On Low Frequency Entrainment Using Auditory Steady State Responses

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Introduction: Frequency following effect of the brain has been utilised for various applications: the visual responses in brain-computer interface designs [1] and the auditory steady state responses (ASSR) for both diagnosis [2] and therapeutic purposes [3]. ASSR can be evoked either through monoaural (acoustic) or binaural tones. In this study, three different entraining frequencies (7 Hz, 13 Hz and 40 Hz) for both these methods are compared for their effectiveness to entrain the electroencephalogram (EEG). It has been shown that entrainment at 40 Hz is possible [4] but the aim of this study was to investigate effectiveness of entrainment at lower frequencies and to compare the two procedures to evoke ASSR for entrainment.

Materials and Methods: Three male subjects (aged 23 to 30) participated in the study. EEG data were captured using channels T7 and T8 (with mastoid references) following the 10-20 international electrode placement with Biosemi Active Two system. Subjects were instructed to close their eyes and relax while listening to the tones using Etymotic insert earphones (that have flat frequency responses). Six different protocols (each lasting two minutes) were designed with MATLAB: three monoaural protocols with 7 Hz, 13 Hz and 40 Hz amplitude modulated sinusoidal tones with 400 Hz 'carrier' wave was presented to the left ear and three protocols with 7 Hz, 13 Hz and 40 Hz binaural tones were presented to both ears following the procedure to be explained. All these tones were played with sound of ocean waves as background music to mask the sinusoidal tones. The binaural tones were generated using two sinusoidal tones. For example, binaural tone of 40 Hz was 'generated' using 400 Hz and 440 Hz tones played separately into each ear. The inferior colliculus neurons' firing patterns will follow the difference of the tones [4], i.e. 40 Hz and this unheard beat will be present in the EEG. The two second EEG was segmented into ten segments and bandpass filtered using Elliptic FIR filters in the range of 5 to 9 Hz, 11 to 15 Hz, 38 to 42 Hz for the 7 Hz, 13 Hz and 40 Hz protocols, respectively. Energy was computed from each segment. Student's t-test (with alpha = 0.05) was used to obtain statistical evidence on the entrainment effects.

Results and Discussion: Results from all subjects did not indicate any statistical difference between the entrainment effects of monoaural and binaural protocols for all the tested frequency tones. For subject 1, entrainment was only significant for 40 Hz, while for subjects 2 and 3, entrainment was significant for 13 Hz and 40 Hz tones. There was no significant entrainment for 7 Hz tone for all the subjects, either the entrainment was not possible at such low frequency or there could have been interference from alpha waves (as the eyes were closed) that could have masked the entrainment effects.

Conclusion: The ability to entrain EEG at low frequencies would be useful for both diagnostic and therapeutic purposes and the results here indicate that the entrainment effects are significant for 13 Hz in addition to 40 Hz using both monoaural and binaural methods. However, it should be noted that the study conducted here utilised only two minutes of EEG recording and further study with longer recording period and more subjects would be necessary to confirm the results obtained here.

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