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Brain areas involved in scene rotation task：A fMRI study

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When human perceivers compare two visual scenes presented from different viewpoints, recognition time increases with the rotation angle between them. We used fMRI to determine the brain areas involved in the scene rotation task. During the task, activation was observed in V1/V2, fusiform gyri, occipito-parietal cortices, and lateral prefrontal cortex. Moreover, ventral posterior insular cortices and anterior cingulate cortex were deactivated. Activation patterns of the areas were different. As the angle of rotation increased, volume of activation in V1/V2, right fusiform gyrus, right-occipito-parietal cortices and lateral prefrontal cortices increased, but level of activation did not. In left occipito-parietal cortices and anterior cingulate cortices, both volume and level was increased. In the insula, both volume and level were not changed over the rotation conditions, showing constant deactivation.

Keywords: high level vision, scene recognition, mental rotation, fMRI

Introduction

It has been reported that recognition time for a scene increases as it is rotated (Diwadkar & McNamara, 1997; Nakatani & Pollatsek, 2004; Nakatani, Pollatsek, & Johnson, 2002). In the current study, we tried to identify the brain network involved in scene recognition over viewpoint rotation using functional MRI (fMRI) techniques.

Our investigation proceeded in three steps. Firstly, the areas involved in scene recognition over viewpoint change were identified. Secondly, activation patterns of individual areas were analyzed. Change in activation level as well as in size of the activated area were examined. Thirdly and finally, the task-relevant areas were classified based on the analyses of the activation patterns. We will discuss the function of each category of areas based on our results.

Method

Participants Eight healthy adults (4 men and 4 women, mean age 27.38 year–old) participated in the experiment.

Task Two simple scenes, three office objects on a desk, were presented in sequence. Participants were asked to report by button press whether the locations of the objects in the scenes were same or different. Viewpoints of the two images were rotated 0º, 35º, or 70º, as if the viewer walked around the desk (Figure 1, top and middle panels). Prior to fMRI recording, practice trials were given to the participants.

Data acquisition MRI data were acquired with a Varian 4T system at the RIKEN Brain Science Institute. T2*-weighted images were acquired with a bird-cage RF coil and a two-segment EPI pulse sequence (TR = 50ms; TE = 25ms; twenty 5mm slices covering the entire cerebrum; volume TR=2s; in-plane resolution = 3.75 × 3.75mm^2) sensitive to blood oxygen level-dependent (BOLD) contrast.

Task conditions were blocked (Figure 1, bottom panel). Each block contained 10 trials (40 sec). Before each task block, 30 sec baseline period was recorded, in which participants viewed a fixation cross.

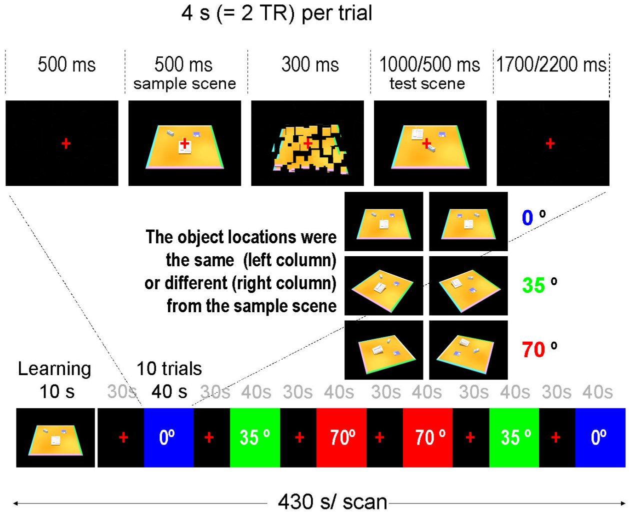

Figure 1. Scene rotation task (top), types of test scenes (middle) and fMRI scan sequence (bottom).

Results & Discussion

Performance Response time increased with the angle of rotation, $F(2, 14) = 8.35$, $p < .01$. Error rates remained constant, $F < 1$, at less than 10%.

FMRI A general linear model (GLM) with 4 predictors (fixation baseline, 0º, 35º, and 70º task conditions) was fit to the BOLD time series of all voxels. Family-wise error was corrected using a permutation method (Nichols & Hayasaka, 2003). As a result, the following areas were indicated as task-relevant: V1/V2 (BA17/18), right fusiform gyrus (BA19), bilateral superior occipital gyri (BA19), bilateral superior parietal lobule (BA7), bilateral inferior frontal gyri (BA44), left middle frontal gyrus (BA46), bilateral anterior cingulate gyri (BA32/10), left superior temporal gyrus (BA38), and left ventral posterior insula. The results are summarized in Figure 2.

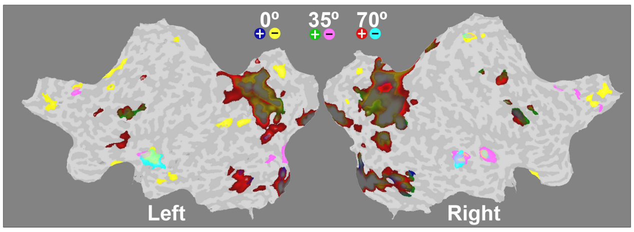

Figure 2. Task-relevant regions projected on inflated and flattened hemispheres – light gray and dark gray indicate gyri and sulci, respectively. Color coding of significant activation change from the baseline: activation increase is indicated in blue (0º > baseline), green (35º > baseline), and red (70º > baseline). Activation decrease (deactivation) in yellow (0º < baseline), pink (35º < baseline), and light blue (70º < fixation). Family-wise error was corrected in each contrast with false detection rate, $p < .05$.

In each region, changes in activation volume as well as the level of activation were analyzed. According to these analyses, areas are classified into three types. In the first activation volume increased with the rotation angle, while the level of activation did not. These *volume-changed* areas are mostly in ventral stream of visual processing: V1/V2, right fusiform gyrus, right superior occipital gyri, right superior parietal lobule, and bilateral inferior frontal gyri. Involvement of these areas has been reported in scene recognition literature (Epstein, Graham, & Downing, 2003).

The second type of areas showed increase in activation level as well as size. These *volume-and-level changed* areas include: left superior occipital gyrus, left superior parietal lobule, left middle frontal gyrus, bilateral anterior cingulate gyri and left superior temporal gyrus. These areas are located either in the dorsal visual processing stream or in prefrontal – frontal areas. Involvement of the former in mental rotation is frequently reported (Podzebenko, Egan, & Watson, 2002), the latter constitute a performance monitoring network (Carter et al., 1998).

The third type showed no change in activation volume and level. Left ventral-poterior insula showed such *constant activation* pattern. Moreover, the insula showed deactivation relative to the baseline.

Discussion

The current study identified the brain areas that are involved in recognizing a rotated scene. Several subsystems sensitive to orientation angle could be distinguished. It is likely that volume-changed areas process viewpoint changes (Epstein et al., 2003). Volume and-level changed areas seem to engage in performance monitoring and its feedback to the ventral areas. Results from the volume changed areas are monitored by the anterior cingulate – lateral prefrontal network (Carter et al, 1998). These two systems are probably linked via left occipito-parietal areas. The role of constant deactivation in the left insula is not clear. It might relate to a basic dynamics of brain activity, such as activity of task related global network (Raichle et al., 2001).

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