Lateralization of the mirror neuron system during observation and execution of object-related actions: a functional magnetic resonance study in right and left-handed subjects

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Introduction

Mirror neurons are a particular class of visuomotor neurons first discovered in the monkey Ventral Premotor Cortex, active during both observation and execution of object-related hand movements [1]. It is hypotesized that these neurons are involved in action understanding as well as in motor learning. Neuroimaging studies demonstrated that the observation of actions done by others activates a complex cortical pathway also in human brain. Cortical areas related to the Mirror Neuron System (MNS) in humans are the lower part of the precentral gyrus (IFG), the Dorsal Premotor Cortex (PMd) and the Ventral Premotor Cortex (PMv), the posterior part of the Inferior Frontal Gyrus (IFG) and the Inferior Parietal Lobule (IPL). To date there are no studies that looked at the lateralization of the human MNS during the observation of object-related grasping movements. Aim of this study is to evaluate if the activation of human MNS is lateralized during the execution and observation of grasping movement in left and right handed subjects.

Materials and Methods

26 normal volunteers, 16 right-handed (7 M, mean age 29, range 20-48) and 10 left-handed (6 M, mean age 31.7, range 21-53) underwent a Functional Magnetic Resonance Imaging (fMRI) study during both observation and execution of a grasping movement. The degree of handedness was evaluated in all subjects with the Edinburgh Inventory [2]. Brain MRI scans were obtained using a 3.0 Tesla Scanner (Intera, Philips Medical System, Best, The Nedherlands). Functional MR images were acquired using an Echo-Planar Imaging sequence (EPI) (TE 30 msec, TR 3000 msec, FOV 240 mm, 40 slices). The experimental design was a block design, fully-randomized. Subjects were asked to observe movies of a hand (left or right) grasping different objects or to perform grasping movements appropriate to the shape of an object projected on a screen (with the right or left hand). fMRI data were analyzed using SPM5 (www.fil.ion.ucl.a.c.uk/spm). We defined 4 contrasts for every subject: observation of a right hand grasping (OR), observation of a left hand grasping (OL), perform grasping movements with right hand (GR), perform grasping movement with left hand (GL). In order to identify MN areas we performed two Conjunction Analyses ($p<0.001$, uncorrected), between OR and GR contrasts and between OL and GL contrasts. We masked the conjunction analysis with the active areas in the two contrasts used to do the conjunction, with a threshold of $p<0.05$. With this analysis we determined which voxels were active during both observation and execution of hand movements, distinctly for right hand and left hand in every group (right-handed and left-handed). These voxel should be considered part of the MNS.

Results

In right-handed subjects, the observation and execution of action done with the right, dominant, hand determined the activation of the left Premotor Cortex (Brodmann Area 6 – BA 6) and the bilateral activation, with a clear predominance of the left hemisphere, of the Prefrontal Cortex (BA 9), Postcentral Cortex (Primary Somatosensory areas, BA 2), Inferior Parietal Lobule (BA 40) and Superior Temporal Sulcus (BA 41). Processing of visual and motor stimuli done with the left hand activated more bilaterally the same network (BA 6, BA 9, BA 2, BA 40). Also in this case the activation is clearly prevalent in the left hemisphere. Interestingly only in the analysis of the left hand condition we observed a bilateral activity in BA 7, an area that is involved in mental rotation tasks. In left-handed volunteers, processing of visual and motor stimuli done with the right hand activated bilaterally the Premotor Cortex (BA 6), with a clear predominance of the right hemisphere, and caused the bilateral activation in the Inferior Parietal Lobule (BA 40), Superior Parietal Lobule (BA 5) and in the Inferior Occipital Gyrus (BA 18). In this analysis we also observed the left-sided activation of BA 7. Processing of stimuli executed with the left, dominant, hand showed a pattern mainly on the right hemisphere: we found activation in the right Premotor Cortex (BA 6, BA 9), in the right Parietal Cortex (BA7) and a bilateral activation in the Inferior Parietal Lobule (BA 40) although predominantly right. We also found the bilateral activation in the Primary Somatosensory Cortex (BA 2, BA 3) and in Extrastriatal Visual Cortex (BA 37).

Conclusions

In normal right-handed subject the Mirror Neuron System is left-lateralized. The processing of action object-related done with the right dominant hand requires the left-lateralized activation of the somatosensory and of the premotor areas of the MNS. The elaboration of the same actions done with the left non dominant hand induces a more bilateral activation of the same cortical pattern, but again with a predominance of the left hemisphere, and the involvement of parietal areas, associated to mental rotation tasks.

In left-handed volunteers we observe a mirror-like pattern of cortical activation compared to right handed subjects, with a clear right hemisphere dominance in premotor cortex during the processing of stimuli executed with the left dominant hand and a more bilateral network in processing of stimuli with the right non dominant hand.

Fig. 1

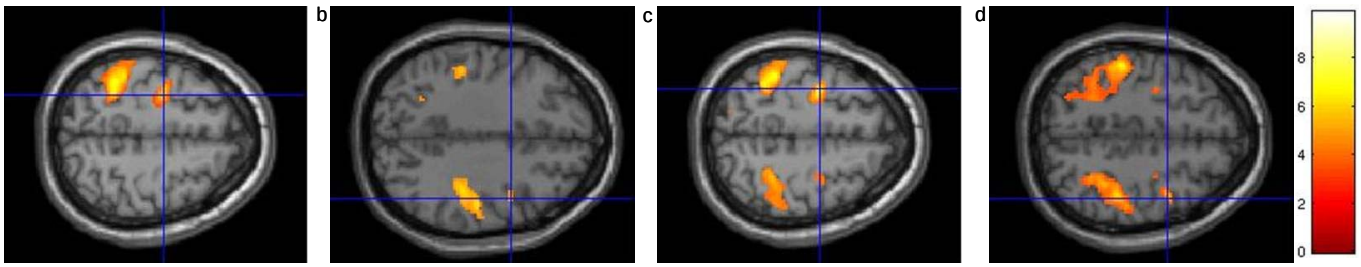

Fig 1 Cortical activation in right and left-handed subjects during both observation and execution of grasping movements done with left or right hand. **a)** Right-handed – movement with the right (dominant) hand **b)** Left-handed – movement with the left (dominant) hand **c)** Right-handed – movement with the left (non-dominant) hand **d)** Left handed - movement with the right (non-dominant) hand

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