Ann.Bull.RILP No.28(1994)41-44

Megnetoencephalographic Components Correlated to Auditory Short-term Memory during Pitch and Phoneme Discrimination

K. Mori, S. Imaizumi, S, Kiritani, K. Miyagishima and M. Yumoto[1]

Research Institute of Logopedics and Phoniatrics,
University of Tokyo Hospital[1]
7-3-1 Hongo, Bunkyo-ku, Tokyo 113 Japan

Judgement of difference in the phonemic content or pitch of sequentially presented sounds requires auditory short-term memory, the substrate and time course of which in the brain are not well understood. Recent advances in the methodology of visualizing human brain functions enable us to study higher brain functions in normal behaving subjects. Magnetoencephalography, or recording of brain magnetic fields, using SQUID (superconducting quantum interference device), and estimation of neural current dipole locations from the pattern of magnetic fields are the methods that enabled us to detect local cortical activities evoked during pitch and phoneme discrimination tasks in a millisecond time resolution with accurate localization of activity foci.

Auditory evoked magnetic fields were recorded from the temporal region of four normal-hearing, right-handed male subjects with a 37-channel magnetometer (BTi, Magnes). The subjects were required to respond to pairs of stimuli which are different in pitch (pitch GO-NOGO task) or phoneme (phoneme GO-NOGO task) by releasing a button 500 ms after the sound stimuli. Stimuli for a session consisted of 400 random pairs of PARCOR-synthesized Japanese /ga/ and /ba/ 150 ms in duration with 140 Hz and 180 Hz of fundamental frequencies presented with a 100 ms interval. Stimuli were presented monaurally to the ear contralateral to the recorded hemisphere. The evoked magnetic fields were averaged in four groups according to the nature of the pair; same pitch and same phoneme, same pitch and different phonemes, different pitches and same phoneme, different pitches and different phonemes. In any groups the numbers of averaged responses to any of the two phonemes and of the two pitches.were approximately equal after exclusion of a small number of incorrect response trials (less than 10%). The pitch and phoneme tasks were each performed four times by each subject with the order and recording sides varied in a balanced fashion. A control recording without requiring any response of the subject was performed after the GO-NOGO tasks. Root mean squares (RMS) of the evoked magnetic fields were calculated after a band-pass filter of 1 to 50 Hz. Local peaks of the RMS were detected and their amplitude, latency and estimated dipole locations at those peaks were statistically analyzed.

M1 response to the first sound The largest peak was found approximately 100 ms from the first sound, which probably correspond to N100 in the electroencephalographic evoked auditory response. The amplitude was larger in the left (192 fT) than the right (163 fT) hemisphere ($P < 0.001$), which is not due to a recording artifact like unbalanced detector placement between the sides because the later peaks than M1 did not show similar left dominance. The peak latency was longer in the left (105 ms) than the right (100 ms) hemisphere. The estimated dipole locations were affected by the subject, the side and the interaction of the subject and side, which would presumably reflect anatomical and functional hemispheric differences. The averaged locations of the activity foci at the peak were located in the temporal auditory area and (0.8, 5.7, 6.2) cm in the left and (1.1, 5.9, 6.0) cm in the right (location vectors are in distances anterior form the coronal plane including the left and right preauricular points, lateral from the mid-sagittal plane, and high from the axial plane of nasion and the preauricular points). The dipoles for the phoneme task located on average 0.2 cm anterior and superior to those for the pitch task, which may reflect the attentional or strategic differences of the subjects between the tasks.

M2 response to the first sound The average peak amplitude of M2 component, whose latency is around 200 ms from the start of the first sound of the pair, was half of that of M1 and did not show significant left and right difference (left 81 fT, right 73 fT). The dipole locations were estimated at (1.4, 5.3, 5.9) cm in the left and (2.2, 5.9, 5.9) cm in the right, which were anterior to the respective ones of M1 peak.

M1 response to the second sound The latency of this component is more delayed as measured from the second sound of the paired stimuli than that of M1 for the first sound. Shorter latency of 374 ms from the first stimuli (124 ms from the second) was observed in the left hemispheric recording than in the right (383 ms), which is different from the tendency seen with M1 to the first sound. This component showed variation dependent on the sameness of the stimulus pair. The peak amplitude was larger by 7.6% for the pairs of different phonemes than for the same phoneme pairs. The dipole locations for the same phoneme pairs were medial by 0.5 cm on average to those for the different phoneme pairs ($p < 0.05$). The same-different contrast of pitch showed significant medial shift only in the right hemisphere. However, the dipole locations for the same pitch pairs were estimated 0.9 cm more lateral on average than those for the different pitch pairs ($P < 0.01$), the relation of which is in contrast to the phoneme. These dependencies of the component on the pitch and phoneme sameness cannot be attributed to GO-NOGO potentials in the frontal cortex or mismatch negativity (MMN) in the auditory cortex, (1) because GO and NOGO trials are included in equal numbers in the averaged signals both for the same and different pairs, (2) because the latency to the second sound of the pair (approximately 130 ms) is too short for MMN and GO-NOG potentials and (3) because numbers of the same and different pairs are equal and therefore would not evoke MMN, which requires rare and frequent stimuli.

M2 response to the second sound Although only a limited number of recordings allowed reliable estimation of dipole locations due to low amplitude, the pairs of the same phonemes evoked current dipoles medial and inferior to the different pairs ($p < 0.05$).

We found that magnetoencephalography detected that, while M1 to the first sound showed a task related variation, M1 and M2 components to the second sound of the stimulus pair was sensitive to the same-different contrast in phoneme and pitch in the stimuli. Since the response to the contrast requires memory, the signal detected in the present study may reflect the activity related to auditory short-term memory earlier than MMN.