Timecourse of visual and motor activation during observation and self-selection of action using rapid event-related fMRI

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Introduction

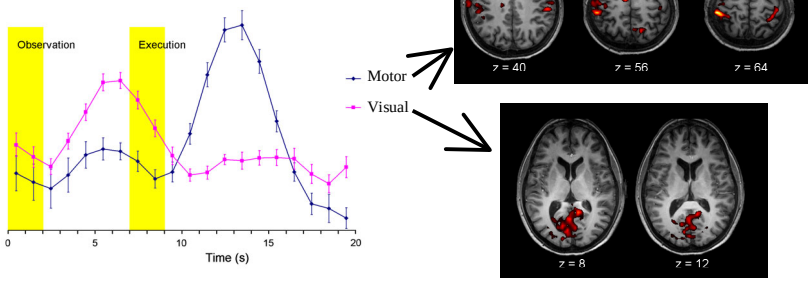
There is much evidence that cortical representations for action are generated and encoded in activity across motor and premotor areas of the brain. Such representations can be formed prior to actual movement performance in readiness for action, during mental imagery of movement, or during the observation of others' movement. In this study we specifically examined the differences between the external observation of others' actions and the internal volitional self-selection of action. By using event-related functional MRI with relatively high temporal resolution, together with exploratory and model-free analysis methods, we aimed to separate early activation relating to the observation/self-selection of action from later activation relating to execution of movement.

Subjects and Methods

Fourteen right-handed healthy subjects performed experiment conditions of observing and imitating finger gesture movements of an actor, and selecting finger gesture movements themselves without external reference. ***Observed movements*** consisted of video sequences of the hand of an actor moving from a resting position to form a finger gesture from American Sign Language (ASL), then returning to the resting position (2 s duration). For ***self-selected*** movements, subjects saw a visual cue indicating that they should select a previously learnt finger gesture to perform. Following a 5 s delay, subjects performed the observed/self-selection finger gesture movement. A total of 36 trials were performed in a single fMRI acquisition sequence.

Imaging was performed on a 3 T Bruker Medspec S300 scanner (Ettlingen, Germany) using a gradient-echo EPI sequence (64x64, 17 slices 5mm thick, TR=1000ms, TE=40ms). Images were corrected for slice timing differences, realigned and registered to Talairach (MNI) space, and spatially smoothed at 5 x 5 x 5 mm using SPM99. Independent component analysis (ICA: Melodic, FSL) was used to separately identify time-courses of activation within visual and motor networks relating to the observation and execution of movement all subjects to determine the optimal hemodynamic response delay for a better informed model for subsequent GLM analysis. For GLM analysis, separate box-car functions were used to model activation during observation (2 s), during the delay period (2+2+1 s), and during execution (2 s) for each trial and second-level random-effects analyses were used for group results.

Results



Motor and Visual area activation with ICA
In all subjects, ICA components relating to activation of motor networks and visual areas could be separately identified.
Far Left: *Event-related time-courses of activation in motor and visual areas in a single subject. Plotted is the mean ± standard error for all Action Observation Go trials. The yellow bars mark the periods of observation of action (2 s duration) and execution of the same action.*
Left: *Independent Component maps overlayed on the subjects' own T1 structural brain image.* ***Motor networks*** *(above left) involve the supplementary motor and left primary motor areas (z=56), cingulate and bilateral inferior parietal areas (z=40), and bilateral superior parietal and lateral premotor areas (z=64).*

Observation of action involved activation of the supplementary motor area and lateral premotor areas bilaterally, extensive parietal activation covering both inferior and superior parietal areas and the intraparietal sulcus bilaterally, bilateral inferior frontal activation and extensive activation in visual cortex extending laterally into higher visual areas. The ***self-selection*** of action also involved significant activation of the lateral premotor cortex and supplementary motor area, but involved significantly greater frontal activation within the pre-SMA/anterior cingulate and dorsal lateral prefrontal cortex (middle frontal gyrus) compared with observation of action.

Conclusions

A common network of supplementary motor, lateral premotor, inferior frontal and superior parietal areas was involved in both the observation of finger movements, with the intention of imitating, and the self-selection of actions. We suggest that this reflects a general encoding or representation of the movement formed and held in readiness for action. The route to this representation, however, differed between conditions. Observation of action involved more extensive higher-visual and parietal activation, following the dorsal stream of processing suggested to link perception and action. Self-selection of action, or the internal decision of intention, involved more frontal networks including lateral prefrontal and anterior cingulate areas.