Separation of Auditory Evoked Responses to the Right- and Left-Ear Inputs

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1 INTRODUCTION

In the clinical examination of auditory cortical function, it is desirable to observe the evoked responses separately to the right- and left-ear inputs during binaural stimulation. Due to the dominance of contralateral auditory pathway, it is expected that the right ear response represents the function of the left central auditory system and vice versa. However, the response to the input of the same-ear side is also included due to the conduction through ipsilateral pathway. Difficulty exists how to discriminate the mixed responses in the auditory cortex into their input channels. From a view point of basic science, separate observation of the two ears' responses to different acoustic stimuli such as tones and speech sounds may be interesting to study the hemispheric difference in the auditory function (Zatorre and Belin, 2001). Here, we developed a novel method for the separation of evoked responses based on synchronous and asynchronous averaging of signals.

2 PRINCIPLE

In the conventional averaging of evoked responses, recorded signals, which are mixed with biological, environmental and sensor noises, are averaged with a trigger time-locked (synchronous) to the stimulus epochs. This is based on the fact that noise signals are asynchronous to the stimuli and thus attenuated by averaging. Transient evoked responses are usually phasic, being composed of several peaks changing in polarity, e.g., P1, N1, P2, N2 components, of auditory response. It is expected that such phasic responses are attenuated in amplitude after averaging over many epochs if we use such triggers that are asynchronous to the stimulus epochs. This attenuation should be maximal when the jitter of the trigger time extends to the whole response period that may contain multiple peaks. For the relevant response to be observed, synchronous triggers are used besides the ongoing asynchronous averaging, reducing the noise but not the signal.

We prepared two sets of time series of onset-triggers in the simulation, where each set had random onset-to-onset intervals varying in a period of 500 ms. Figure 1a shows the distribution of the onset intervals of the first trigger series, where bars indicate the number of triggers included within time bins of 50 ms width. The trigger onsets were distributed uniformly in the 500 ms period, keeping random intervals. It was confirmed that the second trigger series prepared also had similar distribution.

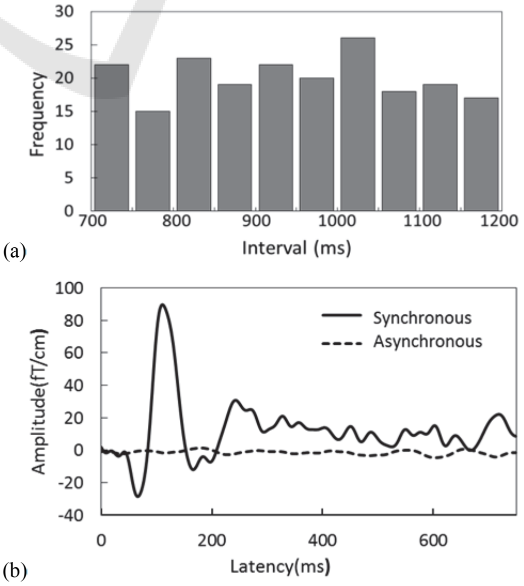

Figure 1: (a) Distribution of the onset-to-onset intervals of the triggers used in the simulation and (b) waveforms of the signals averaged using synchronous and asynchronous triggers.

As the signal, we used a waveform of auditory evoked response consisting of several peak components superposed with white noises. Signal epochs of 500 ms length were generated repeatedly at the onset of triggers of the first series. Averaging

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was performed across 200 signal epochs using the same trigger set and also using the second set of triggers that were not time-locked to the signal epochs. The result (Fig. 1b) showed clear waveform of the original response for the synchronous averaging, while no visible response was left for the asynchronous averaging.

3 EXPERIMENTAL

We have carried out magnetoencephalograpy (MEG) measurements of dichotic stimulation using a speech sound /a/ to the right ear a 600-Hz pure tone to the left ear of 500 ms length. The sound intensity was 70 dB SPL in both ears. Inter-stimulus intervals were randomized between 250 and 750 ms, where the right and left sounds were synchronized to two sets of triggers having random onset times with no correlation between them. Three male and a female subjects of 22-25 years old participated in the measurements. A whole head 122-channel magnetometer was used to measure MEG signals.

Averaging was performed across 200 epochs of the recorded signals using the trigger set synchronous to the tone epochs and also using the other trigger set synchronous to the vowel epochs. The averaged signals were filtered to 2-40 Hz offline. The responses obtained at 6 channel sensors over the right and left temporal areas were averaged to represent the hemisphere response. The waveform of the response was expressed as the root-mean-squared magnitude.

4 RESULS AND DISCUSSION

Figure 2 shows the waveforms of the responses obtained by synchronous averaging. The contralateral vowel response was larger than ipsilateral tone response in the left hemisphere, as expected. However, the contralateral tone response was reduced to a comparable magnitude to the ipsilateral vowel response in the right hemisphere. The results suggest that at short-interval stimulation (0.25-0.75 s) the vowel response in the left hemisphere does not attenuate much, as compared with the tone response and the responses in the right hemisphere.

MEG sensors in the temporal area can detect exclusively the auditory cortical response in the right or left hemisphere due to highly spatially localized magnetic signals. So far, steady state responses that are tagged with modulation frequency (Tononi et al., 1998) have been used to discriminate the responses to two-channel inputs. In addition to this, the present method allows us to examine transient responses, representing higher auditory functions, separately to the speech and tone sounds in the two hemispheres. It may be used in dichotic listening test in diagnosis of auditory processing disorder (Moncrieff, 2006).

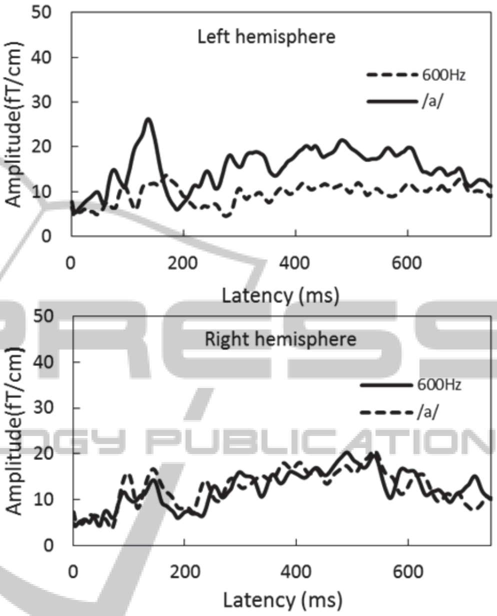

Figure 2: Waveforms of separated grand-mean responses (n = 4) in the right and left hemispheres evoked by vowel and pure tone stimuli, which were delivered to the right and left ears, respectively.

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