Effect of continuous and short burst binaural beats on EEG signals

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Abstract— **Binaural beats are perceived when two slightly different frequencies of sound are presented to each of the ear. The difference between the two frequencies would be the frequency of the binaural beats. Binaural beats of different frequency ranges were found to influence the brain waves producing cortical entertainment and was reported to affect the subject behavior and cognitive functions. The continuous presentation of binaural beats for a prolonged time has been found not to cause any significant changes. Hence the aim of this paper was to find the effect of continuous and short burst presentation of binaural beats on EEG signal. Eighteen participants were divided into two groups and one group was initially exposed to 12 Hz short burst beat stimulus followed by continuous beat stimulus and the other group was exposed to 18 Hz short burst beat and continuous beat stimulus. Both the groups were exposed to white noise prior to the binaural beat stimulation and also between the short burst and continuous beat stimulations. The recorded EEG signals showed increase in cortical mean absolute power after short burst stimulation while continuous stimulation decreased mean absolute power. However, no significant difference or frequency following effect elicited by either continuous or short burst stimulation was observed.**

Keywords: Binaural beats; Continuous beat; Short burst.

I. Introduction

When two sinusoidal waves of slightly different frequency are given separately to each ear as auditory stimulus, the sound is perceived as single tone of frequency equal to the difference between two waves known as binaural beats [1]. If the standard tone is 400 Hz and the carrier tone is 410 Hz, then the brain perceives the difference in frequency as binaural betas of 10 Hz. Better perception of binaural beat occurs if the standard and carrier tone are close to 400 Hz and frequency difference of less than 35 Hz. [2]. Human perception of binaural beats can be explained from the phase-locked response of inferior colliculus neurons to the given binaural beat stimulus in cats [3].Binaural beats are reported to cause the frequency following effect over the scalp [2].The phase-locked neural activity of brainstem auditory pathways are responsible for scalp-recorded frequency following response (FFR) [4]. EEG is used to record the auditory evoked responses produced by the binaural beat stimulus [5]. Previous studies shows binaural beats of different frequency ranges are found to affect the brain waves. The method of presentation of binaural beat influences the FFR. The prolonged presentation of binaural beats for 3 minutes are found to affect divergent but not convergent thinking [6]. However, binaural beats of 2 minutes stimulation failed to affect the vigilance performance and cortical frequencies when 7 Hz alpha and 16 Hz beta stimulation are given [7]. Effect of binaural beats on EEG are found to occur after an average 5 minutes of stimulation [8]. But, recent studies shows binaural beats of 5 minutes stimulation does not change the relative power of EEG [9]. Also, binaural beats stimulation did not reduce the symptoms of inattention in children and adults following 20 minutes of prolonged presentation [10]. Alternatively, intense short burst of stimulation affected EEG waves as reported in the recent study where a 100 ms beat stimulus that increases the amplitude responses but the frequency modulation responses are not observed [11]. Studies involving the continuous stimulation for several minutes reported that the stimulation duration is insufficient and suggested to increase it. However, prolonged duration might result in habituation to the given stimulus. Further, there was no study that compares the short burst stimulation and continuous stimulation effect on EEG. Hence, this study is attempted to compare the effect of short burst and continuous stimulus on EEG using two different binaural beat frequencies of 12 Hz and 18 Hz.

II. METHOD

A. Participants

Eighteen participants (18 males) volunteered for the study with the age group varying from 22 to 26 (mean 23.6y). No hearing loss or any neurological disorders were reported in any subjects. The participants were randomly distributed to one of the two binaural beat frequency groups of 12 Hz and 18 Hz that resulted in 9 participants in each group. All the participants were subjected to the study only after obtaining the written informed consent approved by Human research ethical committee of the University.

B. Binaural beats

BrainWave Generator software version 3.1.12 (http://www.bwgen.com/) was used to produce the binaural beats of 12 Hz and 18 Hz frequency. Carrier tone frequencies close to 400 Hz were found to produce clear binaural beat [1]. Hence, a standard tone of 380 Hz and a carrier tone of 392 Hz were used to produce 12 Hz frequency while a 398 Hz carrier tone was used to produce 18 Hz frequency. For both 12 Hz and 18 Hz beat frequencies, the short burst stimulus contained 10 epochs of 1600 ms beat frequency interspersed by 800ms white noise. While for the continuous stimulation, 10 minutes of beat frequency was produced without any interval.

C. EEG data acquisition

The EEG was recorded from all the participants using RMS Brainview plus 24 channel EEG system. The electrodes were placed according to the standard 10-20 electrode placement method [14] as shown in the fig.1. The EEG system was connected to a desktop that contains RMS SuperSpec software that controls the EEG recordings. All the EEG data were sampled at 30mm/s. The sensitivity was set at 75µV/mm. The electrode impedances were kept below 50kΩ throughout the recordings.

D. Experimental procedure

The participants were requested to be relaxed in eye closed position during the whole EEG recordings. Initially, both the 12 Hz and 18 Hz frequency groups received the white noise as control for the period of 2 minutes which was followed by short burst stimulation. The white noise was given again for 1 minute before giving the continuous beat stimulation for 10 minutes. The binaural beats were given to the participants using in-ear headphones. The EEG was recorded throughout the procedure from all the 21 electrodes. The absolute cortical power (μV^2) of the 19 electrodes except the linked ear electrodes were obtained from analysing the last three seconds of the EEG data at the end of each stimulation group including control stimulation. The mean of the absolute power (μV^2) was calculated from the average of 19 electrodes for both short burst and continuous stimulation. The mean Absolute power was determined for peak alpha frequency (10 – 13 Hz) and broadband beta frequency (16-19 Hz).

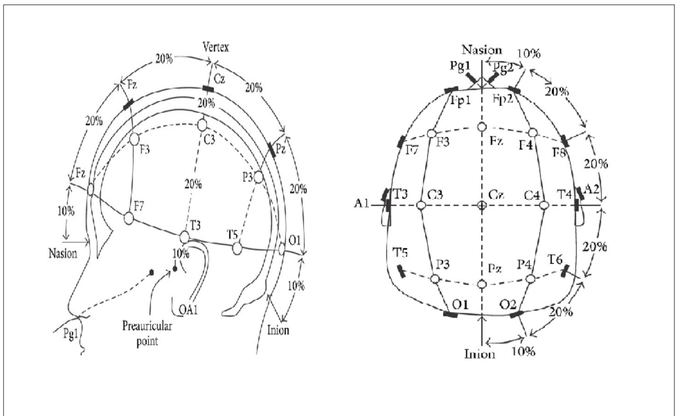

Fig. 1. Standard 10-20 EEG electrode montage position [14].

III. RESULTS

The EEG data were analysed using RMS SuperSpec software version 4.2.6.A and the EEG was sampled with low pass filter of 0.5 Hz and high pass filter of 35 Hz. The notch filter was set at 50 Hz. The reference was taken as common average of standard 21 EEG electrodes.

A. 12 Hz stimulation

One way repeated measures analysis of variance was conducted for absolute cortical power distribution for both peak alpha (10 – 13 Hz) and broadband beta (16 – 19 Hz) frequency. Tukey's multiple comparison test was done to determine the effect of 12 Hz beat frequency on the cortical absolute power. For peak alpha frequency (10 – 13 Hz), no significant difference was found between control white noise and short burst stimulus ($p = .95$) or between control and continuous stimulation ($p = .83$). No significant difference was observed between short burst and continuous stimulus ($p = .79$). For broadband beta frequency (16-19 Hz), there were no significant difference between control and short burst stimulus ($p = .94$) or between control and continuous stimulus ($p = .77$). No significant difference was found between short burst and continuous stimulus ($p = .74$).The mean and standard deviation of absolute cortical power (μV^2) at the end of 12 Hz stimulus was plotted in the fig.2 for both peak alpha and broadband beta frequency range.

B. 18 Hz stimulation

One way repeated measures ANOVA with tukey's multiple comparison test was done to determine whether the 18 Hz beat frequency changed the cortical absolute power. For peak alpha frequency (10 – 13 Hz), no significant difference was found between control white noise and short burst stimulus ($p = .99$) or between control and continuous stimulation ($p = .73$). No significant difference was obtained between short burst and continuous stimulus ($p = .23$). For broadband beta frequency (16-19 Hz), there was no significant difference between control and short burst stimulus ($p = .99$) or between control and continuous stimulus ($p = .70$). No significant difference was found between short burst and continuous stimulus ($p = .14$). The mean and standard deviation of absolute cortical power (μV^2) at the end of 18 Hz stimulus was plotted in the fig. 3 for both peak alpha and broadband beta frequency range.

IV. DISCUSSIONS

The frequency following effect was not observed either in short burst or continuous stimulation for both 12 Hz and 18 Hz groups. Although, no statistical significance was obtained, the increase in mean cortical absolute power was observed in peak alpha frequency (10 - 13 Hz) and broadband beta frequency (16 - 19 Hz) for 12 Hz short burst group comparing the control. While the mean absolute power decreases for 12 Hz continuous group in both peak alpha and broadband beta frequency ranges. Thus, increased mean absolute power was recorded at the end of 12 Hz short burst stimulus as shown in table I.

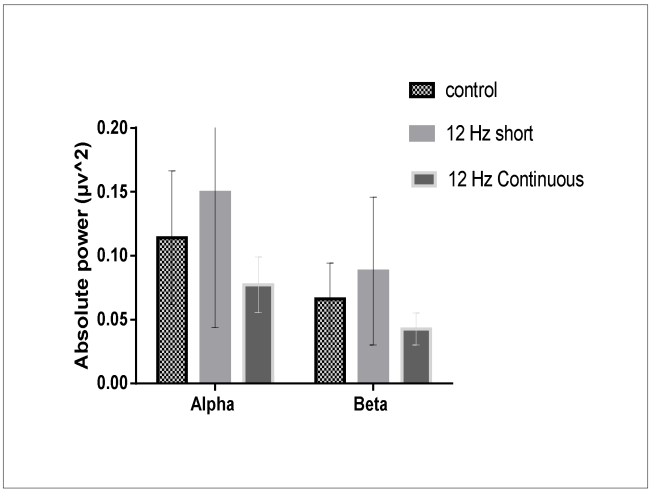

Fig. 2. Mean absolute cortical power for peak alpha(10–13 Hz) and broadband beta(16-19 Hz)

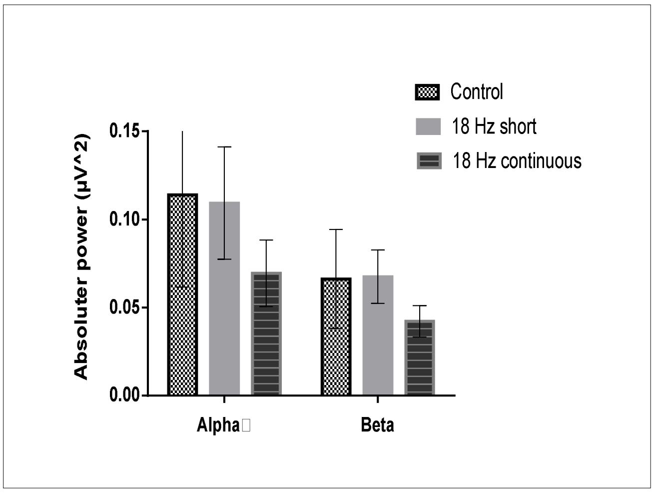

Fig. 3. Mean absolute cortical power for peak alpha(10–13 Hz) and broadband beta(16-19 Hz)

In case of 18 Hz binaural beat stimulus, the mean absolute power of both control and short burst remains unchanged while the continuous stimulation decreases the mean absolute power in both peak alpha and broadband frequency ranges as shown in table II. Hence, the short burst stimulation was found to increase the mean absolute cortical power than continuous stimulation. The result was consistent with the previous study that reported increased amplitude responses but not the frequency modulation effect during 100 ms beat stimulus duration [11]. But, the continuous stimulation of 10 minutes failed to produce any significant changes. This may be due to the habituation to the stimulus that resulted in the decrease absoluter power. This was similar to previous studies that reported no significant changes during prolonged exposure to binaural beats [10] [12]. Also, binaural beat presented as 10 epochs of 1 minute duration reported no frequency modulation effect [13].This suggests that the method of presentation of beat stimulus and its duration play a major role in altering the cortical power and producing the frequency modulation effect.

V. CONCLUSION

In conclusion, this study aimed to determine the effect of short burst and continuous stimulation on the recorded EEG. Although, the cortical mean absolute power changes were recorded during the binaural beat stimulation, no statistically significant differences were observed between the short burst and continuous stimulation or between control and binaural beat stimulation. Future studies with different method of binaural beat presentation using short burst stimulus are recommended rather using prolonged stimulus duration.

TABLE I. ABSOLUTE CORTICAL POWER (μV^2) DURING 12 HZ STIMULUS

Groups	**Absolute power Mean (S.D.)**	
	Peak alpha	***Broadband beta***
Control	0.11(0.16)	0.07(0.09)
12 Hz Short burst	0.15(0.32)	0.09(0.17)
12 Hz Continuous	0.08(0.07)	0.04(0.03)

TABLE II. ABSOLUTE CORTICAL POWER (μV^2) DURING 18 HZ STIMULUS

Groups	**Absolute power Mean (S.D.)**	
	Peak alpha	***Broadband beta***
Control	0.11(0.16)	0.07(0.09)
18 Hz Short burst	0.11(0.09)	0.07(0.04)
18 Hz Continuous	0.07(0.05)	0.04(0.02)

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