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Original Article

Comparison of functional magnetic resonance imaging in cerebral activation between normal Uygur and Mandarin participants in semantic identification task

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Abstract: Purpose: This study utilized blood oxygenation level-dependent functional magnetic resonance imaging (BOLD-fMRI) technology to study the activated cerebral regions in normal participants whose native language was Uyghur or Chinese. Methods: We collected the fMRI data from 15 Uyghur-speaking volunteers and 15 Mandarin-speaking volunteers when executing the semantic identification task and compared the results of two groups. Results: Statistically significant difference of brain activation was found primarily in the left anterior cingulate gyrus (BA23) and the midline precuneus (P<0.05). When performing the semantic identification task, the Uyghur group exhibited significant activation in these two regions, whereas the Chinese group demonstrated relatively weak activation in these areas. Conclusion: The cerebral regions activated by Uyghur and Chinese semantic identification are not identical, the dominant hemisphere for both languages is the left cerebral hemisphere. The left anterior cingulate gyrus might have a language function in Uyghur semantic processing.

Keywords: Magnetic resonance imaging, cerebral hemisphere, Uyghu, mandarin

Introduction

Language is a complex cognitive psychological activity unique to human beings, and the brain mechanism for language processing has become a research focus in many disciplines in recent years. However, current researches in China primarily focus on the brain processing mechanisms of Chinese (Mandarin), while the processing mechanisms of minority languages are rarely discussed. Regarding the Uyghur language (hereinafter referred to as Uyghur), so far there are only two research studies conducted by Jiang Mei et al. [1, 2] on the functional cerebral regions for semantic processing. The brain areas associated with functional language of Uyghur and the difference in brain processing mechanism between Uyghur and Chinese remain to be undiscovered topic.

Uyghur and Chinese have substantially different linguistic characteristics. Uyghur belongs to the Altaic family with linear one-dimensionally arranged alphabetic writing. It has 32 letters, including 8 vowels and 24 consonants. Letters are not case-sensitive, while each letter has different written forms and rules for writing. For example, " ـبـ , ﺑ , ـب, ب " are different forms of a same letter, and these different forms of the letter can stand alone or in different locations within a word, that is, at the beginning, middle or end of a word. There are a total number of 32 letters with 126 variations in written form. Thus, writing Uyghur is more complex than Indo-European alphabetic writing. On the other hand, Chinese belongs to the Sino-Tibetan language system, whose characters consist of strokes and segments which are arranged in two-dimensional space according to orthographic rules with graphical features. Uyghur writing is also completely different from Chinese writing in the internal relationships among shape, pronunciation and meaning. Chinese is a language based on morphemes, whose basic unit is a unity of shape, pronunciation and meaning. In contrast, alphabetic writing (Uyghur) records phonetic phonemes, and the letter itself does not have actual meanings. In addition, Uyghur uses different directions of reading and writing from Chinese. Chinese is read and written horizontally from left to right, whereas Uyghur is the opposite. Chinese is a tonal language with many homophones and homophones with different tones. On the other side, there are many letters in Uyghur that use number and position of dots to distinguish the forms of the letters. Number of dots or symbols can affect the format of the letter, possibly resulting in altered meanings or unintelligible word, such as "ش" "س" "ۈ" "ۆ" "ۇ" "و", "ج" and "چ".

Previously, a series of studies on Chinese tonal language and Western phonetic language provided confirmatory evidence that different brain areas were activated when the brain processed tonal and phonetic languages. In addition to the neural activity shared by all languages processing, each language has its own specific cortical representation. For example, Li et al. [3] suggested that the left middle frontal gyrus was the particularly active cerebral region in the cognitive processing of Chinese characters.

Previous studies have shown that differences in orthography, pronunciation and syntax among different languages may lead to different cognitive strategies, resulting in different cortical representation [4]. Zhao [5] argued that the formation of the language areas of the brain was the result of long-term, adaptable contention within the language environment; moreover, according to the features of partitioning and functional specialization of the brain, Zhao suggested that the formation of various capacities of human language and their positioning in the cerebral cortex are not only related to the neural layout, but also associated with the "competition" of various brain areas in subsequent training. Additionally, the language ability is a comprehensive capability, including listening, speaking, reading and writing. Therefore, the phenomenon and process of "competing" between brain areas must be more complicated, and the multipolarity of language centers is an inevitable outcome.

A novel CMR application, blood oxygen level-dependent (BOLD) imaging, now offers the possibility of detecting ischemia more directly. This technique exploits the paramagnetic properties of the body's intrinsic contrast agent, hemoglobin. The transition from diamagnetic oxyhemoglobin to paramagnetic deoxyhemoglobin induces magnetic susceptibility differences, resulting in a change in magnetic resonance signal intensity and thereby generating oxygen-dependent contrast.

In sum, Uyghur and Chinese languages are entirely different in characters; the objectives of this study were to explore the possible discrepancy in language center of Uighur and Chinese speakers. This study utilized blood oxygenation level dependent functional magnetic resonance imaging (BOLD-fMRI) technology to study the brain areas activated in normal Uyghur native speakers and Chinese native speakers when executing a semantic identification task. The result of these two language groups were analyzed, thus providing a further reference for the clinical research of the dominant language hemisphere and functional language areas in patients whose native language is Uyghur. We intended to obtain more knowledge of the neural mechanisms of language generation. Also, the clinical implications would be highly valuable in understanding language dysfunction after brain injury and brain rehabilitation mechanisms in clinical practice. Additionally, such clinical findings can provide important information with respect to revealing the universality and particularity of the language processing mechanism in the brain.

Methods and materials

Participants

A total of 30 healthy college students who were not majoring in language participated in the study. Uyghur group (whose native language was Uyghur) has 15 undergraduate freshmen who were admitted in Xinjiang Medical University after passing examinations in Uyghur. Chinese group (whose native language was Chinese) has 15 junior undergraduate students from the same university. All of the participants presented with normal uncorrected or corrected visual acuity, with no history of mental disorders or any brain/systemic organic diseases. Prior to the experiment, all participants underwent a detailed language function test, which included language fluency, spontaneous oral

Table 1. Demographic information and language function test of the participants

	Uyghur group (n = 15)	Chinese group (n = 15)	*P*-value
Sex (M/F)	7/8	8/7	>0.05
Age (years)	18.3±0.5	21.4±0.7	>0.05
Handedness (right/left)	15/0	15/0	>0.05
Years of schooling (years)	13	15	>0.05
Verbal fluency (words/min)	85.1±8.7	137.5±16	<0.05*
Listening comprehension (%)	97.6±2.2	98.9±1.5	>0.05
Naming (%)	99.7±0.9	99.8±0.6	>0.05
Repeating (%)	96.1±1.2	99.2±1.6	>0.05
Reading (words/min)	161.3±8.1	245.1±14.6	<0.05*
Reading comprehension (%)	99±2.1	99.3±1.8	>0.05

Although Statistical analysis of the data for speech fluency and reading projects of the two subject groups revealed that the difference was statistically significant (P< 0.05), due to Chinese and Uyghur differ in language characteristics, these two language aspects are not comparable. However, statistical analysis demonstrated that the differences between the two groups in gender, age, years of education and other demographic information as well as the rest of the language function test indicators were not statistically significant (P>0.05), which indicated that the two groups were comparable. Note: P<0.05 was considered to be statistically significant.

expression, listening comprehension, naming, repeating, reading and comprehension. Also, handedness was assessed using the standard Chinese version of the handedness rating scale. An informed consent prior to the experiment was present and signed by all participants. Demographic information and results of the language function test are shown in **Table 1**. Statistical analysis of the data for speech fluency and reading projects of the two groups revealed significant difference ($P<0.05$). Due to the major difference in Chinese and Uyghur characteristics, these two aspects in language test were marked as irrelevant variable. However, the differences between two groups in gender, age, years of education and other demographic information as well as the rest of the language function test indicators were not statistically significant ($P>0.05$), indicating that these two groups were comparable. Details are also listed in **Table 1**.

Procedure and task

Visual presentation is used as the major experimental task. The stimulation module used the block design paradigm, and the functional scanning process was as follows. The stimulating state and resting state alternated with one another. The initial 18 seconds(s) of scanning signal data was collected as the baseline, which were not included in the statistical analysis. This initial period was followed by 9 trials of block sequences: three different words was shown in the center of the screen for a duration of 3 s, one above and two below a fixation cross-hair, the participants were instructed to determine which the presented words were semantically close with the above word by pressing buttons rapidly. During the 30 s of the stimulating state, the status appeared 10 times, followed by 30 s of the resting state. These steps were repeated with a total of nine cycles with 60 s block sequences and a total scanning time of 9 minutes and 18 s. The content of the tasks was identical for both groups, while Uyghur group used Uyghur, and Chinese group used Chinese. During fMRI scanning, the participants were asked to gaze at the center of the screen and keep the head still during the entire experiment. Prior to the actual experiment, the participants completed a trial session to get familiar with the experimental procedure, in order to decrease the effects of possible stress, anxiety and other emotions related to the experiment.

MRI acquisition

This study used the GE signa 3.0 T superconducting MRI scanning system for image acquisition, and an 8-channel head coil was used for signal reception. First, we used the 3D thin-slice scanning sequence to obtain the craniocerebral axial T1-weighted images. The scanning parameters were shown as follows: TR/TE = 550 ms/67 ms, 1.0 mm thickness, zero interval, field of view (FOV) = 240 mm×240 mm, matrix = 320 mm×192 mm and a total of 136 slices from the base of the skull to the parietal layer. Then, the gradient-echo echo planar imaging (GRE-EPI) sequence was used to acquire BOLD signals data. The scanning parameters were as follows: TR/TE = 2,000 ms/30 ms, 5.0 mm thickness, zero interval, 90° flip angle, FOV = 240 mm×240 mm, matrix

Table 2. Differentially activated brain regions during the semantic identification task between the Uyghur group and the Chinese group

Differentially activated brain regions (Uyghur > Han)	cluster p (cor)	cluster equivk	cluster p (unc)	voxel p (FDR-cor)	voxel T	voxel p (unc)	x,	y,	z
							{mm MNI}		
Left anterior cingulate gyrus	0.004	7	0	0.000	5.21	0	0	-63	24
Praecuneus				0.000	4.46	0	0	-66	33

The analysis results of the one-sample t-test and the two-sample t-test are shown in **Table 2**. During the execution of the Uyghur and Chinese semantic identification tasks, the discrepancy of activated cerebral regions was primarily found in the left anterior cingulate gyrus (BA23) and the midline precuneus. The Uyghur group exhibited significant activation in these two regions, whereas the Chinese group exhibited relatively weak activation in these areas. The difference between the two groups was statistically significant ($P<0.05$). Note: $P<0.05$ was considered to be statistically significant. Statistics level: $P<0.05$ (PDR correction) voxel ≥6.

= 960 mm×960 mm, 25 slices from the base of the skull to the parietal lobe, 279 frames collected at each slice to collect a total of 6,975 images and an acquisition time of 558 s.

Data processing

Image pre-processing and analysis was conducted using statistical parametric mapping software (SPM5) (Welcome Department of Imaging Neuroscience; http://www.fil.ion.ucl.ac.uk). The data for the first 9 trials were removed followed by time-alignment and head movement calibration. Then, the data were standardized to the standard template of the Montreal Neurological Institute (MNI) using SPM5. Each pixel was re-sampled to 3 mm×3 mm×3 mm. A general linear model (GLM) was used to estimate the parameters for the time series of functional images. Next, the SPM was gathered through random effects analysis. The stimulation function convolved with the hemodynamic function acted as the design matrix, which was used for parameter estimation. The parameters were subjected to statistical tests to obtain the specific t-values of each voxel. The maps of activated parameters above the selected threshold were superimposed on the T1 template of standard brains from MNI (avg152) to obtain a two-dimensional image of activation. The SPM plugin xjview (http://www.nitrc.org/projects/xjview/) was used to acquire the spatial coordinates for each activated region, the corresponding function positioning on the standard brains from MNI and the size of the activated voxels.

Statistical analysis

The obtained clinical data were processed and analyzed using the SPSS 17.0 statistical software. First, we tested the normality of each group of data. Under the premise of satisfying normal distribution, the data within the same group were tested using a two-sample t-test. Image analysis the SPM5 software was performed for individual and group analysis. In the individual analysis, the influence of head movement data produced by head movement calibration was removed. In the group analysis, the impact factors between the two groups, such as age, sex and mean whole brain signals, were removed. The statistical threshold was adjusted to $P \leq 0.05$ with voxels (cluster size) ≥10 after false discovery rate (FDR) correction to indicate statistically significant differences.

Results

Behavioral results

All participants were asked to make judgment by pressing buttons rapidly during the experiment. Reaction time (RTs) were recorded: Uyghur group varied from 438.5 ms to 862 ms with an average of 658 ms, whereas Chinese group were in the range of 425 ms to 801.5 ms with an average of 632 ms. No significant differences in RTs between these two groups were observed.

Differentially activated cerebral regions during the semantic identification task between the Uyghur group and the Chinese group

The analysis results of the one-sample t-test and the two-sample t-test are shown in **Table 2**. During the execution of the Uyghur and Chinese semantic identification tasks, the discrepancy of activated cerebral regions was primarily found in the left anterior cingulate gyrus (BA23) and the midline precuneus. The Uyghur group exhibited significant activation in these two regions, whereas the Chinese group exhibited relatively weak activation in these areas. The

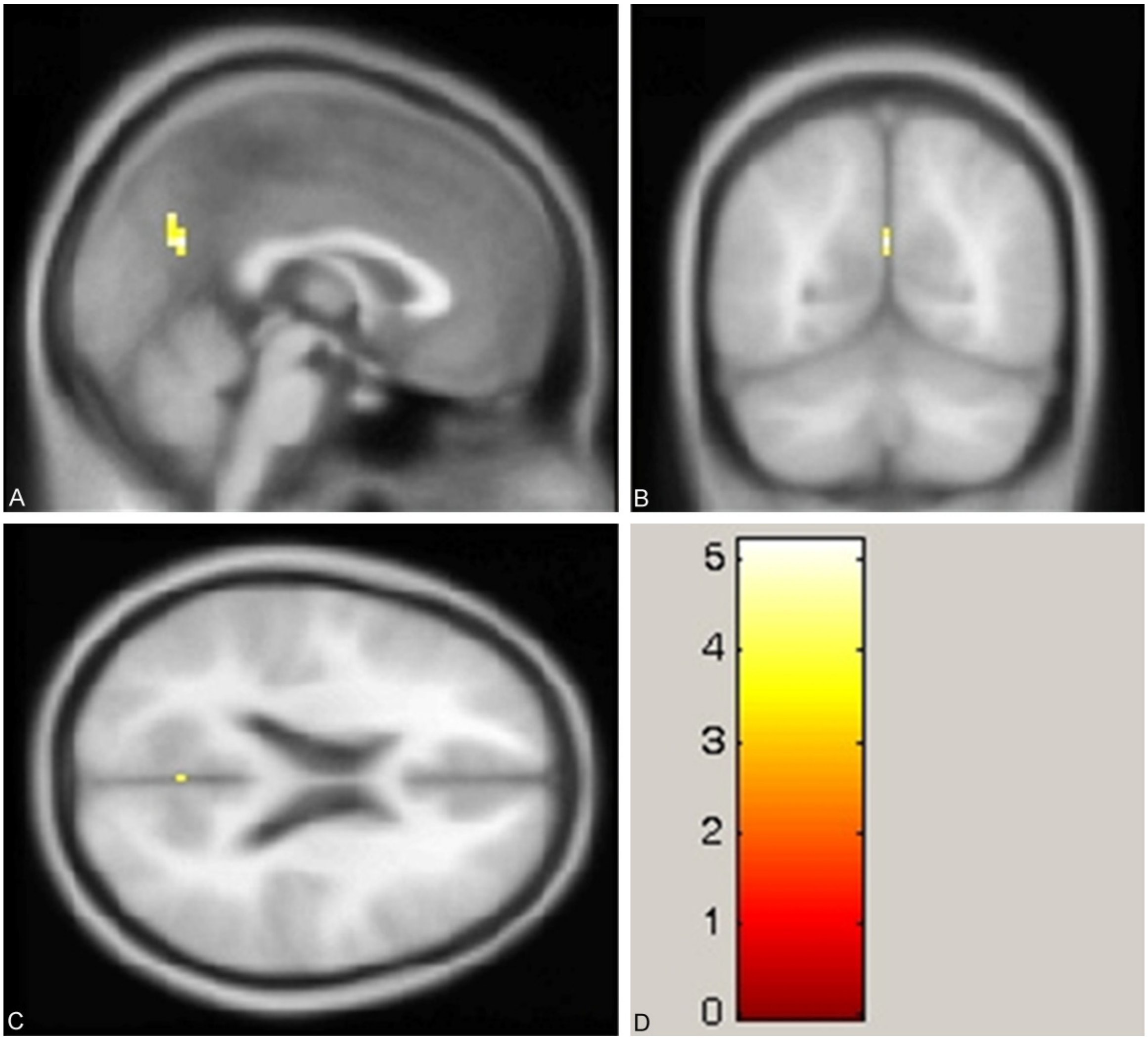

Figure 1. Differentially activated brain region during the semantic identification task-Left anterior cingulate gyrus (BA23) and the midline precuneus. A. Left anterior cingulated gyrus. B and C. Midline precuneus. D. The statistical scale of the brain regions.

difference between the two groups was statistically significant ($P<0.05$) (**Figure 1**).

Discussion

The semantic processing of words is a basic language process activity of the human brain. Compared to the functional areas related to phonetics and orthography, semantic processing activates the widest range of brain areas, which overlaps significantly with the former two language aspects [6]. In addition, fMRI studies of English and the alphabetic language system [7, 8] demonstrated that the left inferior frontal gyrus was the most important and relatively constantly activated region during semantic processing. Shan et al. [9] used auditory and visual stimulation fMRI studies and suggested that the inferior frontal gyrus, the inferior temporal gyrus and the fusiform gyrus in left hemisphere, the middle temporal gyrus and the supramarginal gyrus in right hemisphere, and the bilateral cerebellum and occipital lobe were involved in the semantic processing of Chinese characters. Chee et al. [10] reported that there was a semantic processing network for regular English words, pictures and Chinese characters, including the left inferior frontal gyrus, the middle frontal gyrus, the fusiform gyrus and the inferior temporal pole. When the participants tried to determine which two objects or Chinese characters were semantically closer, this neural network displayed activation. In this study, the brain areas activated by the semantic distinction of Uyghur and Chinese mostly overlap with the previously mentioned activated brain areas.

The results of this study indicate that multiple brain areas present various levels of activation during Uyghur and Chinese semantic discrimination task. This outcome is consistent with the conclusion of previous researches [1, 9]. The differences in activated brain areas between the two languages primarily locate in the left cingulate gyrus (BA23) and the precuneus. The Uyghur group exhibited the expansion of activated areas beyond the frontal and temporal language regions and significant positive activation in these two areas, whereas the Chinese group exhibited relatively weak activation in these two areas. The positively activated cerebral regions are the brain areas directly involved in completing the task, which indicates that the cingulate gyrus and the precuneus might have certain language functions in the semantic processing of Uyghur. Further large-sample studies should examine the specific role of these two areas in Uyghur semantic processing and the possibility of unique language centers for Uyghur.

The cingulate gyrus is an anatomical structure in the medial frontal lobe and an important part of the brain's limbic system. It incompletely wraps around the corpus callosum. Although it has been frequently mentioned in many previous studies focused on language, limited evidence of its specific language features was found. It has been reported [11] that the anterior cingulate gyrus is an important control center of attention and has the function of processing conflict, such as overcoming a set response in reaction to a novel stimulus. It is possible that activation of anterior cingulate gyrus in language tasks may be a result of attention control. Researchers [12] also found relationship between posterior cingulate gyrus and phonetics.

Unlike the pictographic Chinese characters, Uyghur consists of linear alphabetic text. In terms of the perception level, orthography has a stronger connection with semantics than phonetics in Chinese. In addition, it is difficult to directly extract phonetics from the orthography. Therefore, the Chinese stimulus tends to automatically activate semantic processing to directly extract semantic information. In the recognition of phonetic language, word pronunciation can be directly spelled out according to the lexical sub-units. In the recognition of written words, phonetic information is activated earlier than semantics. Understanding the meaning of the word is often accomplished by word pronunciation, and the phonological system automatically activates, extracts, and facilitates semantic judgments. Thus a Uyghur stimulus tends to automatically activate the phonological system or relies more on phonological processing in semantic processing. Moreover, Chinese text is written from left to right, whereas Uyghur is a phonetic language written from right to left. Therefore, this study implicated that in the semantic processing of Uyghur, the left cingulate gyrus may be more involved in phonological processing.

The precuneus is located in the medial parietal lobe. There are relatively fewer neuroimaging and neuropsychological researches on the precuneus. Recent brain-imaging studies [13] found that the precuneus was associated with many high-level cognitive functions, such as episodic memory, the processing of self-related information and various aspects of consciousness. Recent studies [14] also reported that the precuneus participated in imagination tasks related to memory and the successful retrieval of episodic memory. This role of the precuneus is consistent with the conclusion of Mechelli et al. [15], who found that imagination of objects resulted in fMRI signal enhancement in the precuneus and this activation was not associated with the type of the imagined objects. Shibata [16, 17] suggested that the activation of the precuneus was related to the imagination of objective words. Cabeza et al. [18] argued that the posterior region of the precuneus was involved in conscious short-term memory recall. Additionally, evidence has supported [19] that the precuneus was involved in visuospatial processing, and animal studies [20] found association with environmental positioning. Remarkably, this activated area locates at the midline of the precuneus instead of inside the cerebral cortex. Was the activation of this area related to language? Was it related to the semantic discrimination in Uyghur? Or was it caused by the differences in the degree of operation between the two groups of participants or other differences? These questions require further study and argument.

China has a Uyghur population of nearly ten million, and the vast majority of Uyghur population locates in Xinjiang, which providing favorable conditions for cognitive science focused on Uyghur language comprehension and generation. However, research on the Uyghur language processing mechanism remains scarce. Which brain areas are involved in Uyghur language processing? How is the neural pathway for Uyghur generation constructed and remodeled? How this pathway is intentionally selected? In addition, the localization of brain function in multilingual Uyghurs and the language transition mechanisms in bilingual and multilingual participants must be further clarified. With improvement in imaging and electrophysiological techniques and enhanced spatial resolution and time resolution, we can observe at the microscopic level how the cortex accurately completes the work when given a task. Research in this area has important clinical implications would be highly valuable in understanding language dysfunction after brain injury and brain rehabilitation mechanisms in clinical practice. Additionally, such clinical findings can provide important information with respect to revealing the universality and particularity of the language processing mechanism in the brain.

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Disclosure of conflict of interest

None.

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