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Short communication

Contribution of the human superior parietal lobule to spatial selection process: an MEG study

Tadahiko Shibata*, Andreas A. Ioannides

Laboratory for Human Brain Dynamics, RIKEN-Brain Science Institute, 2-1 Hirosawa, Wako-shi, Saitama, 351-0198, Japan

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Abstract

The magnetoencephalographic signal was collected in a visually guided response-finger selection GO/NOGO task. The minimum norm distributed source analysis identified the sources in bilateral superior parietal lobules (SPL), with stronger activity for contralateral finger movement. Our results suggest that the human SPL plays a role in the spatial selection in a visuomotor task similar to that identified recently in monkeys. © 2001 Elsevier Science B.V. All rights reserved.

Theme: Motor systems and sensorimotor integration

Topic: Control of posture and movement

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Recently, the posterior parietal cortex (PPC) has been proposed to play an important role in the visuomotor task [2,7,12,14]. Animal studies suggested that the PPC participates in motor planning with respect to both eye and hand movements [12,14] and carry out the coordinate transformations necessary to convert sensory signals into motor commands [2]. Moreover, the cells in the superior parietal lobule (SPL) showed directionally selective responses even in cases where the movement is never actually executed, suggesting that potential movements are coded by SPL cells [7]. However, few studies reported PPC activities in humans, so how the human PPC contributes to the visuomotor task is still unclear.

In the present work, we employed a response-finger selection GO/NOGO task, which consists of sub-processes in multiple areas [4,10,13]. We used magnetoencephalography (MEG) and examined the PPC activity in the GO/NOGO task, especially its role in the spatial selection process (i.e. selection of the response finger). Here, we focused on the brain activities related to the most prominent complex of the signal observed in the parietal area around 300 ms in the GO condition.

The subjects were six right-handed adults (five males, a female, aged 23–36). Ethical committee approval was obtained from the host institution and informed consent from the subjects before the experiment. The subject was seated in a magnetically shielded room (MSR) and asked to fixate a small cross on the screen placed 60 cm ahead. Six types of visual stimuli were used using red and green arrows pointing to the left, right or to both directions (Fig. 1a). Each stimulus was back-projected for 32 ms onto the screen by a video-projector placed outside the MSR. In each active and control run, 60 stimuli for each type were presented in random order with inter-stimulus-interval ranging from 1.2 to 2.0 s. In the active task, the subject was required to extend the index finger(s) indicated by green arrow(s) immediately after the stimulus onset (GO condition), but to withhold movement for red arrow(s) (NOGO condition). In the control task, the subject watched the same stimuli without discrimination or any finger movement.

The MEG signal was collected with a 151-channels whole head system (OMEGA-151, CTF Systems Inc.) at a rate of 1250 Hz with DC-300 Hz filter. The electrooculogram and the electromyography (EMG) of both arms were recorded simultaneously. The response times (RT) of both fingers were measured by optical switches. The recorded MEG signal was converted to 3rd-order synthetic gradient

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*Corresponding author. Tel.: +81-48-462-1111 (ext. 7182); fax: +81-48-467-9731.

E-mail address: shibata@brain.riken.go.jp (T. Shibata).

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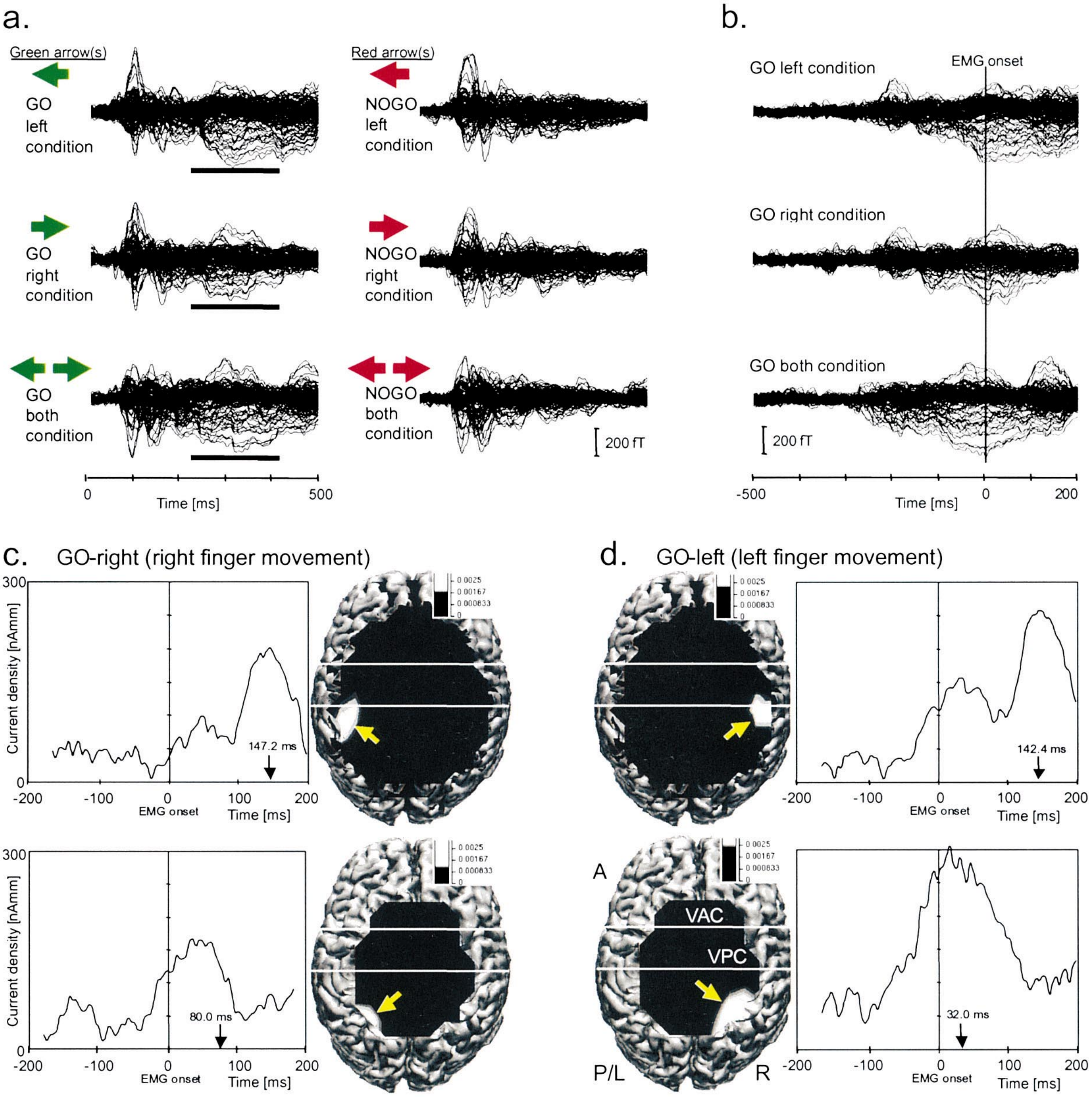

Fig. 1. The activation curves in the superior part of the posterior parietal cortex (PPC) extracted from the signal averaged with the EMG onset for four subjects. The left (right) graph shows the activation curves in three GO conditions at the red spot in the adjacent MRI; the red spot marks the local maximal activity within the left (right) superior PPC in the GO-right (-left) condition. The yellow lines mark the central sulcus. The number with 'mm' in the MRI indicates the distance of the display plane from the AC–PC line. For each subject, the same scale is used for left and right hemisphere.

formation and was resampled off-line at 625 Hz with additional 90 Hz low-pass filter. The signal was averaged for each condition separately with respect to the stimulus onset (−400 to 600 ms) and the onset of the arm EMG (at least −500 to 150 ms). The pre-stimulus period was used for a baseline. The trials contaminated with artifacts or wrong response were removed.

The source reconstruction was performed using minimum norm least squares (MNLS) method provided with the CURRY4 (NeuroScan Labs.), which produces estimates for cortical activation without a priori assumption about the location, number and spatial extent of the generators [3,6,8]. The inner shape of a skull extracted from subject's magnetic-resonance-image (MRI) was used for the forward calculation (i.e. one compartment model). The computation used a 3-dimensional grid restricted inside of the brain with grid points every 10 mm. More than 1100 grid points were used and MNLS method computed the optimal orientation and moment at each grid point from the measured MEG signal. The activation curve (i.e. time course of strength) at each grid point was computed and its mean values were compared between conditions using the two-factor analysis of variance (ANOVA) and a post-hoc test. The first factor was the conditions and the second one the subjects.

The mean (±S.D.) RT of six subjects was 425.2±50.7

ms. The percentage of wrong responses was 12.6% in the GO conditions and 0.8% in the NOGO conditions.

In all subjects, a prominent MEG signal was observed around 300 ms after the stimulus in the GO conditions, but not in the NOGO or control conditions (Fig. 1a). This signal was clearly the most prominent in terms of strength and duration. On the signal averaged with the EMG onset, the prominent peak was observed around the EMG onset (Fig. 1b). The signal of subject 6 was too noisy and was not used for further analysis.

Since the prominent activity was observed only in the GO condition and was closer to the finger response, we report on the reconstructed source distributions obtained from the signal averaged with the EMG onset. The mean

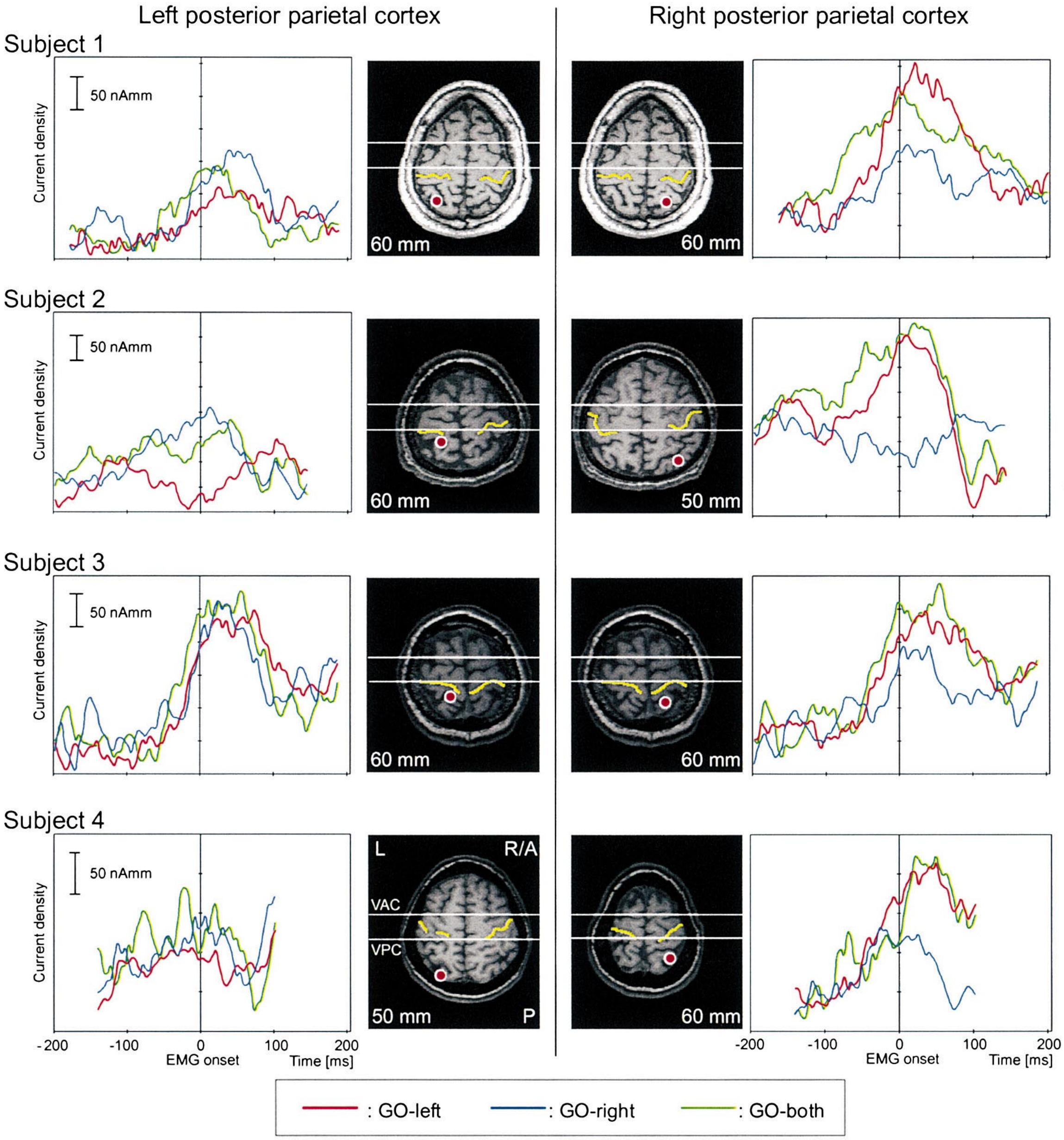

Fig. 2. Subject 1. (a) Superimposed MEG signal from all 151 channels for the six conditions in the GO/NOGO task after averaging with the stimulus onset. The prominent peaks are observed around 300 ms in the GO conditions (underlined). (b) The corresponding waveforms for the three GO conditions after averaging with the EMG onset. (c) The local maxima (white area indicated by yellow arrow) of estimated current sources and its activation curves around the left central sulcus (upper, the plane displayed is 50 mm above the AC–PC line) and in the superior part of the left posterior parietal cortex (PPC) (lower, 60 mm above the AC–PC line) with the GO-right condition, computed from the MEG signal averaged with the EMG onset. Activity in the PPC appears before the EMG onset and it is followed by two peaks around the central sulcus. (d) As in (c) but for the right hemisphere from the GO-left condition. In (c) and (d), the white horizontal lines indicate the vertical anterior commissure (VAC) plane and the vertical posterior commissure (VPC) plane, respectively. The level of the contour map is normalized for each map. The unit is uAmm/mm^2. The latency of each map is indicated by an arrow on the corresponding activation curve.

unexplained variance of the fit over the range −100 ms to 100 ms was 9.96±6.07%. Local maxima within the parietal lobe were observed bilaterally around the central sulci (all subjects), the superior part of the PPC (four subjects) and around the parieto-occipital region (two subjects). Some local maxima were also observed in the inferior part of the PPC with considerable inter-subject variability. We focused on the activation curves around the superior PPC and around the central sulcus which were the most common local maxima across subjects.

The activation curves of the sources around central sulcus showed two peaks and the one in the superior PPC showed a peak with contralateral finger response. Activities in both areas started before the EMG onset. The superior PPC activity preceded the one around the central sulcus (Fig. 1c and d). While the second peak around the central sulcus was clearly observed in all subjects with the mean latency of 116.5 ms (S.D. 13.9 ms), the first peak was not apparent with subjects 2, 4 and 5. Fig. 2 compares the activation curves of the superior PPC among three GO conditions. In the left superior PPC, the ANOVA (3 conditions×4 subjects) showed significant difference among the mean values (from 0 to 50 ms) of the three conditions ($P<0.05$). The mean values of the GO-right and the GO-both conditions were significantly larger than that of the GO-left condition ($P<0.05$). On the other hand, the activation in the right superior PPC showed larger activity with the GO-left and GO-both conditions than the GO-right condition ($P<0.05$).

The activities around the central sulci relate to the motor execution process [3], with the first activity consistent in latency to the motor field (MF), the second to the movement-evoked field I (MFEI) [5,9]. The activities in the superior part of the PPC exhibit some inter-subject variability for location, not too surprising a finding given the highly variable and asymmetrical surface anatomy of this area [15]. The strongest loci of activity were within the SPL and in the Brodmann's areas 5 and 7a. The onset of the SPL activity preceded the EMG onset and the motor-related activities. The ANOVA showed that each SPL was significantly strongly activated with responses which included the contralateral finger movement. Such SPL activity was not observed in unilateral voluntary finger movement [3].

The latency of our SPL activity is consistent with a P300 type response which is implicated with activity in the temporal-parietal cortex [11]. This explanation is nevertheless rejected because of the laterality of our SPL response relative to the finger movement. Although correspondence between function in the parietal cortex of monkeys and humans is not straightforward [1], recent monkey studies provided useful analogies to the SPL activity we have identified. In these studies, the PPC activity was associated with coordinate transformation operations [2], information processing directly linked to motor planning [12,14], and the way potential movements are coded by cells in area 5 [7]. Interpreting the response-finger selection in our study as the spatial selection in the subject's body coordinate system [2], our result together with the previous monkey studies suggested that the human SPL relates to the spatial selection process in visuomotor task.

It should be noted however that in monkeys activity related to the spatial selection was also identified in the NOGO condition [7], but it was only observed in the GO condition in our study. An explanation for this may be that the presence of many options forced our subjects to distinguish the GO or NOGO first and afterwards select the response finger(s) in only the GO condition cases. The high error percentage in GO condition comparing with NOGO condition and relatively slow RT supported this interpretation [5,13]. In summary, our findings provide evidence in humans for an SPL role which is intermediary between the visual input processing and motor output within a spatial selection task as already reported for monkeys [7].

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