© 2016 IJSRSET | Volume 2 | Issue 3 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Binaural Entrainment and Its Effects on Memory

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ABSTRACT

Memory is a cognitive process which aids in learning. The pschycological and neurological brain states related to memory can be assessed with the help of brain mapping technique EEG. In this paper, we will study these brain states and their modulation with the help of brain therapeutic exercise using binaural beat stimulation called brain entrainment. This training of brain by audio stimulation can alter the brain impulses and can be used to improve working memory performance by increasing theta (4-8 Hz) band. Here we used the upper alpha frequency of 10.7 Hz to train the brain. Subsequently EEG analysis is used to observe the enhancement during active states along with psychological tests to support the results**.**

Keywords: memory, entrainment, binaural, EEG

I. INTRODUCTION

The human brain is the most complex organ of our body which has millions of neurons. These neurons transmit electrical impulses which are responsible for our day to day activities whether they are movement, thinking, emotions, memory etc. Each of these activities is associated with different frequencies [1] [2]. These frequencies are classified in four groups as: delta (1-4 Hz) associated with deep sleep, theta(4-8 Hz)associated with creativity, memory, meditation, alpha(8-13 Hz) related with active learning, reduced stress and beta (14-24 Hz) dominates during alert state [3].

This electrical activity of brain can be mapped through EEG using electrodes on the scalp. EEG is a non-invasive technique to read the brain waves. It has gained popularity because of its high resolution and cost efficient system which is easy to use with simple acquisition and easy analysis [4].

This paper focuses on altering these impulses by the application of audio stimulation using binaural beats. Two different auditory frequencies combine to give a frequency equal to the difference between the two original frequencies called as binaural beat. For example, mixing frequencies of 300 Hz and 315 Hz will give a binaural beat of 15 Hz. Each ear hears the individual frequencies but the brain perceives their difference [5]. This frequency was chosen because it was found in researches that it has a significant effect in improving mental cognition [6]. The Audio Stimulation in this experiment was done for 28 minutes.

Researches have been done in this area to synchronize the brain impulses in order to achieve improved performances [7]. Here, we have used the upper alpha frequency of 10.7 Hz to see the effects on memory. Memory can be classified in three forms as sensory memory, short term memory and long term memory [8]. Sensory memory is where all the registration of external stimuli is done. It is the initial perception of external environment. Short term memory (STM) is the working memory and it processes that information with understanding and reasoning which are perceived with attention. Long term memory is the repetition of STM and can be kept for years. It affects the human behaviour [9][10].

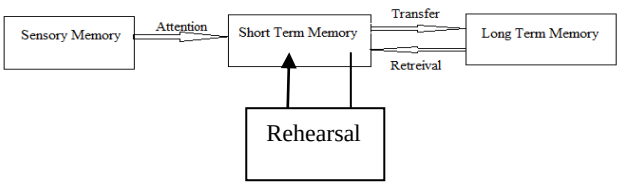

Figure 1 : Classification of memory

In this study, we work on STM and its delayed recall. The paper has following objectives:

(i) Whether the upper alpha frequency can have training effects.
(ii) To support the hypothesis that entrainment with alpha can improve memory.

Thus, results can be analysed to see the cognitive effects of brain wave entrainment.

II. METHODS AND MATERIAL

The whole experimental procedure was conducted after filling of the consent form by the individuals. None of them had participated in brain entrainment before.

A. SUBJECTS

9 subjects participated in the study (7 males and 2 females) aged from 23 to 26. They had not been under the entrainment before and hence are detailed about the whole protocol. They were asked to be quiet and relaxed during the process. However, no information is dispensed about the purpose of the study. All subjects had no history of mental or attention deficient disorder.

B. Psychological Test

Before acquiring the signal, subjects underwent a pre-memory test which is called the visual spatial memory test. First, the subject is shown some figures for 10 seconds and after the exposure of 10 seconds, he/she is asked to draw the same figures on a paper. This process is repeated 2 more times. These three trials were done to assess the short term memory. For delayed recall, the subject is asked to draw the same figures after a time gap of 30 minutes.

In the same way, a post psychological memory test is also done after brain entrainment following the same steps but with different figures.

The scoring in both pre and post is done on the basis of following criteria:

(i) If the subject has drawn the same figure or figure with some close approximation with the original one.
(ii) If he/she has drawn the figures at the correct position with respect to the one shown in the original figure.

C. Signal Acquisition Through EEG

The EEG equipment used is the RMS MAXIMUS EEG which is a 24 channel system with notch filter at 50 Hz. The placement of electrodes on the scalp follows 10/20 international standard of electrode placement. These electrodes cover different areas: frontal (FP1, FP2, F7, F3, FZ, F4, F8), left temporal (T3, T5), right temporal (T4, T6), central (C3, CZ, C4), parietal (P3, PZ, P4) and occipital(O1, O2).The sampling rate is 256 Hz with sensitivity user selectable (7.5μV/mm).

For binaural beat, two frequencies of 440 Hz (left ear) and 450.7 Hz (right ear) Hz are taken to give the final signal of frequency of 10.7 Hz. The whole session was conducted at 10 dB. Frequencies are produced with the help of Audacity version 2.1.2 software.

The session was conducted in an air conditioned room and was devoid of any electromagnetic interference.

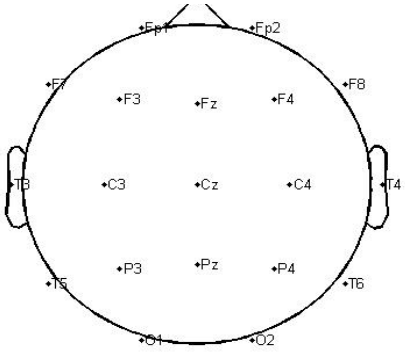

Figure 2: Montage with 19 electrodes configuration

D. Procedure

The whole procedure is shown in the Figure 3 . Subject is asked to relax with eyes closed during the whole session. Then, following the 10/20 international standard of electrode placement, 25 electrodes including the ECG are planted on the scalp. After the placement, first, the baseline of the subject is recorded with first 5 minutes of silence. After this, binaural beat is given with first few minutes of beta which is consequently followed by upper alpha of 10.7 Hz. This BB session is done for 28 minutes. Finally, 5 minutes of silence follows for

recovery state. During the whole session, the subject is asked to open his/her eyes to avoid drowsiness.

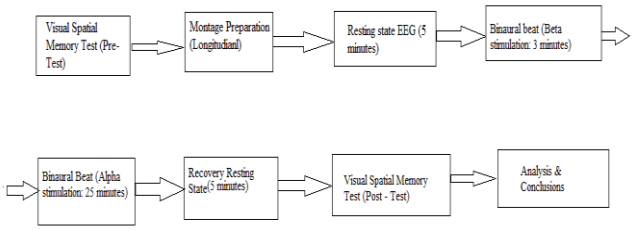

Figure 3 : Block diagram showing experimental

E. Signal Processing

Raw EEG data is recorded using RMS MAXIMUS. The data was accompanied with artifacts mainly from eye movement, eye blink, jaw movement etc. To ensure EEG data is clean, these artifacts are marked as events during the recording.

Recorded data is analyzed through MATLAB using EEGLAB tool where the EEG data is imported in ASCII format. Basic FIR filter has been used to filter the data with maximum frequency marked at 40 Hz. The filtered data is then divided in two sets of data using EEGLAB tool of MATLAB as:

(i) Pre –data of 5 minutes before binaural stimulation.
(ii) Post-data of 5 minutes after binaural stimulation.

These two sets of data are the subjected to artefact removal using independent component analysis. After the rejection of artefacts, power spectral density of all the electrodes is constructed showing the dominance of the theta frequency over the different areas of brain. Consequently, relative energy ratio is also measured using relative percentile of theta is calculated during pre and post data analysis.

III. RESULTS AND DISCUSSION

Figure 4 depicts the power spectral density of theta over different areas of brain with respect to 19 electrodes which shows that expanse of the 8 Hz frequency has increased after binaural stimulation.

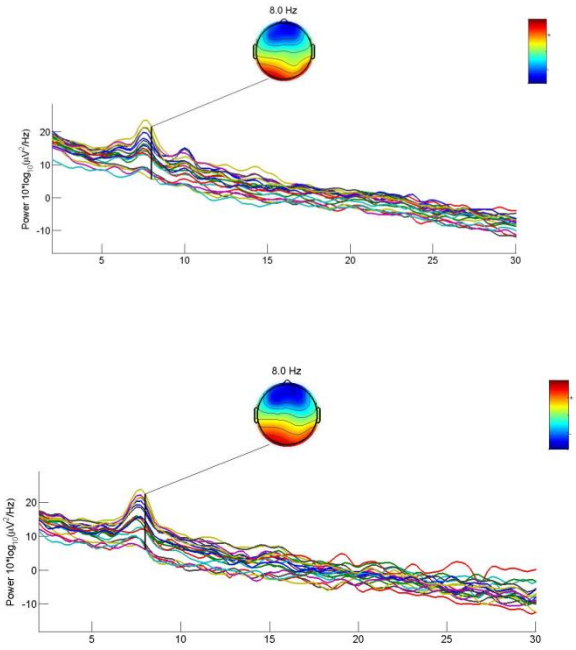

Figure 4 : Power spectral (a) pre-power (before binaural) (b) post-power (after binaural)

Similarly, Table 1 shows the relative change in theta in terms of relative energy ratio. The relative energy ratio calculates the relative percentage of theta power in total power where subjects responded positively to audio entrainment as evident from the increase in percentage of relative energies in theta in post session as compared to pre session.

TABLE I
RELATIVE ENERGY RATIO

Electrodes	S1		S2		S3		S4	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
FZ	0.13	0.15	0.12	0.16	0.15	0.19	0.17	0.18
CZ	0.13	0.15	0.23	0.25	0.19	0.23	0.18	0.22
PZ	0.14	0.16	0.21	0.22	0.21	0.29	0.19	0.20
FP1	0.15	0.16	0.17	0.19	0.12	0.18	0.19	0.21
FP2	0.10	0.13	0.18	0.19	0.15	0.16	0.15	0.17
F3	0.15	0.19	0.17	0.20	0.15	0.22	0.14	0.19
F4	0.13	0.17	0.19	0.20	0.20	0.22	0.18	0.19
C3	0.13	0.18	0.17	0.20	0.20	0.24	0.19	0.21
C4	0.13	0.16	0.17	0.20	0.20	0.24	0.19	0.20
P3	0.14	0.17	0.18	0.21	0.22	0.28	0.20	0.21
P4	0.14	0.17	0.17	0.21	0.22	0.25	0.19	0.18
O1	0.16	0.17	0.21	0.22	0.33	0.34	0.16	0.19
O2	0.15	0.17	0.18	0.22	0.29	0.30	0.18	0.16
F7	0.15	0.17	0.24	0.21	0.20	0.22	0.20	0.22
F8	0.15	0.18	0.19	0.20	0.21	0.20	0.20	0.20
T3	0.13	0.17	0.19	0.21	0.22	0.24	0.17	0.18
T4	0.13	0.17	0.18	0.19	0.24	0.25	0.22	0.18
T5	0.14	0.16	0.21	0.21	0.28	0.30	0.18	0.20
T6	0.13	0.17	0.20	0.22	0.32	0.31	0.21	0.18

Further, the results are corroborated by visual spatial memory test which measures the memory in terms of learning and retention parameters of individuals. Table 2 and Table 3 shows all the trials and corresponding learning done in two sessions as pre-intervention and post-intervention.

TABLE 2
VISUAL MEMORY TEST

Subjects	Learning		Delayed recall	
	Pre	Post	Pre	Post
S1	92	16	84	84
S2	>99	79	58	82
S3	92	92	34	62
S4	2	16	84	84

Here learning defines how fast the subject has grasped the test quickly. It should be low foe good cognition. Delayed recall defines memory in terms of percentage retained after test. It should be high for good memory.

IV.CONCLUSION

The study was conducted to analyse the effect of alpha stimulation on theta enhancement and subsequent effect on memory. Out of 19 electrodes used for the brain map, 13 electrodes (FZ, CZ, FP1, FP2, F3, F4, C4, P3, P4, F7, T3, T4 and T5) showed significant change in theta dominance in majority of subjects. The psychological test also confirms the result.

Hence, the results show that alpha frequency has indeed positive effects on theta where frontal, parietal and temporal areas of brain are affected more significantly by audio entrainment. Thus, the results stand by the proposition that audio entrainment by binaural frequency can impact the brain chemistry and can be used for improvement of brain performance by inducing frequency following response to enhance cognition.

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