Carrier Frequency Specificity of Short-sound Elicited Auditory Steady-State Response and Effect of Animation Presentation

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1 INTRODUCTION

The auditory steady state response (ASSR) of the scalp potential is elicited by repetitive acoustic stimuli with a maximum response at 35-45 Hz repetition rate (Galambos et al., 1981). In most previous studies using amplitude-modulated (AM) tones of stimulus sound, long lasting tones of more than 10 s in length were used. However, characteristics of the ASSR elicited by short AM tones have remained unclear. The aim of this study was to clarify the basic characteristics of the ASSR elicited by sequential short amplitude modulated (AM) tones having a length of less than 1 s. We examined how the magnitude of ASSR of Electroencephalogram (EEG) depended on the carrier frequency while the modulation frequency was fixed to about 40 Hz. In the previous study, when the stimulus amplitude was adjusted along the equal loudness curve between 440 and 990 Hz, the ASSR amplitude stayed constant (Kuriki et al., 2013).

In this study, we examined the amplitude of the ASSR in response to AM tones varying in carrier frequencies for 290 and 3840 Hz and investigated whether its amplitude was modulated by watching silent animation movie.

2 METHODS

Eleven males (21-26 years), without histories of hearing loss or neurological disorder participated in the study. A written form of informed consent was obtained from all of them.

The subjects sat in a chair in a sound-attenuated chamber. In the two experiments, the subjects were presented an auditory stimulation with a silent animation movie and without the movie.

The stimulus sound was a amplitude-modulated (AM) tones of 780 ms in length having different carrier frequencies (f_c) connected in series without intermission (Fig. 1). The modulation frequency (f_m) was 41.0256 Hz and the modulation depth was 100%. The 780-ms length of each f_c-tone included 32 cycles of modulated waves, where transition of the f_c change occurred at the time of zero amplitude. The stimulus sounds were generated with a PC at a sampling frequency of 44.1 kHz and presented in a sequence of six f_cs of 960, 3840, 1920, 480 and 240 Hz in 3.9 s. A measurement run of EEG recording consisted of the delivery of this stimuli sequence. Each subject underwent 200 measurement runs in about 13 min.

The sound pressure level (SPL) of the AM tones was measured with a sound meter at the earpiece of the sound delivery system. The SPLs of different *fc* tones were adjusted by controlling the amplitude of the sound signal to follow the equal loudness curve, where the SPL at 960 Hz was set to be 70 dB.

Electrodes for EEG were placed on the vertex (active), the posterior midline neck just below the hairline (reference) and the nasion (grand). The EEG signals were digitized at 1 kHz and averaged across 200 epochs of 3.9 s period (1 sequence). The averaged data were digitally band-pass filtered 40 to 42 Hz. We obtained the amplitude of ASSR from Hilbert-transform of the averaged waveforms under the two conditions of with and without animation.

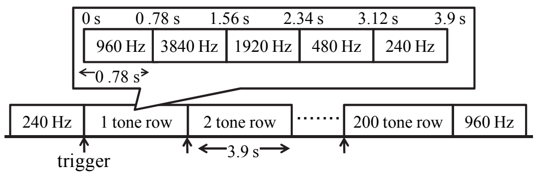

Figure 1: AM modulation tones and stimulus sequence.

3 RESULTS AND DISCUSSION

Figure 2 shows the waveforms of 40-Hz ASSR to the auditory stimulation during the condition of without animation. ASSRs to the AM tones are

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clearly observed in this figure.

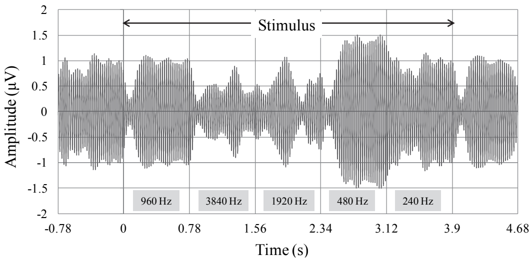

Figure 2: ASSR waveform to the auditory stimulation without animation presentation in one subject.

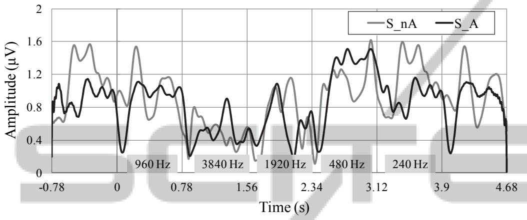

Figure 3: Hilbert transformed ASSR for S_A and S_nA conditions.

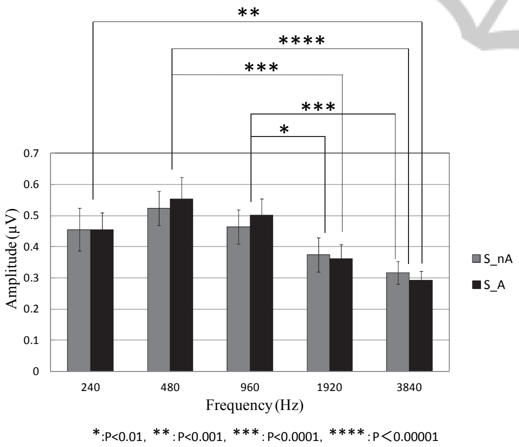

Figure 4: Comparison of the amplitude of ASSR during the animation (S_A) and with no animation (S_nA) conditions. Grand-mean values across all eleven subjects are shown for different carrier frequencies. Bars indicate SE of the mean.

Figure 3 shows the time-course of amplitudes of SSVEF in the averaged response for 'the sound and animation (S_A)' and 'the sound with no animation (S_nA)'. These waveforms were obtained from Hilbert-transform of 40-Hz component.

Figure 4 shows the comparison of the amplitude of ASSR during the S_A and the S_nA. Grand-mean values across all eleven subjects are shown for different carrier frequencies. It was found that the amplitude of the ASSR was invariant with tone frequencies when the level of sound pressure was adjusted along an equal-loudness curve from 240 Hz to 960 Hz. This was consistent with the result of 440 - 990 Hz in the previous ASSR study of MEG (Kuriki et al., 2013). From 1920 to 3840 Hz, the amplitude of ASSR decreased with increasing carrier frequency. Ross et al. (2005) reported that the amplitude of ASSR decreased in high carrier frequency (> 1 kHz). Two way (carrier frequency and animation conditions) ANOVA applied to the amplitude of ASSR exhibited significant effect of a carrier frequency. Therefore, we applied multiple comparisons for carrier frequency. As the results, the amplitude exhibited significant differences between frequencies under 960 Hz and over 1920 Hz (see figure 4).

On the other hand, no significant difference in the amplitude was observed between the animation and no animation conditions (n.s). Therefore, amplitude of ASSR may not be depended on the attention to the sounds.

This study shows that ASSR might be useful tool for audiometry in a limited frequency band (240 Hz - 960 Hz).

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REFERENCES

Galambos, R., Makeig S., Talmachoff, PJ., 1981. A 40-Hz auditory potential recorded from the human scalp. *Proc Natl Acad Sci* U S A. 78: 2643-2647.

Kuriki, S, Kobayashi Y, Kobayashi T, Tanaka K, Uchikawa Y, 2013. Steady-state MEG responses elicited by a sequence of amplitude-modulated short tones of different carrier frequencies. *Hear Res.* 296: 25-35.

Ross, B., Borgmann, C., Draganova, R., Roberts, L.E., Pantev, C., 2000. A high-precision magneto-encephalographic study of human auditory steady-stateresponses to amplitude-modulated tones. *J. Acoust. Soc. Am.* 108, 679-691.