

Can high field functional MRI detect interhemispheric transfer of visual and motor information?

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Introduction

Split-brain patients (i.e., patients who have undergone corpus callosotomies) are generally unimpaired in daily life, but have severe deficits when performing tasks that require interhemispheric transfer [1]. In tasks in which complex visual stimuli (e.g., words) are presented to only one hemisphere (using visual hemifield stimulation), processing is restricted to the hemisphere that initially receives the information. In healthy individuals, interhemispheric transfer of visual information is associated with decreased behavioural performance relative to uncrossed conditions. Using functional magnetic resonance imaging (fMRI) at 1.5T, our group recently linked visuovisual interhemispheric transfer to greater activity in medial extrastriate cortex near the splenium of the corpus callosum [2]. However, this activation was reduced in more anterior regions (i.e., closer to the splenium) relative to posterior extrastriate regions. Using high field fMRI, we explored whether activation near the corpus callosum could be recovered. To do this, we used 4T fMRI and expanded on the experimental design in [2] to include interhemispheric transfer of motor information in addition to visual interhemispheric transfer. We hypothesized that it would be possible to detect activation differences between crossed and uncrossed conditions using high field fMRI, with activation depending on the type of interhemispheric transfer required (visual or motor).

Visual hemifield stimulation was used to present stimuli to a single hemisphere, and subjects made unimanual responses to stimuli. Complex visual stimuli that have been associated with lateralized brain processing were used to manipulate interhemispheric transfer (words: left hemisphere; faces: right hemisphere). For example, no interhemispheric transfer would be required for a trial in which a face was presented in the left visual field (right hemisphere) and a left hand response was made (right hemisphere). In contrast, both visual and motor interhemispheric transfers would be required for a word presented under the same conditions.

Methods

Stimuli: Monosyllabic, four letter words were selected from the MRC Psycholinguistics Database [3]. Pseudowords were created by replacing one letter of each word. Faces were provided by the Max Planck Institute for Biological Cybernetics in Tuebingen, Germany [4]. Scrambled faces were created by changing the order of the eyes, nose, and mouth. Subjects were instructed to indicate via a four-button forced choice whether each stimulus was a word, pseudoword, face, or scrambled face.

Experimental design: We employed a block design with two factors: visual (crossed/uncrossed) and motor (crossed/uncrossed). Visual interhemispheric transfer was manipulated via hemifield of presentation, with word and face stimuli presented in the right and left visual fields (respectively) for uncrossed blocks, and vice versa for crossed blocks. Motor interhemispheric transfer was manipulated via response hand, with the right and left hands assigned to word and face stimuli (respectively) for uncrossed blocks, and vice versa for crossed blocks. See Figure 1 for a schematic of the visual and motor experimental manipulations. Stimuli were presented for 150ms to avoid saccades. Each 22s stimulation block consisted of eight stimuli (four word and four face stimuli) with variable inter-stimulus intervals within a block (2-4s). Stimulation blocks were alternated with 18s rest blocks (fixation).

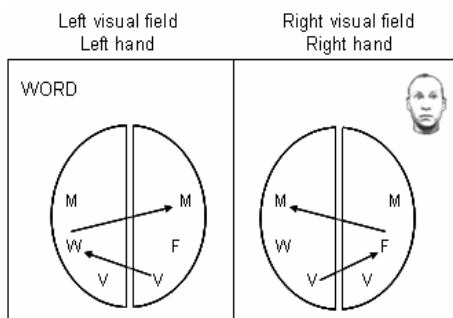


Figure 1. Schematic of visual and motor transfers using word and face stimuli. V: visual area; W: word processing area; F: face processing area; M: motor area.

Data acquisition: Images were acquired on an Oxford 4T MRI system using a Varian INOVA console. Whole brain fMRI data were acquired using a two-shot spiral sequence (TR/TE = 1000/30ms, flip angle = 60°, 20 axial slices [6mm thick, 0.6mm gap], 240mm FOV, 64 x 64 matrix). Four dummy scans preceded each fMRI run. A total of 660 volumes were acquired. A navigator echo and field map correction were applied. A T₁-weighted anatomical image was acquired for each subject using MPFLASH (TR/TI/TE = 10/650/5ms, flip angle = 11°, 240 x 240 x 192mm FOV, 256 x 256 x 64 matrix, 4 segments, 200ms segment delay).

Data analysis: Motion correction, coregistration between functional and anatomical images, normalization to standard space, smoothing, and statistical analyses were performed using SPM5 [5]. Boxcar functions representing the onset and duration of each condition were convolved with the canonical hemodynamic response function and included in the design matrix. The general linear model was used to create statistical parametric maps. Activation specific to interhemispheric transfer was visualized using *t*-contrasts (*z*-score > 3, extent = 10).

Results and Discussion

Consistent with previous studies, decreased behavioural performance was observed for crossed conditions. In all conditions, activation was observed in regions that have been implicated in word and face processing (e.g., left and right fusiform gyrus). As expected, activation differences were detected between crossed and uncrossed conditions. Interestingly, activation patterns for visual and motor interhemispheric transfer could be dissociated. Both visual and motor transfers were associated with activation in cortical regions near the corpus callosum, but visual transfer was associated with more posterior activation (around the splenium of the corpus callosum), whereas motor transfer was associated with more anterior activation (around the body of the corpus callosum). Activation from a representative subject is presented in Figure 2. While some fMRI studies have reported white matter activation (e.g., [6]), its existence remains controversial. The current findings contribute novel evidence to this controversy, particularly because the experimental design targets two distinct functional regions of the corpus callosum (i.e., both visual and motor interhemispheric pathways).

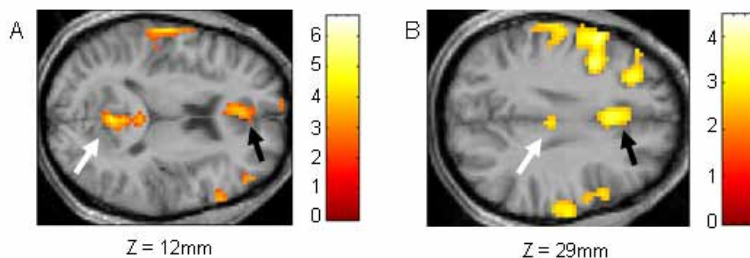


Figure 2. **A:** Visual interhemispheric transfer (*t*-contrast of $2c > Mc$). The white arrow highlights activation near the splenium of the corpus callosum. **B:** Motor interhemispheric transfer (*t*-contrast of $2c > Vc$). The white arrow highlights activation near the body of the corpus callosum. Anterior cingulate activation is present in both *t*-contrasts (black arrows), and likely reflects increased attention in the $2c$ condition, due to greater task difficulty (indicated by decreased behavioural performance in the $2c$ condition). Activation scales show *z*-scores.

Conclusions and future directions: Using an innovative experimental design and 4T fMRI, we demonstrated that it is possible to detect activation associated with visual and motor interhemispheric transfer. This study highlights the benefits of high field fMRI for studying activation in cortical regions near white matter such as the corpus callosum. Ongoing work is characterizing the activation results using analysis techniques that are specifically aimed at uncovering the functional dynamics of brain connectivity (e.g., dynamic causal modeling).

References

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