Modulation of human mirror neuron system by task complexity and laterality

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Introduction

The anterior intraparietal cortex is known to be active both during grasping movements (Culham et al., 2003; Frey et al., 2005) and simple observation of object manipulation (Shmuelof and Zohary, 2005 and 2006), and is therefore considered as part of the human mirror neuron system. Interestingly, in this area external actions are represented according to the identity of the observed hand, regardless of the location of the actions in the visual field (Shmuelof and Zohary 2006). These findings support the hypothesis of the anterior parietal cortex as a putative region for visuomotor transformations necessary for visually guided actions which would take place by an online integration of an efference copy of the motor commands with incoming visual inputs. Should this be true, one would expect that the load of activity of the anterior parietal cortex is modulated by the complexity of the task observed. This would further confirm its specific role in the final stage of visuo-motor transformation, which is necessarily dependent both from the hand identity and task complexity. In order to test this hypothesis, we conducted an fMRI study exploring the brain representation of action observation with two sets of actions grouped according to the laterality and complexity of the task.

Subjects and Methods

Twelve right-handed healthy volunteers (six women; mean age 32 y) participated to this study. A set of 12 clips of object-manipulation, lasting 8 seconds each, was used in this experiment: 3 easy actions and 3 difficult actions, performed with the right or the left hand. The difficult actions consisted of: i) performing a simple scale on a piano keyboard, ii) grasping and turning a key in a lock, iii) grasping little cubes and putting them in a box. The easy actions consisted of a whole hand grasping of a small box. The two sets of clips were perfectly balanced as to the visual content. The static initial frame of each clip was presented as control condition. The experiment was performed using a block design format. Eight blocks were interleaved with as many control periods and repeated four times, with different stimuli, in a counterbalanced manner. Each block lasted 24 s, as the following control period. Subjects were instructed before the experiment to maintain fixation in the middle of the screen. Stimuli were presented binocularly displayed in a virtual reality sep-up (VisuaStim XGA - Resonance Technology).

BOLD responses were acquired on a 1.5 T General Electric Signa Horizon LX System (GE, Milwaukee, USA), equipped with Echo-speed gradient coil and amplifier hardware. Activation images were acquired using Echo Planar Imaging (EPI) gradient-recalled echo sequence (TR/TE/flip angle = 3 s/50ms/90°, FOV = 240x240 mm, matrix = 64 x 64, 5 mm thick slices). Time-course series of 132 scans for each volume were collected in 16 blocks alternating between control and active conditions, resulting in an acquisition time of 6'36''. The first block always lasted 4 scans more to allow the signal to stabilise. This initial period was eliminated from any successive analysis. For each subject the total effective time of the fMRI signal acquisition was 25 minutes and 36 seconds. A volumetric set of data (3D FSPGR: TR/TE/TI/flip angle = 21.1 ms/3.8 ms/700 ms/10°; FOV = 280 x 280 mm, matrix = 256 x 256) was also acquired to generate a 3D whole brain reconstruction. Data analysis was performed using the Brain Voyager QX software package (Brain Innovation, Maastricht, the Netherlands). For each subject, the two-dimensional functional data were aligned to the three-dimensional high resolution images and transformed into Talairach space. A General Linear Model approach was used to generate statistical maps on the group (Random Effect Analysis). For the purpose of this study, the General Linear Model and the resulting ANOVA were conducted considering four conditions: easy tasks performed by the right hand (ER), easy tasks performed by the left hand (EL), difficult tasks performed by the right hand (DR), difficult tasks performed by the left hand (DL).

Results and Discussion

During the observation of object-related hand actions (all stimuli>rest), activation foci were present in areas 6 and 44 and in area 40 on both sides. Left hemisphere activation was larger and stronger than right hemisphere activation. The comparison between the observation of actions performed with the right hand and actions performed with the left hand (all stimuli right >or< all stimuli left) showed an activation of the anterior intraparietal sulcus (±35,-48, 50) contralateral to the active hand. When performing the same comparison (observation of actions of the right hand vs actions of the left hand) separately for the easy tasks and for the difficult tasks, the anterior intraparietal sulcus was found active, at the standard corrected p values, only for the difficult tasks. A ROI analysis confirmed that the differential activation between the two hemisphere is higher for the difficult tasks (Figure 1). In conclusion, we confirmed the presence of a hand identity area in the anterior intraparietal sulcus of the contralateral hemisphere to the observed acting hand and that this area seems to be sensitive to the complexity of the task.

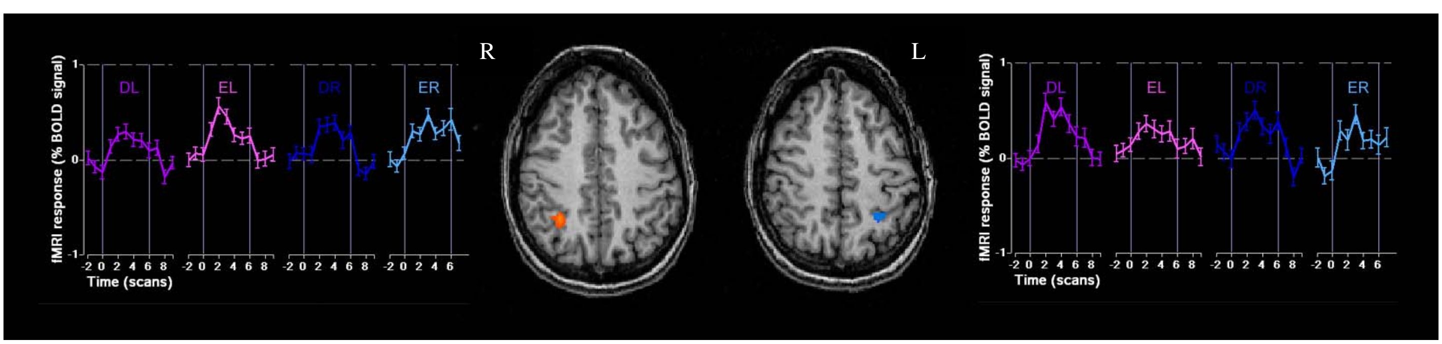

Figure 1: ROI analysis. Averaged hemodynamic response curves for the four experimental conditions in the right (R) and left (L) anterior intraparietal cortex. Activations in the areas contralateral to the observed hand were stronger than those in the opposite hemisphere for the difficult tasks (right hand (DR), left hand (DL)) and less for the easy ones (right hand (ER), left hand (EL)).