequencies. The frequencies can be taken from delta, theta, and beta ranges. Various music samples of either different artistes or different genres can also be used to study the effects of music on the human mind. The effect of all these samples can be well observed on the brain using the headset instrument.

In the future, this experiment can be done better using an actual EEG equipment which gives more distinct and significant results than the NeuroSky MindWave Mobile Headset. The whole pattern of the brain can be mapped when EEG is used in case of playing Binaural Beats. Using EEG equipment, the effects of alpha binaural beats can also be monitored in left and right parts of the brain separately. The MindWave mobile equipment is an easy way to monitor the results as well as graphically see the results. This paper will be very helpful for further studies in brain-wave pattern. It can also help in improvising the music therapy on an individual or a patient. This study also improvises over the significance of external alpha binaural beats in controlling of the mind. The external alpha binaural beats force the brain to oscillate with the same alpha (8-10 Hz) frequency and helps in relaxation of the brain. Thus it also signifies the importance of alpha brainwaves in meditation and relaxation of the brain.

REFERENCES

[1] Walter J. Freeman, "Making sense of brain waves: The most baffling frontier in neuroscience", in *Biocomputing*, ch. 3, vol. 1 pp. 1-23, Feb. 2002.

[2] Vilayanur S. Ramachandran, "The tell-tale brain: A neuroscientist's quest for what makes us human", *Norton & Company Inc.*, 500th Fifth Avenue, 1st Edition, 2012 (context: Introduction No Mere Ape - A brief tour of your brain).

[3] Den'etsu Sutoo and Kayo Akiyama, "Music improves dopaminergic neurotransmission: Demonstration based on the effect of music and blood pressure", in *Science Direct Brain Research*, vol. 1014, no. 2, pp. 255-262, June 2004.

[4] Ivana Andelkovic, "Brainwave music", in MAT 200B, winter 2010.

[5] Pantech solution (2013, August 1). *Brainwave starter Kit - Brain computer interface*, [Online]. Available: https://slideshare.net/pantech solutions.

[6] Jeffrey L. Fannin, Understanding your brainwaves, in *Center for Cognitive Enhancement*, Glendale, Arizona.

[7] Jim Robbins, "Types of Brainwaves", in *A symphony in the brain: The Evolution of the new Brainwave Biofeedback*, Revised Edition, Ed. New York: Grove Press, 2001.

[8] Patrick A. McConnell, Brett Froeliger, Eric L. Garland, Jeffrey C. Ives, and Gary A. Sforzo, "Auditory driving of the autonomic nervous system: Listening to theta-frequency binaural beats post-exercise increases parasympathetic activation and sympathetic withdrawal" , in *Original Research Article*, vol. 5, no. 1248, Nov. 2014.

[9] Rossitza Draganova, Bernhard Ross, Andreas Wollbrink, and Christo Pantev, "Cortical steady-state responses to central and peripheral auditory beats", in *Advance Access Publication*, vol. 18, no. 5, pp. 1193 1200, Sep. 2007.

[10] Gerald Oster, "Auditory beats in the brain", in *Scientific American*, vol. 1073, no. 94, pp. 94-102, 1973.

[11] Jan Forster, Lucas Bader, Stefan Hebler, Oliver Roesler, and David Suendermann, "A first step towards binaural beat classification using multiple EEG devices", in *International Conference on Applied Informatics for Health and Life Sciences*, Turkey, Oct. 2014.

[12] Kamlesh H. Solanki and Hemangi Pujata, "Brainwave controlled robot", in *Internation Research Journal of Engineering and Technology*, vol. 2, no. 4, pp. 609-612, July 2015.

[13] Siliveru Ramesh, K. Harikrishna, and J. Krishna Chaitanya, "Brainwave controlled robot using Bluetooth", in *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 3, no. 8, pp. 11572-11578, Aug 2014.

[14] Lavanya Thunuguntla, R. Naveen Venkatesh Mohan, abd P. Mounika, "EEG based brain controlled robot", in *International Journal of Engineering Research and Applications*, vol. 4, no. 4, pp. 195-198, Apr. 2014.

[15] Norbert Jausovec, Ksenija Jausovec, and Ivan Gerlic, "The influence of Mozarts music on brain activity in the process of learning", in *Elsevier Clinical Neurophysiology*, vol. 117, no. 12, pp. 2703-2714, Oct. 2006.

[16] Donald A. Hodges, "Implications of music and brain research", in *Music Educators Journal Special Focus*, vol. 87, no. 2, pp. 17-22, 2002.

[17] Gortfried Schlaug, Andrea Norton, Katie Overy, and Ellen Winner, "Effects of music training on the child's brain and cognitive development", in *New York Academy of Sciences*, vol. 1299, no. 99, pp. 219-230, 2005.

[18] Shivam Sharma and V. K. Mittal, "Singing characterization using temporal and spectral features in Indian musical notes", (accepted for publication) *IEEE International Conference on Signal Processing and Communication*, Dec. 26-28, 2016.

[19] Seema Ghising and V. K. Mittal, "Classifying musical instruments using speech signal processing methods", (accepted for publication) *IEEE INDICON*, Dec. 16-18, 2016.

[20] Shivam Sharma and V. K. Mittal, "Window selection for accurate music source separation using REPET", in *3rd International Conference on Signal Processing and Integrated Networks (SPIN)*, Feb. 11-12, 2016.

[21] V. K. Mittal and B. Yegnanarayana, "Production Features for Detection of Shouted Speech", *IEEE Tenth Cibsumer Communications and Network Conference (CCNC)*, vol. , no. , pp. 106-111, Jan.2013.

[22] V. K. Mittal and B. Yegnanarayana, "Study of characteristics of aperiodicity in Noh voice", *The Journal of Acoustic Society of America*, vol. 137, no. 16, 2015.

[23] V. K. Mittal and B. Yegnanarayana, "Analysis of production characteristics of laughter", *Computer Speech & Language*, vol. 30, no. 1, pp. 99-115, Mar. 2015.

[24] The Alkaline Zone (2016, May 14). *Binaural Beats for Relaxation and Sleep* [Online]. Available: https://thealkalinezone.com. Last viewed on 05 Nov. 2016.

[25] Body Mind Soul Spirit (2014, Oct. 24). *Understanding Brainwaves to expand our consciousness* [Online]. Available: http://www.bodymindsoulspirit.com. Last viewed on 05 Nov. 2016.

[26] Patterson Education Therapy Helping kids who learn differently (2014, Nov. 9). *Synchrony or growing out of ADHD* (Online). Available:http://www.pattersoneducationtherapy.net. Last viewed on 04 Nov. 2016.