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# Research of cerebral activation in Uygur-speaking and Chinese-speaking participants during verb generation task with functional magnetic resonance imaging

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**Abstract**

The aims are to investigate and compare the activated cerebral regions of Uygur-speaking and Chinese-speaking participants during verb generation task.

A total of 31 cases of Uygur and 28 cases of Han healthy volunteers were enrolled. They were requested to take verb generation tasks. Blood oxygenation level-dependent functional magnetic resonance imaging (BOLD-fMRI) was performed. The fMRI images were collected and activated brain regions were analyzed.

In Chinese-speaking participants, the main activated cerebral regions were as follows: the left caudate nucleus, the left occipital gyrus, the left fusiform gyrus, bilateral supplementary motor area (BA8/ 6), the left BA32, left precuneus, the left superior parietal lobule, the left inferior parietal lobule (BA7), the left angular gyrus, the right side of the central gyrus (BA9), the left inferior frontal gyrus triangular section, the right pars opercularis gyri frontalis inferiorista, and bilateral cerebellum. In Uygur-speaking subjects, the main activated cerebral regions included left precentral gyrus (BA9 region), inferior frontal gyrus of left opercular part, inferior frontal gyrus of left triangle part, and left cerebellum. Left caudate nucleus, left orbital frontal gyrus, right caudate nucleus, and bilateral anterior cingulate gyrus (BA32 region) of Chinese group were significantly activated compared with Uygur group. By contrast, Uygur group showed no region that was more activated than Chinese group.

The present study demonstrates that activated brain regions in verb generation tasks are different between Uygur and Chinese languages. Processing of Uygur characters is mainly in the left hemisphere of the brain, while the processing of Chinese characters needs more participation by the right hemisphere of the brain.

**Abbreviations:** BOLD-fMRI = blood oxygenation level-dependent functional magnetic resonance imaging, GLM = general linear model, GRE-EPI = gradient-echo echo-elanar imaging, MNI = Montreal Neurological Institute, SPM8 = Statistical Parametric Mapping 8.

**Keywords:** BOLD-fMRI, Chinese, Uygur, verb generation

## 1. Introduction

Studies on the mechanism of language generation are mainly focused on Indo-European languages. In China, language studies are mostly focused on the mechanism of Chinese language processing,[1–4] and studies on minority languages such as Uygur are rare.[5] Previous studies show that brain areas that are activated during language tasks in Uygur and Chinese do not overlap completely, probably due to different language characteristics of Uygur and Chinese.[6,7] Uygur language belongs to Western Xiong branch of Turkic language subfamily of Altai language family, and is alphabetic writing with linear one-dimensional array, while Chinese language is ideogram with graphic features that is composed of strokes and components in 2-dimensional array. In addition to differences in fonts, alphabetic writing and Chinese characters have different forms, sounds, and meanings. Chinese characters are a type of morphemic writings with unified forms, sounds, and meanings, while alphabetic writing records phonemes and the letters themselves do not have meanings. The reading and writing direction of Uygur is also different from Chinese language. Chinese characters are written and read from left to right, while Uygur is reversed. In addition, Chinese language is a tonal language with many homophones, but Uygur language uses the

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numbers and locations of dots to discriminate the forms of letters and many letters have different forms due to different locations of dots. In addition, the 2 languages are different in word formation.

Research on language brain processing mechanism using functional magnetic resonance imaging (fMRI) has become a hot topic in recent years. fMRI is currently the most commonly used nontraumatic brain function testing technology that can locate human brain function-related cortical areas. fMRI detects activity of neurons that is reflected by magnetic resonance signal changes, which are produced by blood oxygen level-dependent changes. fMRI is widely used in studies of language processing, aphasia injury, and recovery mechanism due to its invasiveness and high spatial resolution.[8–10] Studies on functional brain areas of verb generation in Uygur and Han people can help explore neural mechanism of language understanding and generation, and have important significance in understanding speech disorders after brain damage and its rehabilitation mechanism. In the present study, we use blood oxygenation level-dependent functional magnetic resonance imaging (BOLD-fMRI) to investigate the activated brain areas during verb generation tasks in normal Uygur and Han people.

## 2. Materials and methods

### 2.1. Subjects

A total of 59 healthy subjects were included in the present study, including 31 Uygur subjects and 28 Han subjects. Among the 31 Uygur subjects, 8 subjects were aged between 20 and 29 years, 5 subjects were aged between 30 and 39 years, 9 subjects were aged between 40 and 49 years, 7 subjects were aged between 50 to 59, 1 subject was aged between 60 and 69, and 1 subject was aged between 70 and 75; 1 subject had 3 to 6 years of education, 9 subjects had 7 to 12 years of education, 9 subjects had 13 to 15 years of education, and 12 subjects had more than 16 years of education. Among the 28 Han subjects, 9 subjects were aged between 20 and 29 years, 2 subjects were aged between 30 and 39 years, 4 subjects were aged between 40 and 49 years, 7 subjects were aged between 50 to 59, 4 subject was aged between 60 and 69, and 2 subject was aged between 70 and 75; 1 subject had 3 to 6 years of education, 13 subjects had 7 to 12 years of education, 4 subjects had 13 to 15 years of education, and 10 subjects had more than 16 years of education. The inclusion criteria were: 20 to 75 years of age and long-term use of mother language of Uygur or Chinese; education history higher than primary school; normal language ability; dextromanuality; no history of brain stroke or trauma; no severe diseases such as heart, lung, and kidney failures, and no diseases that might affect brain structure and functions such as trauma, drug intake, or alcohol dependence; no cognitive or other mental disorders; and willingness and compliance to participate in the experiments. The exclusion criteria were: sight or hearing impairments; and contraindication for magnetic resonance imaging (MRI). All the procedures were approved by the Ethics Committee of Xinjiang Medical University. Written informed consents were obtained from all participants or their families.

### 2.2. Language function test and handedness assessment

Before experiments, language function was checked, including speech fluency, spontaneous oral expression, listening comprehension, naming, reading, and reading comprehension. Handedness assessment was performed using standard Chinese version of handedness assessment scale. All were right-handed. Although fluency and reading were significantly different between Chinese and Uygur groups, the 2 were not considered comparable due to the differences in language characteristics. Other data and language functions were not significantly different between the 2 groups (Table 1).

### 2.3. Experimental tasks

Test tasks were performed in the way of visual presentation and excitation mode was block design paradigm. In the function scanning process, excited state and resting state were alternated. The initial 18 seconds was scanned as baseline, followed by 9 times of block sequences. First, a noun word was displayed in the center of screen for 2 seconds, and the subject stared at the "+" sign in the center of the screen. In the meantime, the subject was asked to think about a 2-character verb that was connected with this noun within 3 seconds. During the 30 seconds of excitation state, the 2 states were presented alternatively for 6 times, followed by 30 seconds of resting state. Chinese language was used in Chinese group, while Uygur was used in Uygur group, with the same content. Before the test, all the subjects participated in simulation training to get familiar with the whole process. The subjects took supine position, and a sponge was used to fill the gap between head and coil. During the test process, the subjects were told to keep their bodies and heads still and stare at the center of the screen. The subjects were asked to complete tasks in silent reading mode. After completing the tests, the subjects were asked to report their emotional states in magnetic environment, and to remember the execution states during the test.

### 2.4. MRI

MRI measurement was performed after all other tests in the end. GE signa 3.0 T superconducting magnetic resonance instrument scanning system was used to collect images (GE Healthcare, Little Chalfont, UK), and 8-channel head coils were used to receive the signals. First, the sequences were scanned using a 3D thin layer to

**Table 1**

**General information and language function check.**

| | Gender (no. of cases) | | | | | Language function check (M; Q) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Groups | Male | Female | Age (y; M/Q) | Education (y; M/Q) | Fluency (characters/min; M / Q) | Listening comprehension (%; M/Q) | Naming (%, M/Q) | Repeating (%, M/Q) | Reading (characters/min; M/Q) | Reading comprehension (%, M/Q) |
| Han | 17 | 11 | 49/36 | 13.5 / 7 | 119/41 | 96.9/4 | 98.7/3 | 97.9/3 | 222/58 | 97.6/4 |
| Uygur | 16 | 15 | 41/26 | 15/4 | 74/21 | 97.5/3 | 98.9/2 | 97.5/2 | 139/25 | 96/4 |
| *P* value | .48 | | .25 | .26 | $P<.01$ | .48 | .19 | .96 | $P<.01$ | .16 |

Note: $P<.05$ indicates statistical significance.
M = median, Q = interquartile.

obtain T1-weighted images of head transverse plane. The scanning parameters were: TR 550 ms, TE 67 ms, layer thickness 1.0 mm, gapless, visual field 240 mm × 240 mm, matrix 320 mm × 192 mm, and 136 layers from skull base to parietal lobe. Then, gradient-echo echo-planar imaging (GRE-EPI) sequences were used to collect the data of BOLD signals. The scanning parameters were: TR 2000 ms, TE 30 ms, layer thickness 5.0 mm, gapless, flip angle 90°, visual field 240 mm × 240 mm, matrix 960 mm × 960 mm, and 25 layers from skull base to parietal lobe. Then, 279 frames were sampled in each layer, and a total of 6975 frames were collected in 558 seconds.

### 2.5. Data processing

Images were preprocessed and analyzed using statistical parametric mapping 8 (SPM8; http://www.fil.ion.ucl.ac.uk/spm/software/spm8/). First, data at initial 9 time points were excluded. After time layer correction and head correction, data were standardized to Montreal Neurological Institute (MNI) templates. Each pixel was sampled at 3 mm × 3 mm × 3 mm, and subjected to spatial smoothing. Individual data analysis was performed using general linear model (GLM). After parameter estimation of design matrix of excitation patterns, statistical examination was performed to obtain the statistical parametric map and t values of each voxel. After overlapping the activated parametric map with MNI standard brain T1 template, the activation plot was obtained. SPM plug-ins were used to obtain the coordinates of each activated region, which corresponded to MNI standard brain functional positions and the size of activated voxels.

### 2.6. Statistical analysis

The results were analyzed using SPM8 software. Before *t* test, K to S test was performed to check the normality of our data. Intragroup comparison was performed using single sample *t* test. Statistical threshold with $P < .05$ (familywise error correction) was considered for statistical significance. Intergroup comparison between Uygur and Chinese groups was carried out using double sample *t* test. Statistical threshold with $P < .01$ (Alphasim correction) was considered for statistical significance if activated volume was larger than 20 voxels. Finally, the activation plots and difference plots were overlapped on MNI template, and area sizes, brain region, coordinate, and *t* value with statistical significance were recorded.

## 3. Results

### 3.1. Activated regions in the brain for Chinese language group

To identify the activated regions in the brain of Chinese group, fMRI was carried out. The activated region of Chinese group included left caudate nucleus, left inferior occipital gyrus, left fusiform gyrus, bilateral cerebellum, bilateral supplementary motor area (BA8/6 region), left BA32 region, left praecuneus, left superior parietal lobule, left inferior parietal lobule (BA7 region), left angular gyrus, right precentral gyrus (BA9 region), inferior frontal gyrus of left triangle part, and inferior frontal gyrus of right opercular part (Fig. 1, Table 2).

### 3.2. The activated brain regions of Uygur group have left hemisphere structure, with obvious laterality

To identify the activated regions in the brain of Uygur group, fMRI was used. The activated region of Uygur group included left precentral gyrus (BA9 region), inferior frontal gyrus of left opercular part, inferior frontal gyrus of left triangle part, and left cerebellum (Fig. 2, Table 3). The result indicates that the activated brain regions of Uygur group have left hemisphere structure, with obvious laterality.

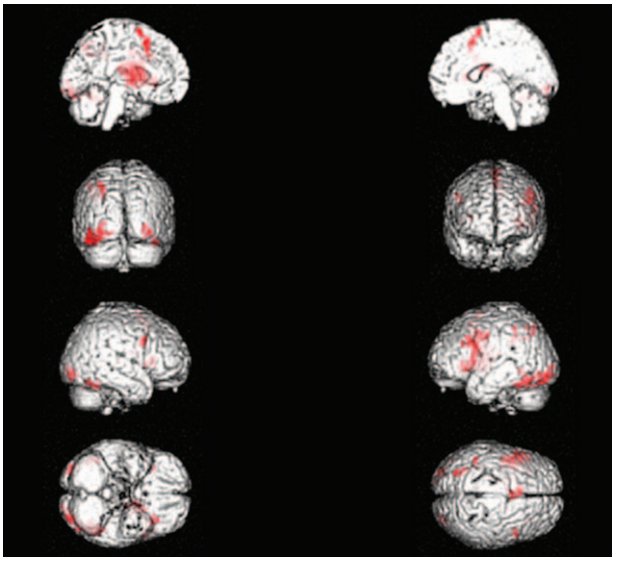

**Figure 1.** Activated brain MRI of Chinese group. GE signa 3.0 T superconducting magnetic resonance instrument scanning system was used to collect images (GE Healthcare, Little Chalfont, UK), and 8-channel head coils were used to receive the signals. The images were preprocessed and analyzed using statistical parametric mapping 8 (http://www.fil.ion.ucl.ac.uk/spm/software/spm8/). MRI = magnetic resonance imaging.

### 3.3. The activated brain regions of Uygur group are fewer than those of Chinese group

To identify the differences in activated regions between Chinese and Uygur groups, the 2 images were overlapped. The data showed that left caudate nucleus, left orbital frontal gyrus, right caudate nucleus, and bilateral anterior cingulate gyrus (BA32 region) of Chinese group were significantly activated compared with Uygur group ($P < .05$) (Fig. 3, Table 4). By contrast, Uygur group showed no region that was more activated than Chinese group. The result suggests that the activated brain regions of Uygur group are fewer than those of Chinese group.

## 4. Discussion

The present study shows that Broca region, left inferior parietal lobule, bilateral cerebellum, and bilateral supplementary motor area in Chinese group are activated, being consistent with previous studies.[11,12] Broca region is closely related to motor language, speech and semantics, and is an important region responsible for word storage and extraction.[13] Left inferior parietal lobule is part of Wernicke region, and is important for semantic understanding. Chen et al[11] report that left inferior parietal lobule participates in visual search, spatial attention, and linguistic working memory in motor language. In the present study, bilateral cerebellums are activated and the activated region in left cerebellum is larger than that in right cerebellum, being consistent with the study by Xiao and Zhai.[14] This suggests that both cerebellums participate in language processing. It is also

**Table 2**

**Activated brain region in Chinese group.**

| Activated brain region | Voxels | *t* value | *P* | MNI coordinate (mm; x/y/z) |
|---|---|---|---|---|
| Left caudate nucleus | 782 | 9.38 | <.05 | −15/−3/21 |
| Left inferior occipital gyrus | 250 | 8.75 | <.05 | −30/−87/−9 |
| Left fusiform gyrus | 250 | 8.72 | <.05 | −30/−81/−18 |
| Left cerebellum | 250 | 8.44 | <.05 | −36/−60/−21 |
| Left supplementary motor area (BA8 region) | 113 | 8.11 | <.05 | ¯3/15/51 |
| Left BA32 region | 113 | 6.97 | <.05 | −12/15/36 |
| Right supplementary motor area (BA6 region) | 113 | 6.84 | <.05 | 3/6/66 |
| Left praecune | 70 | 7.83 | <.05 | −27/−63/39 |
| Left superior parietal lobule (BA7 region) | 70 | 7.24 | <.05 | −30/−60/51 |
| Left angular gyrus | 70 | 6.56 | <.05 | −30/−54/36 |
| Left parietal gyrus | 43 | 7.67 | <.05 | −42/−45/42 |
| Left inferior parietal lobule | 43 | 7.23 | <.05 | −39/−39/33 |
| Right anterior central gyrus (BA9 region) | 38 | 8.09 | <.05 | 51/9/33 |
| Inferior frontal gyrus of left triangular part | 34 | 8.29 | <.05 | 33/24/9 |
| Inferior frontal gyrus of right opercular part | 34 | 7.26 | <.05 | 48/12/3 |
| Right cerebellum | 24 | 8.54 | <.05 | 9/−84/−24 |
| Right cerebellum | 24 | 7.98 | <.05 | 33/−78/−27 |
| Right cerebellum | 24 | 7.21 | <.05 | 21/−84/−24 |

Note: statistical level, $P < .05$ (PDR correction). No. of voxels > 20.
MNI = Montreal Neurological Institute.

reported that cerebellar lesions lead to impaired language fluency, dysgrammatisum, impaired speech and comprehension, and Verb generation disorder.[15] Lin and Weng[16] argue that bilateral cerebellums are not directly related to actual movements, but are activated during imagination of movements.

The present study shows that the activated brain region in the Uygur group is left hemisphere structure. Ibrahim and Eviatar[17] discover that left visual field is not sensitive to Arabian writing, suggesting that the right hemisphere does not participate in the recognition of Arabian writing. Consistent with this report, the result of the present study shows that identification of Uygur letters and recognition and extraction of Uygur words are mainly based on left hemisphere, being similar with Arabian writing. The present study also shows that Broca region, left cerebellum, and left precentral gyrus in Uygur group are activated. Most of the Uygur words are compound words, and Uygur is more complex than phonetic writing of other languages. A study on English and other phonetic languages shows that Broca region is activated in verb generation tasks, suggesting that Broca region participates in semantic analysis, as well as the reading of phonetic writing.[18] Mohammad et al discover that Broca region participates in phonological and semantic processing,[19–22] being consistent with our results. Another study shows that left cerebellum is mainly related to word morphological processing, and grammatical disorder and expression-acceptance syndrome may occur after left cerebellum damage.[23] Uygur writing has special morphological characteristics, and left cerebellum may play important roles in the morphological processing of Uygur language.

The present study shows that left orbital frontal gyrus, right caudate nucleus, bilateral anterior cingulate gyrus, and left caudate nucleus of Chinese group are more activated than Uygur group. Left orbital frontal gyrus participates in working

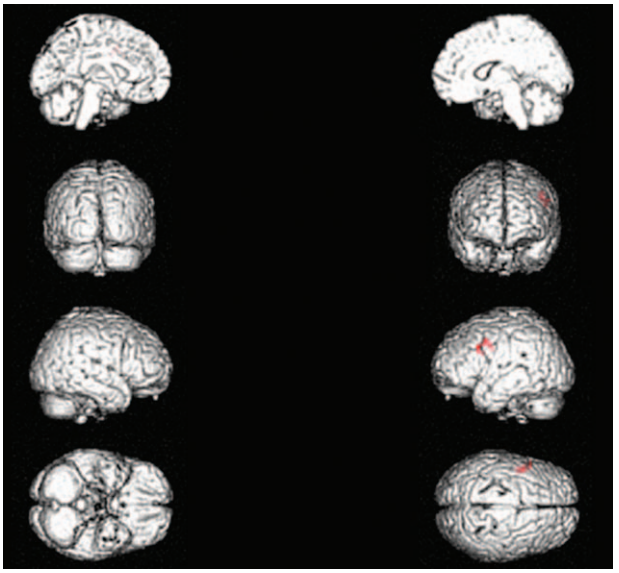

**Figure 2.** Activated brain MRI of Uygur group. GE signa 3.0 T superconducting magnetic resonance instrument scanning system was used to collect images (GE Healthcare, Little Chalfont, UK), and 8-channel head coils were used to receive the signals. The images were preprocessed and analyzed using statistical parametric mapping 8 (http://www.fil.ion.ucl.ac.uk/spm/software/spm8/). MRI = magnetic resonance imaging.

**Table 3**

**Activated brain region in Uygur group.**

| Activated brain region | Voxels | T value | *P* | MNI coordinate (mm; x/y/z) |
|---|---|---|---|---|
| Left precentral gyrus (BA9 region) | 44 | 7.66 | <.05 | −45/6/39 |
| Inferior frontal gyrus of left triangular part | 44 | 6.5 | <.05 | −51/15/30 |
| Inferior frontal gyrus of right opercular part | 44 | 6 | <.05 | −51/9/24 |
| Left cerebellum | 23 | 7.19 | <.05 | −42/−63/−21 |
| Left cerebellum | 23 | 6.12 | <.05 | −39/−75/−21 |

Note: statistical level, $P < .05$ (PDR correction). No. of voxels > 20.
MNI = Montreal Neurological Institute.

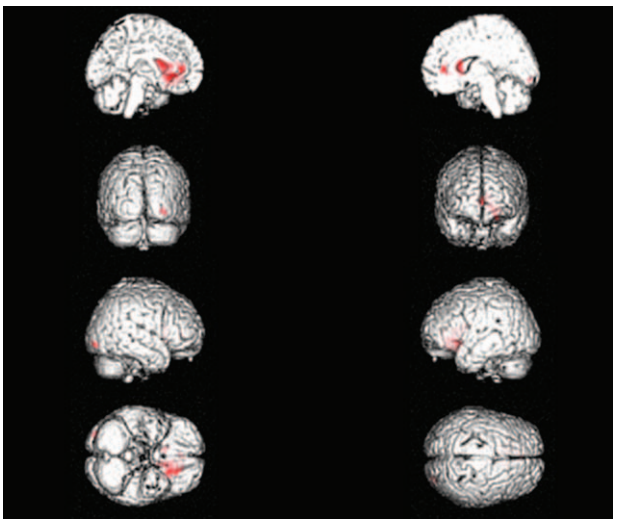

**Figure 3.** Differentially activated brain region of Chinese and Uygur groups. GE signa 3.0 T superconducting magnetic resonance instrument scanning system was used to collect images (GE Healthcare, Little Chalfont, UK), and 8-channel head coils were used to receive the signals. The images were preprocessed and analyzed using statistical parametric mapping 8 (http://www.fil.ion.ucl.ac.uk/spm/software/spm8/).

memory,[24] and has selective attention function, being responsible for endogenous orientation in directed networks.[25] Nouns and verbs in Uygur language can be mutually transformed by change of forms, but nouns and verbs in Chinese language cannot be mutually transformed by directly changing the forms. In addition, gerunds and nouns in Uygur language have close morphological and semantic connections, but verbs in Chinese language are distinct from nouns in both morphology and semantics. Therefore, transformation between verbs and nouns in Chinese language is more complex than that in Uygur language. There are few reports on the language functions of right caudate nucleus and right cingulate gyrus (BA32 region). Li et al[26] report that right cingulate gyrus (BA32 region) is activated in reading and semantic discrimination of Chinese characters. The recognition of Chinese characters is related to extensive central nervous system and may need to activate larger areas of right hemisphere. However, whether right caudate nucleus and right cingulate gyrus participate in the recognition of Chinese characters still needs further studies. The present study shows that left caudate nucleus and left anterior cingulate gyrus are activated in Chinese group, being consistent with the report by Zhang et al.[12] Gao et al[27] report that left caudate nucleus and left anterior cingulate gyrus are both activated in speech and semantic tasks in Chinese language, but are neither activated in character tasks. Zhang et al[12] believe that left caudate nucleus is a node in motor language function network. In addition, bleeding in left caudate nucleus can lead to speech disorder and amnesia.[28] Previous study shows that left inferior temporal gyrus (BA37), inferior parietal lobule, fusiform gyrus, and parahippocampal gyrus in Uygur group are activated in contrast to Chinese group.[7] However, no activated regions are observed in Uygur group in comparison to Chinese group. This may be because of different sample size, different statistical threshold, or different age and education levels. The activated brain regions in Uygur group in the present study include Broca region, left precentral gyrus, and left cerebellum, with similar regions but smaller area compared with Persian, Hebrew, and Arabian.[19–22,29] The reasons for this may be: different statistical threshold; most Uygur verbs are compounded from verb roots and nonverbs; the extraction of sound and meaning from Uygur words is slower than Chinese language, leading to smaller activated brain region in Uygur group. In conclusion, activated brain regions in verb generation tasks are different between Uygur and Chinese languages. Processing of Uygur characters is mainly in the left hemisphere of brain, while processing of Chinese characters needs more participation by the right hemisphere of brain.

**Table 4**

**Differentially activated brain region in Chinese and Uygur groups.**

| Differentially activated regions (Chinese > Uygur) | Voxel | T value | *P* | MNI coordinate (mm; x/y/z) |
|---|---|---|---|---|
| Left caudate nucleus | 291 | 4.94 | <.05 | −9/12/12 |
| Left orbital frontal gyrus | 291 | 4.35 | <.05 | −18/30/−15 |
| Right caudate nucleus | 44 | 3.95 | <.05 | 9/12/3 |
| Right anterior cingulate gyrus (BA32 region) | 39 | 4.28 | <.05 | 3/39/6 |
| Left anterior cingulate gyrus | 39 | 3.67 | <.05 | −6/36/12 |

Note: statistical level, $P < .05$ (PDR correction). No. of voxels > 20.
MNI = Montreal Neurological Institute.

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