Mapping cortical areas associated with Chinese word processing with functional magnetic resonance imaging

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Introduction

Wada test has been a primary clinical protocol for assessment of hemispheric dominance of language function. However, this test is invasive and distressing for patients. The past few years has seen a great deal of progress in functional brain imaging techniques. Of particular interest is to precisely localize human brain functions, including language processing, using clinical conventional MRI systems. As a result, fMRI has been proposed for offering a non-invasive alternative to Wada test. The present study was designed to explore if fMRI is also feasible for localizing cortical areas associated with Chinese language processing. To examine reproducibility and enhance reliability, the same experiment was conducted on two different clinical MRI scanners in separate institutions. Synonym and homophone judgement tasks was used in the study.

Methods

Eight normal, right-hanged, native Chinese speakers were included in the study. The age ranged from 23 to 36 years.

MRI was performed on a 1.5T GE MR scanner in Beijing or on a 1.5T Siemens MR scanner in Minneapolis, respectively. On GE scanner, 10-14 axial T1WI were first collected with SE sequence (TR/TE=500ms/14ms, slice thickness=6mm, gap=1mm). 124 functional images per slice were then acquired in the same location with gradient-echo EPI(TR/TE=2000ms/40ms, flip angle=90º, slice thickness=6mm, gap=1mm, matrix=64×64). Finally, 64 continuous sagittal slices were acquired for 3-dimensional reconstruction and spatial normalization. On Siemens scanner, slice thickness was 7mm without gap for T1WI and functional imaging. The T1WI were first acquired with a FLASH sequence. For functional imaging, gradient-echo EPI (TR/TE=2000ms/55ms) was used. 167 images per slice were acquired over 12 slices. Flash was used to obtain a 3-D anatomic data set.

The subjects were instructed to press a button if the presented pairs of Chinese words had similar meanings in the synonym judgement task or had same pronunciation in the homophone task. Passively viewing a crosshair was served as baseline control. A series of functional MR images were collected while 8 to 12 blocks of linguistic task and baseline control task were alternated. Each block lasted 20s or 40s. For each block of linguistic tasks, 10 pairs of Chinese words were presented.

Data analysis was performed using AFNI software. The functional images were spatially registered so as to check and correct for motion artifacts. They were then co-registered to the 3D structure images and normalized according to the standard coordinates defined by Talairach. The runs for time series data were analyzed by correlating the time course for each voxel with ideal trapezoidal reference waveform corresponding to the timing of linguistic tasks (synonym and homophone judgement). The activated voxels were then superimposed on the anatomic images to produce the activation maps. Finally, a Student t-test was used to further examine the possible difference between activation during performance of homophone and synonym judgement tasks.

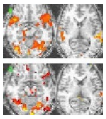
Results

For all 8 subjects, the activation areas of the cerebral cortex during either synonym or homophone judgement tasks were mainly located on the left hemisphere, including Broca´s area and Wernicke´s area. Activation was also observed in bilateral SMA, extrastriate visual areas, and ventral temporal cortex. There was no significant difference between activation patterns based on data collected on Siemens scanner and that based on data collected on GE scanner.

One of the subjects was scanned on both scanners while he was performing the same linguistic tasks. Both GE and Siemens data revealed activation of an extensive network, including Broca´s area, Wernicke´s area, SMA, bilateral ventral temporal cortex, and extrastriate cortex (Figure). However, more activated voxels in Broca´s and Wernicke´s areas were found in Siemens data than in GE data.

The time course of signal intensity changes in 4 primary activated areas (Broca´s area, Wernicke´s area, left extrastriate visual areas, and left ventral temporal cortex) was compared. Again, no substantial difference was found between signal changes from data collected in both scanners.

Student t-test failed to show significant difference between activation during performance of synonym and homophone judgement tasks.



Activation maps in the same subject during performance of homophone and synonym tasks. Siemens data in top panel, GE data in bottom panel

Discussion

The laterality of language function assessed by fMRI was reported to be consistent with that determined by Wada testing. A set of language related structures, including Broca´s area and Wernicke´s area, was activated in our experiments, demonstrating that fMRI can also detect brain activation during Chinese word processing.

Previous studies have demonstrated left hemispheric dominance in processing of alphabetic languages. However, several authors proposed a right-hemisphere dominant hypothesis of Chinese word processing based on the prominent pictorial nature of Chinese characters. The current study indicated that the brain activity during Chinese word processing was generally in accordance with that of word processing of western languages, with strong left-hemisphere dominance.

No significant difference between semantic and phonological processes was revealed in our study. The possibility is that both systems are automatically and spontaneously engaged during word reading whether or not specific instruction is provided.

From the activation maps and time courses in 4 primary activation cortical areas, we revealed almost identical activation in data acquired on different scanners. As a result, the research was highly reproducible and reliable.

In the subject who performed the same linguistic tasks on different scanners (first on Siemens system, then on GE scanner), we did find more activated voxels in Broca´s and Wernicke´s areas in Siemens data than in GE data. It may be explained as a learning effect.

In conclusion, the present study demonstrated that fMRI is feasible for localization of Chinese language processing and may become a widely accepted clinical tool for localizing functional brain areas in patients.

References

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