Correlations between cerebellar activities during spatial judgment detected by functional MRI and the clinical observations

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Introduction

Intact visual-perceptual function is the foundation of normal processing and organization of the enormous inputs from the visual world. In lesion studies, spatial perception is usually impaired by right parietal lesions (1). This observation has been confirmed by lesion as well as functional MRI (fMRI) studies (2, 3). However, recently, there has been speculation that spatial judgment could be subserved by a more widely distributed network than just the parietal regions (4). We noticed that spatial judgment was impaired in two clinical cases of cerebellar stroke that spared the parietal regions. Case 1 was a 22-year-old right-handed man with 13 years of education who was suffering from a cerebellar AVM affecting the cerebellum bilaterally. Case 2 was a 38-year-old right-handed man with 11 years of education who was suffering from a cerebellar hemorrhage affecting the left cerebellum. Spatial judgment was measured by the Benton's Judgment of Line Orientation Test (JLO), a visual measure of line orientation that is the most frequently used test for assessing spatial judgment (5). The results of the assessment indicated impairment in spatial judgment by z scores of over 4 relative to their age peers. The notion that the cerebellum is exclusively involved in motor control has been challenged by studies of cerebellar damaged patients and by functional neuroimaging results (6, 7). To integrate the clinical observations of impaired spatial judgment of our cerebellar patients with the recent theoretical discoveries about the role of the cerebellum in cognitive functions, we employed fMRI technology and studied if the cerebellum was involved in spatial judgment.

Methods

We recruited 10 normal healthy male right-handed subjects (ages 22 - 25 yrs) for this study. The experimental task (2) contained control and experimental conditions. Under the control conditions, the subject was asked to judge whether two horizontal lines were on the same level. Under the experimental conditions, the subject was asked to judge whether the two stimulus lines displaced with varying degrees of orientation matched the angles of the two highlighted lines in the exemplar. The experimental task was administered in a blocked fMRI study to investigate if the activity of the cerebellum is involved during spatial judgment measured by judgment of the orientation of lines. Each stimulus was exposed for 0.25 sec, with an interstimuli interval of 1.75 sec when the subject could make the response. Each condition was repeated four times, giving a total of eight blocks in each run, the duration of which was 264 sec. The stimuli were delivered through a goggle display system. The experiment was performed on a 1.5 T Magnetom Vision MRI scanner (Siemens, Erlangen, Germany). A single-shot GRE EPI sequence was used for the fMRI scans (SW = 5 mm, in-plane resolution = 3.3 mm x 3.3 mm, and TR/TE/θ = 3000 ms/60 ms/90°). Twenty-four contiguous axial slices were acquired to cover the whole cerebellum and most of the cerebrum. Analysis of the imaging data was conducted using the SPM99 procedure. The data sets were then spatially smoothed with a 3D Gaussian kernel (FWHM = 8 mm). Data were analyzed by modeling the experimental conditions using boxcar functions convolved with a hemodynamic response function. The regionally specific differences with an uncorrected threshold of $p<0.001$ (with cluster size > 50 voxels) were considered statistically significant.

Results

The performances of the 10 male subjects were 100% accurate under the control conditions. The accuracy of their performance under the experimental conditions was about 97%. Cortical regions activated included the bilateral precuneus and the extrastriate regions. Activation of the bilateral prefrontal regions was also observed (Fig. 1). The pattern of activation observed in the cortical regions was largely consistent with the results reported in Ng et al. (2). We then examined the activity recorded in the cerebellum and observed activation of the cerebellar regions while the subjects were performing the experimental task of spatial judgment of the orientation of lines (Fig. 1) at Talairach coordinates x = 52, y = -64, z = -18; x = -12, y = -84, z = -18; and x = -20, y = -92, z = -22. The imaging data suggested bilateral activation of the cerebellum when the subjects were performing the experimental task of spatial judgment.

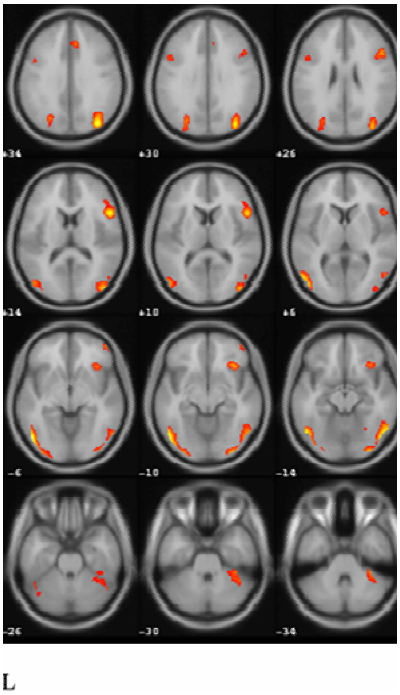

Fig. 1: Normalized activation maps averaged across 10 male subjects. Planes are labeled with the height (mm) relative to the bicommissural line.

Discussion

Prompted by the impaired spatial judgment performance of our patients suffering lesion in the cerebellum but sparing the parietal regions, we conducted this fMRI study to examine neural activity associated with spatial judgment measured by judgment of line orientation. The pattern of neural activation at the cortical regions observed in our subjects was largely consistent with the results of a previous study examining the role of the parietal lobe in spatial function (2). We then examined the imaging results in the cerebellum and observed activation, bilaterally, when our subjects were engaged in spatial judgment of line orientation. The multiple closed-loop circuits between the cerebellum and the cerebral cortex make it possible for the cerebellum to process motor function as well as participate in higher-order cognitive processing. The findings of this study are consistent with those of previous clinical studies that suggested the involvement of the cerebellum in visual-spatial function. Our work thus compliments previous functional imaging and clinical studies and adds to the literature showing that the cerebellum together with the parietal regions are involved in spatial judgment measured by the JLO. Clinically, since spatial perceptual difficulty could be an early sign of cerebellar dysfunction, the association between damage to the cerebellum and spatial judgment difficulty requires further investigation. Our study illustrates how fMRI and clinical data can be integrated to further knowledge of the realm of neuropsychology, so that the behavioral impact of neurological diseases can be better understood.

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