Scalp Topography of Auditory Evoked Responses Elicited by Binaural Beat Illusions

Todor Mihajloski, *Member, IEEE,* Jorge Bohorquez, *Member, IEEE*, and Ozcan Ozdamar, *Member, IEEE*

***Abstract*— Auditory binaural beat (BB) illusions are elicited when two sinusoidal sounds with slightly differing frequencies are presented separately to each ear. Neural processing of BBs can be explored using auditory evoked potentials (AEP). In this study BB AEP topography is investigated using eight bipolar channels with 9 electrodes (Fz, Cz, Pz, Oz, A1, A2, T3, T4 and Neck) and a ground placed on the forehead. Young adults with normal hearing were recorded with the BB paradigm using 400Hz, 50ms beats with a repetition rate of 1Hz. The Electroencephalogram (EEG) was acquired at 5Ksps and -references, Neck and Avg ((A2+A1)/2), were generated offline. Results demonstrated that while the Avg reference montage showed higher peak amplitudes for all electrodes, the A1 and A2 earlobe electrodes exhibited significant activity for the first BB peak (100ms) when referenced to the Neck. Additionally, the Neck reference revealed several differences between scalp regions: a maximum amplitude at Cz for the second peak (180ms), a polarity reversal for early peaks and substantial suppression of late peaks at T3 and T4. These results suggest lateral generators for the first BB peak and deep central/rostral generators for the late BB peaks.**

I. Introduction

Recently the authors investigated a set of novel stimuli to elicit binaural AEP. The auditory stimulus presented to the right ear is a 400 Hz sine wave that begins at 0º phase and ends at 180º phase. The auditory stimulus presented to the left ear is a 400 Hz cosine wave that begins at 180º phase and ends at 0º phase. During the first 50ms after the stimuli onset the right stimulus modulates to 390 Hz and the left stimulus modulates to 410 Hz; the acoustical addition of the right and left stimuli generates a single 50ms beat. The two stimuli, left and right, were created with duration of 1sec (Figure 1)[1].

In order to eliminate the electromagnetic interference produced by the stimulator in the EEG channels the presentation phase of the stimuli was alternated. Because the stimuli ended with a phase of 180º with respect to the beginning, no gaps are perceived by the subject. When presented simultaneously to both ears the two stimuli create a BB illusion. Currently, the EAP caused by the beating effect are recorded using the standard electrode placements (Cz-A2 and Cz-A1).

Todor Mihajloski is with the Department of Biomedical Engineering at the University of Miami (e-mail: t.mihajloski@umiami.edu).

Jorge Bohorquez, PhD, is with the Department of Biomedical Engineering at the University of Miami (e-mail: jbohorquez@miami.edu).

Özcan Özdamar, PhD, is professor and chairman at the Department of Biomedical Engineering at the University of Miami in Coral Gables FL 33146 USA (phone 305-284-2136; fax: 305-284-6494; e-mail: oozdamar@miami.edu).

In order to better determine the source and generation of the BB responses a new electrode montage was examined in addition to the original. The new montage consisted of additional six bipolar channels. The six channels had a common negative reference to the neck and the positive electrodes were Fz, Cz, Pz, Oz, T4, and T3[2], adding up to a total of eight recording channels.

II. Methods

Following the policies of the Institutional Review Board of the University of Miami, three young adult subjects with normal hearing were enrolled in the present study. The recordings were performed using Intelligent Hearing Systems (IHS) Universal Smart Box. The EEG signals were sampled at 5000 Hz with a bandpass filter from 1Hz to 1500Hz. The stimulus was presented isochronously at a rate of one per second and a sampling frequency of 20kHz at 75 dB SPL using Etymotic Research ER3 insert earphones. The recordings were performed in an electrically shielded and sound proof booth. The subjects were recorded while lying comfortably in a bed and watching a captioned movie. The EEG signals were averaged using the split buffer method, 1024 epochs per subject, with threshold rejection to remove muscle and other artifacts.

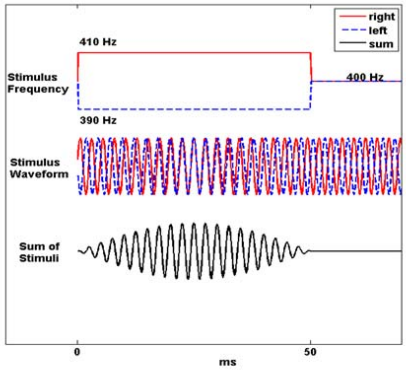

Figure 1
Binaural stimuli, frequency shift (Top), stimulus visualization (Middle), and the sum of the two stimuli (Bottom).

The recordings from all the subjects were averaged forming a grand average used for analysis. The data was analyzed utilizing the original montage, with neck reference.

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A second montage was mathematically calculated with a reference to the average of A2 and A1 (Avg). Furthermore, [Fz-Avg] = [Cz-Neck]-([Cz-A2]+[Cz-A1])/2 + [Fz-Neck]; [Pz-Avg], [Oz-Avg], [T4-Avg], and [T3-Avg], were calculated in the same manner. The grand averages for both montages were plotted for visual and analytical analysis (Figure 2). The amplitudes and delays of the baseline, the first negativity, two positive peaks (P80 and P170) and two negativities (N140 and N270) were measure and recorded. Figure 3 shows the amplitude differences of (P80-Base), (P80-N140), (P170-N140), (P170-N270) for both montages.

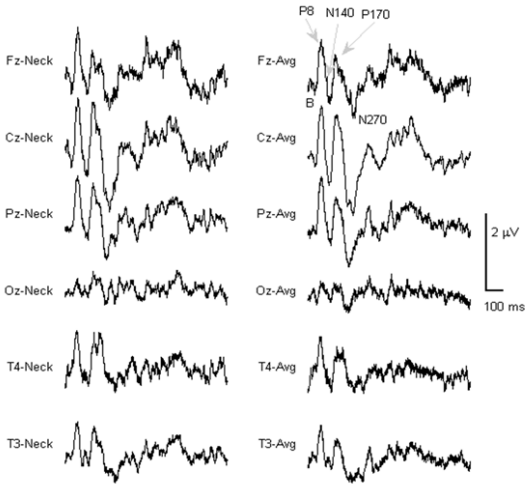

Figure 2
AEP responses, raw, recorded montage (Left) and re-referenced montage (Right).

III. Results

In the sagittal and coronal planes Cz exhibits the greatest peak amplitudes. The complex N140-P170-N270 is very well localized around Cz, decreasing quickly when the position change to Fz or Cz. The complex base-P80-N140 is also maximum at Cz but is less sensitive to the sagittal location. For P170-N270 at Cz the amplitude is 2.634/2.87µV (Avg/Neck) and 1.66/1.57µV at Fz, while P80-Base is 1.57/1.83µV at Cz and 1.45/1.75µV at Fz. The same behavior applies to changes in the coronal plane where P80 is more resilient to the position. The amplitudes of all peaks were the smallest at Oz. A slight asymmetry can be observed between the right and left temporal channels (T4 and T3); the amplitudes were greater at T4 when compared to T3, P80-N140 1.467/1.44µV at T4 and 1.17/1.158µV at T3.

IV. Conclusion

It was observed that the responses have the largest peak to peak amplitudes when measured at Cz, regardless of the reference electrode. Due to the high sensibility of the magnitude of the later responses, N170-N270, with the distance from Cz, it can be postulated that their generators are close to the scalp. The peak P80 appears to have a deeper generator since its amplitude is less sensitive to the scalp position. The absence of responses and the slight inversion of polarity at Oz indicate that the generators may be aligned with the Neck-Oz direction. This study represents one step forward in the study of the BB illusion; in previous studies our group perfected the design of stimuli that elicits a reproducible BB AEP using a carrier frequency of 400 Hz

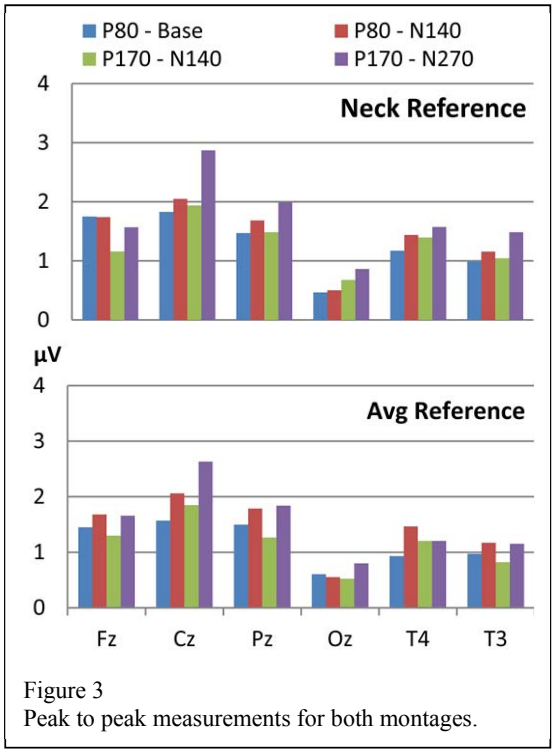

Figure 3
Peak to peak measurements for both montages.

and beat duration of 50ms. This study provides information that points to multiple generators involved in the AEP elicited by the BB illusion. The team efforts are now focused on the study of the adaptation patterns of the different peaks in response to increase stimulation rate.

References

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