

fMRI of Writing and Mirror Writing in Right and Left Handed Subjects

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We used fMRI to study the neural correlates of normal and mirror writing of the alphabet. In changing from writing with the preferred to non-preferred hand, activation in left sensory-motor cortex became bilateral in right-handed subjects, but remained on the right in left handed subjects. However, for mirror writing activation was bilateral in both groups of subjects whether the preferred or non-preferred hand was used. Bilateral activation of SMA was present, except for tasks involving the right hand in left handed subjects, and of IFG for mirror writing tasks in right handed but not left handed subjects.

Introduction

Tankle and Heilman (1983) reported that left handed subjects read and wrote mirror words (i.e. script that runs in the opposite direction to normal with the individual letters also reversed) faster than right handed subjects and suggested that this could be due to (i) a motor hypothesis in which the requirement for abductive movements in left handed subjects and adductive movements in right handed subjects makes the former superior mirror writers, (ii) a mirror-engram hypothesis in which normal engrams are stored in the left hemisphere and mirror engrams in the right hemisphere in both right and left handed subjects and (iii) a spatial hypothesis in which left handed subjects are better able to overcome the usual left to right directional bias in normal writing than are right handed subjects. Application of functional neuroimaging techniques to establish the neural correlates of normal and mirror writing with the preferred and non-preferred hand in right and left handed subject has the potential to provide information relevant to testing these hypotheses.

Methods

So far we have performed fMRI studies of the neural correlates of letter writing in 24 subjects, 12 of whom were characterised as right handed and 12 left-handed according to the Edinburgh Handedness Inventory (Oldfield, 1970). T2* weighted gradient-echo Echo Planar MR images (TE = 40 ms, TR = 3 s, Flip angle = 90°, Matrix = 64 by 64, FOV = 24 cm) were obtained for 22 contiguous 5 mm thick axial slices covering the whole cerebrum using a 1.5T LX/Nvi Neuro-Optimised MR imaging system (General Electric, Milwaukee, USA). Each functional run comprised 10 alternating periods of 15 seconds of rest followed by 15 seconds of task, lasted a total of 5 minutes and provided 100 EPI volumes. The instructions for each task were presented to the subject on a back-projection screen using a Macintosh computer and an Epson LMP73000 liquid crystal display projector. The respective task conditions for each of 4 functional runs were:

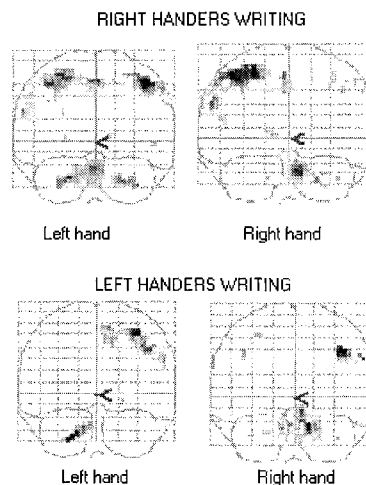
- (i) Writing the alphabet with right hand,
- (ii) Writing the alphabet with left hand,
- (iii) Mirror-writing the alphabet with right hand,
- (iv) Mirror-writing the alphabet with left hand.

In each run the subject wrote the characters on a pad of paper with a pencil. All tasks were executed without visual feedback. Subjects were instructed to write all characters in lower case, with approximately equal amplitude at the same location and to maintain a constant writing frequency. Prior to study each subject underwent 10 minutes of pre-training. The objective of the training was to ensure that subjects were familiar with the requirements of each task rather than to become expert in the task. Writing samples for each task were acquired before and after fMRI.

fMRI data analysis included motion correction, spatial normalisation and smoothing with a 6 mm Gaussian kernel and was performed using SPM99 software (Wellcome Department of Cognitive Neurology). In particular, for each functional run a conjunction analysis was performed separately for right and left handed subjects. Conjunction analysis enabled identification of common brain regions with significant activation in every subject in each group.

Results and Discussion

For all functional runs conjunction analysis revealed less total activity for left compared to right handed subjects, indicative of greater variability in the patterns of brain activation in left handed subjects. Preliminary analysis of data for normal writing with the preferred hand (upper right and lower left panel of Figure) revealed activation in left but not right sensory-motor cortex, and right but not left cerebellum, for right handed subjects, and in right but not left sensory-motor cortex, and left but not right cerebellum, for left handed subjects. Interestingly, when subjects wrote with their non-preferred hand, activation in sensory-motor cortex and cerebellum was bilateral in right handed subjects but sensory-motor cortex activation remained on the right, and cerebellum activation moved to the right, in left handed subjects (upper left and lower right panel of Figure).



In the case of mirror writing activation of sensory-motor cortex and cerebellum became bilateral for both right and left handed subjects for both the preferred and non-preferred hand. Furthermore, bilateral activation of inferior frontal gyrus was present for mirror writing in right handed subjects but absent in left handed subjects. For all tasks activation of supplementary motor cortex was present in right handed subjects for both hands, however, was absent for the non-preferred hand in left handed subjects. Furthermore, activation of parietal lobe was present for all tasks, and was on the left for normal writing with each hand in right and left handed subjects, bilateral for mirror-writing with each hand in right handed subjects, and on the left for mirror writing with the right hand and bilateral for mirror writing with the right hand in left handed subjects.

We have recruited further cohorts of subjects so as to obtain sufficient data to perform a random effects analysis to identify brain regions which show similar extent and magnitude of activation for the different tasks in right and left handed subjects, divided according to hand posture and sex. We will also perform further fMRI studies in these subjects, using verbal and spatial processing paradigms to test the claim of Levy and Reid (1978), based on tachistoscopic tests, that almost all of the variation in the lateral organisation of the brain may be accounted for by the handedness, hand posture and sex of subjects.

References

- Oldfield, R.G. The assessment of handedness. *Neuropsychologia*, 9, 97-102 (1971).
- Tankle, R.S. and Heilman, K.M. Mirror writing in right-handers and left-handers. *Brain and Language*, 19, 115-123 (1983).
- Levy, J. and Reid, M. Variations in cerebral organisation as a function of handedness, hand posture in writing, and sex. *Journal of Experimental Psychology*, 107, 119-144 (1978).