

Functional Anatomy of the Observation and Imagination of Unimanual and Bimanual Actions

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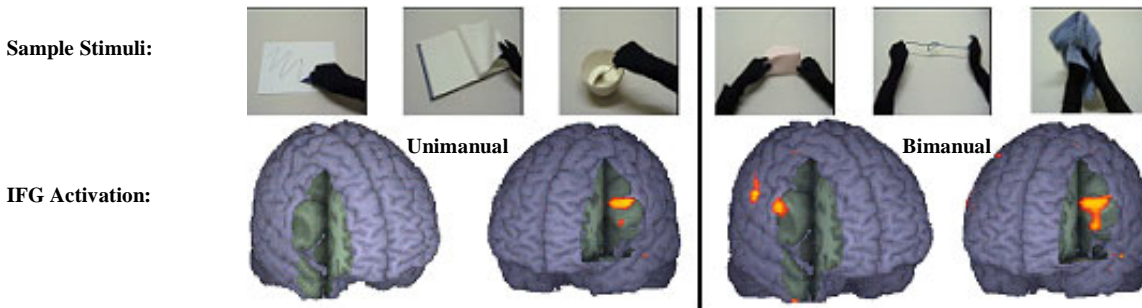
Introduction

Several studies have examined the functional equivalence of execution, action observation and imagination of motor actions (Grezes and Decety 2001), finding neural overlap associated with these different tasks, notably in SMA, premotor cortex and superior parietal lobe. This makes sense in terms of the known role of these neural areas for generating a motor plan appropriate to an intended goal. Recent studies have also identified an important link between properties of action observation and action execution, with the discovery of mirror neurons (MNs) (Gallese et al 1996, Rizzolatti et al 1996). MNs, located in area F5 in the ventral premotor cortex of the monkey, have shown increased firing patterns both when an animal manipulates objects and when an animal observes similar object manipulations produced by a human experimenter (Rizzolatti et al. 1998). The human homologue of F5 is believed to be Broca's area located in the left inferior frontal gyrus (IFG) (Passingham 1993). Neuroimaging studies on humans have demonstrated IFG activation during execution, observation, and imagination of unimanual hand actions (Shlaug et al 1994, Decety et al. 1994, Iacoboni 1999). However, possible differences in IFG related to unimanual versus bimanual actions have had limited description. A recent study by Nair et al (2003) used fMRI to study the neural activity of imagined and executed unimanual and bimanual finger movements. Activation in bilateral superior parietal lobules suggested an important role of these areas in coordinating bimanual sequences, but the study found no evidence of IFG activity. The present study took the next step in identifying the neural correlates of bimanual (and unimanual) action observation and imagination, using ecologically-valid goal-directed skilled hand movements as stimuli that are likely to elicit MN (IFG) activity.

Methods

So far, five healthy right-handed subjects (ages 21 - 45 years, mean age 28 years) have completed the fMRI protocol. Further healthy subjects are currently completing the protocol, as are a clinical group of subjects with Early Onset Psychosis. Subjects received 20 minutes pre-scan training and completed the Edinburgh Handedness Inventory (Oldfield 1971) and the Vividness of Visual Imagery Questionnaire (VVIQ) (Marks 1973). Functional images encompassing the whole cerebrum were acquired using blood oxygenation level-dependent (BOLD) contrast T2*-weighted echoplanar MRI (TR (repetition time), 3s; TE (echo time), 40 ms; α (flip angle), 90°; FOV (field of view) 24 cm, slice thickness 5 mm, 22 slices) on a 1.5 T LX/Nvi neuro-optimised system (GE, Milwaukee, Wisconsin). Prior to the collection of T2* images, T1 weighted images (24 slices) were collected using a conventional spin echo pulse sequence (TR = 500 ms, TE = 14 ms) in positions identical to the functional scans, as an anatomical reference for echoplanar images. In addition, high resolution anatomical images of the entire brain were obtained by using a strongly T1-weighted 3D inversion recovery prepared gradient echo (TE = 5.4 ms, TR = 12.3 ms, TI = 450 ms, 1.57 mm slice thickness, FOV = 20 cm, 256 x 192 matrix). Instructions were presented to subjects from a PC running Presentation® software (Version 0.53, 2002) via LCD projection viewed by a mirror assembly attached to the headcoil. fMRI data were analysed using SPM99. Group analysis was performed using a conjunction model corrected at $p < 0.001$.

The experiment employed a pseudo-randomised and counterbalanced block design. Blocks each lasted 30 seconds, comprising three 10-second stimuli. A 15-second rest condition (fixation) followed each block. Subjects were asked to both watch and imagine bimanual and right-handed unimanual tasks. During observation tasks, subjects watched video clips of familiar actions being performed, whereas during imagination tasks subjects imagined actions being performed whilst watching a still image from the video. Stimuli were varied to minimize learning effects. The same actions were presented in both action observation and imagination conditions. The experimenter's hands were anonymised so subjects could project an identity onto the actions during imagination. Subjects were instructed to keep their eyes open during imagination tasks, in order not to miss the next task, and to place their hands together in the midline, so as to minimize movement. A post-experiment questionnaire evaluated task performance.



Results and Discussion

Scores for all subjects on the VVIQ and post-scan questionnaires demonstrated that all were able to imagine clearly and vividly during the experiment, for both unimanual and bimanual tasks. Inferior frontal gyrus (IFG) activity was found for action observation of both unimanual and bimanual tasks. Interestingly, unimanual action observation produced left-sided IFG activity, whereas bimanual action observation showed bilateral IFG activation. This is a significant finding, which suggests that mirror neurons may be activated bilaterally in the formation of representations of bimanual actions. In common with Nair et al (2003), in a bimanual versus unimanual comparison, bimanual tasks preferentially activated bilateral superior parietal lobules, reinforcing the idea that SPL is important in co-ordinating bimanual sequences. As a whole, action observation activated premotor and parietal cortex and middle occipital gyrus (V5) in common with previous studies (Grezes et al 2001, Howard et al 1995). IFG was not activated during action imagination in unimanual or bimanual modalities. Bilateral cerebellar activity, whilst present for both unimanual and bimanual conditions, was greater for unimanual sequences. Post-scan questionnaires revealed that subjects found the bimanual tasks less familiar, perhaps making these tasks more cognitively demanding. In common with action observation conditions, imagination tasks activated premotor cortex and parietal areas for both unimanual and bimanual variations. SMA was also activated by imagination as has been previously shown. An additional intriguing finding was bilateral fusiform gyrus activation during imagination. In summary, these preliminary findings add to our understanding of the role of MNs in the observation of bimanual actions, suggesting that MNs operate in a bilateral manner when bimanual skills are observed, compared to their left unilateral activation with unimanual observation. Other neural correlates of action observation and imitation associated with unimanual and bimanual sequential skills have also been further defined.

References

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