Neural basis of forming hand postures to prepare for tool-use: an fMRI study

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Introduction

Patients with apraxia often fail to pretend to use a tool even when the tool was visually presented. Previous studies reported that several brain areas including the inferior parietal lobule were involved in this tool-use action [1]. This process is comprised of various cognitive or motor processes such as visual perception of the tool and forming hand postures [1]. Forming hand postures to prepare for tool-use is one of the most important processes, which is common to various tool manipulations. However, the details of neuronal background of the process have not been well understood. To clarify the neural basis of the process involved in forming hand postures for using tools, we investigated the brain activation in normal volunteers while they form their hand postures for tool manipulation using fMRI. The comparisons we designed as follows: (1) forming hand postures for using tool versus forming hand postures to imitate hand postures; (2) forming hand postures for using the tool versus forming hand postures to imitate the shape of the tool. The former comparison attempted to detect area involved in preparing for using tools whereas the latter comparison attempted to detect area involved in forming hand posture specific to tool-use.

Materials and Methods

Subjects: Ten healthy volunteers (three males, seven females, age 20 - 41 years, all right-handed) participated in this study. All subjects gave written informed consent.

Experiment design and tasks: Three conditions were investigated in separate fMRI series; (A) hand posture for using tool, (B) hand posture to imitate a hand posture, (C) hand posture to imitate a shape of a tool. Each series was comprised of four task and six rest blocks (30 seconds each, total 4 minutes and a half). In the task blocks, ten pictures of tools (e.g. scissors) or hand postures (Figure 1) were presented one after the other every 3 seconds. Then participants formed their right hand in a manner specified according to the task conditions. In the condition A, participants formed their hands as if they grasped the tool (Figure 1, upper row). Similar hand posture was formed to imitate the stimulus of hand picture in the condition B (Figure 1, middle row). In the condition C, subjects formed their hand to imitate a shape of the tool (Figure 1, lower row). Subjects hold each static hand posture until next stimulus was presented. All stimuli were presented through a monitor set in front of subjects.

Data acquisition: A T2*weighted gradient recalled echo EPI sequence was employed for functional studies on a 3T MR scanner (GE, Signa VH/i 3.0T). The imaging parameters were TR 3000 msec, TE 30 msec, FA 90 degree, 30 axial slices, FOV 22 cm, and slice thickness 3 mm thick plus 1 mm gap.

Statistical Analysis: The fMRI data were analyzed using SPM2 (http://www.fil.ion.ucl.ac.uk/spm/software/spm2/). The data were realigned, spatially normalized into MNI template, and smoothed (FWHM 8mm). A random-effect model was applied for comparison between conditions with the height threshold of $p = 0.005$ at voxel level (uncorrected).

Results and Discussion

Between-condition comparisons revealed that the condition A activated the left inferior frontal gyrus (BA 45), the left inferior parietal lobule (BA 40), the left PMA and bilateral SMA more intensively than the condition B (Figure 2). Activation in these regions might be related to a process including tool representation such as skilled actions triggered by objects [2], naming tools, observation tools and tool-use gestures [1, 3-4]. Activation in these regions might reflect analysis of tool attributions which would necessary for using the tool. The condition A also induced activation in the right superior parietal lobule (BA 7) as compared with the condition C. Activation in this area might be related to visuospatial attention [5]. Forming hand postures specific to preparing tool-use might need close coordination between a tool and subjects' hand posture whereas imitations of a tool shape only need to match shapes of tools and those of hands.

Conclusions

We investigated the neural basis involved in forming hand postures for using tools. The results suggested that regions of the left hemisphere including the inferior frontal gyrus (BA 45), left inferior parietal lobule (BA 40) and PMA might be involved in a neural network of tool representations which were required for preparing to use tools. In was also suggested that the right parietal lobule (BA 7) might be involved in regulating hand postures for preparing tool-use. Our findings might explain various errors shown by patients with apraxia and provide useful information on the tool-use.

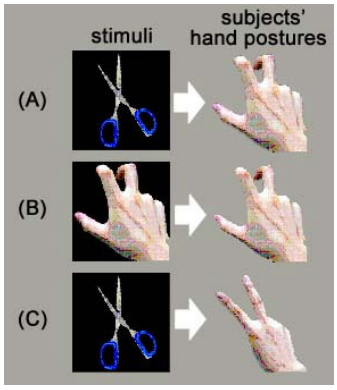

Figure 1
Examples of stimuli and subjects' hand postures

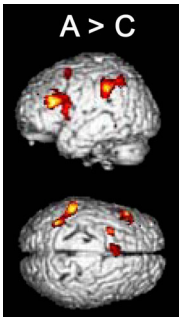

Figure 2
Activation maps generated by a random effect model (n = 10, $p < 0.005$, uncorrected)

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