Brain Activation during extraction of forms from complex figures studied by fMRI

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Introduction
Complex figures are perceived as composition of multiple simple forms. For search of the odd forms hidden in the figures, it is necessary to restructure perceived information. The ability to extract hidden forms from complex figures is assessed as one of visual spatial abilities or cognitive styles [1]. However, the neural substrate of this ability has not been investigated. We conducted an fMRI study to investigate the activation during extraction of explicit or implicit forms from complex figures.

Methods
Eight right handed volunteers (4 females, age 23-40, average 32.7) participated in this study. All subjects gave written informed consent. A gradient recalled echo EPI sequence was employed for functional studies on a 1.5T MR scanner (GE, Signa). The imaging parameters were, TR 5000 msec, TE 43 msec, FA 90 degrees, FOV 22 cm, slice thickness 4 mm and 30 axial slices were prescribed.

Two experiments were designed (Fig. 1). In each experiment, the task block and the control block were alternatively repeated for 3 times. These 6 blocks were interleaved with 7 rest blocks. Each block was for 30 seconds. Seventy eight images per slice were obtained in each experiment. In the task blocks, the form to be extracted was presented for 100 msec as the first stimulus, and the whole figures were presented for 2000 msec as the second stimulus at 1900 msec after the first stimulus. The subjects were asked to search the second stimulus for the first stimulus and trace the first one by moving the right forefinger. In the first experiment, explicit forms were used as the first stimulus. In the second one, implicit forms were used as the first stimulus. In the control blocks, the extraction was not required, since the second stimulus was only the form to be traced. Therefore, the activation related to the visual stimulation of the first stimulus and finger movement could be subtracted from the activation in the task blocks. In the rest blocks, the subjects were asked to look at the fixation point that was presented at the center of the screen.

The fMRI data were analyzed using SPM99b (height threshold: corrected p< 0.05).

Results
Extraction of the explicit forms: In the control blocks, the activation was observed in the left primary motor area (SM1), the premotor area (PMA), the supplementary motor area (SMA), the precuneus (prCu), the intraparietal sulcus (IPS), and the right cerebellum (Cere). In the task blocks, there was additional activation in the left Cer, the inferior frontal gyrus (Brodmann's area [BA] 44/6), the right inferior parietal lobule (IPL), IPS, prCu, the bilateral occipital gyr (OG), the occipitotemporal gyr (OTG) and the inferior temporal gyr (BA 37).

The activation in the task blocks was significant in the left BA 44/6, right IPL, and right OG, and BA 9/46 in contrast to the control blocks. The IPS is involved in visual-proprioceptive integration [2] and in the connection between the IPS and the ventral premotor area is known as the fronto-parieto circuit for manipulation [4]. The ventral premotor area corresponding to BA 44/6 was activated in extraction of both types of form. In particular, the activation during extraction of implicit forms extended to the lower part of BA 44/6. This area is corresponding to the area activated by writing Kanji characters [6]. Overall, it was hypothesized that the lower part of BA 44/6 is associated with reproduction of spatial information as a sequence of movement, while the upper part of this area is associated with reproduction of spatial information as a chunk of familiar movements.

Discussion
The secondary visual area corresponding to BA 19 is associated with processing of form. The activation of this area on the left hemisphere was shared between extraction of explicit and implicit forms, while the area on the right hemisphere was activated only in extraction of implicit forms. These results suggested that reprocessing of the whole figures mainly involves the right BA 19.

The IPS is involved in visual-proprioceptive integration [2] and in particular, the contralateral (left) IPS is crucial for writing characters [3]. The left IPS was activated during all of the task and control blocks. Therefore, the left IPS seems to be involved in visuomotor processing underlying production of line drawings including characters. The right IPL is significantly activated during extraction of explicit forms. This result indicated that the activation of the right IPL is representing natural extraction of forms from the whole figures. The connection between the IPS and the ventral premotor area is known as the fronto-parieto circuit for manipulation [4]. The ventral premotor area corresponding to BA 44/6 was activated in extraction of both types of form. In particular, the activation during extraction of implicit forms extended to the lower part of BA 44/6. This tendency was consistent with the previous study for drawing the whole figures on the basis of unnatural segmentation [5]. In contrast, the activation during extraction of explicit forms was limited to the upper part of BA 44/6. This area is corresponding to the area activated by writing Kanji characters [6].

References