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Auditory cerebral activation patterns of Chinese English learners by fMRI

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【Abstract】 *Objective*: To identify the cerebral activation patterns associated with the processes that occur during viewing Chinese and English words in native Chinese English learners. *Methods*: 12 right-handed Chinese English learners were divided into two groups equally, namely English majors and non-English majors, and took semantic judgement tasks of both English and Chinese words, for whom the fMRI images were collected. *Results*: To various degrees, all subjects demonstrated activation of associated cerebral regions in both hemispheres and the left hemisphere activation was more significant for most subjects. Except for classical regions involved in language processing, such as Wernicke areas and Broca areas, there were other activated cerebral regions, including cerebellum, limbic system and basal ganglia nucleus, etc. To sum up, there were apparent overlap for cerebral activation distribution and no specific processing areas for both tasks. The analysis of ROI (region of interest) suggested that subjects in specialized group were more dependent on right hemisphere to perform English words task. *Conclusion*: Language cognition is dominated by left hemisphere, which is also shared by the right hemisphere to various degrees and thus two hemispheres work by ways of both dissociation and coordination. It is possible that working strategy of the right hemisphere in English task is related to proficiency of the second language. A variety of distinctions are shared by each subject for language cognitive patterns.

【Key words】 English Learners; Functional magnetic resonance imaging (fMRI); Dominance; Cerebral activation patterns
【Document code】 A

1 Introduction

The linguistic study is of much significance in apprehending advanced cognitive activity of human beings. Problems such as virulence, traumatic occlusion and weak precision have been found by means of Wada test [1], destroy cases, neural electrophysiology or PET technique and so on, which have been traditionally adopted to study linguistics. Functional magnetic resonance imaging(fMRI) is based on combing the neural activity with high resolution magnetic resonance imaging, so fMRI is the study method which can locate human cerebrum senior cortex activity center precisely in living organism[2,3] and it has been mastered by human beings now. Since Belliveau [4] and other scholars utilized MRI to study visual cortex for the first time in 1991, fMRI has been widely used in linguistic studies.

Bilingual study is one of the hottest issues in linguistics. Currently, it mainly concerns the differences and similarities of distribution mode of bilingual activated cerebral regions, and the working strategy (participation extent) of right hemisphere when L2 is processed. Chinese, as an ideographic language, has complicated 2-dimen tional structures. Unlike such alphabetic languages as English, the s peech sound, in Chinese, cannot be abstracted from its form. The association of sound and form is wea ker than that of form and meaning [5]. This discrepancy may give rise to different activation modes of ce rebral regions. Using functional magnetic resonance imaging, the experiment adopted auditory stimulation, which is less used by other experiments possibly because

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the discrepancy of visual perception between Chinese and English is to be avoided, and took semantic judgment tasks of both Chinese and English words in order to explore the cerebral activation patterns of Chinese English Learners, learn the distribution of relevant cortex activity center and know the working strategy of both two hemispheres, from whom the fMRI images were collected.

2 Methods and materials

2.1 Subjects

The participants were 12 healthy, right-handed, native Chinese English Learners, with ages ranging f rom 21 to 40 years old. They were divided into two groups: English majors group and non-English majors group. English major group(3 males and 3 females) had 5 English-major undergraduates with TEM8(TEST FOR ENGLISH MAJORS, BAND 8) certifi cates and 1 college English teacher. Non-English majors group(4 males and 2 females) were com prised of medical gra duates with CET6(COLLEGE ENGLISH TEST, BAND 6)certificates. All subjects, Chinese English Learners, were confirmed right-han dedness with Standard Table Investigation and had studied English in junior middle school. All subjects didn't have history of nervous disease and mental disease and had normal hearing and were cooperative voluntarily.

2.2 Design Method: block design

This experiment adopted auditory stimulation. There were Chinese characters task and English words task, in which the subjects were required to listen attentively and to try to apprehend the meani ngs. Each task was implemented for 4 minutes with 12 blocks. Each block lasted 20 seconds. For each block of linguistic task, an English word or a Chinese Character was broadcast. High-frequency, substantive, and two-character words were selected from Dictionary of Modern Chinese Frequency, and High-frequency and substantive English words were selected from New Concept English. All the linguistic materials were recorded in computer in advance and were broadcast by magnetic resonance audio system according to designed scheme. Passively listening to the rhythm of scanning of fMRI served as the baseline control task. A series of functional MR images were collected while linguistic and baseline control tasks were alternately broadcast as follows: baseline-English word-baseli ne-English word, or baseline-Chinese character-bas e-line-Chinese character.

2.3 Functional Imaging

The experiment collected images on the GE Signa Highspeed MR/i 1.5T superconducting MRI machine of Chongqing Medical University. T1WI anatomical images were collected with a Fast Spinning Echo (FSE)sequence (TR=2 000ms, TE=12ms, FOV=24×18, slice thickness=8mm, gap=2mm, matrix 256×256). Blood oxygenation level dependent (BO LD) functional images were then acquired with a single shot Plane Echo List (EPI)sequence (TR= 4 000ms, TE=60ms, FOV 24×24, slice thickness=8mm, gap=2mm, matrix 64×64cm). A total of 512 images were acquired in each of them.

2.4 Data analysis

Data analysis was performed using Functool software. The functional images were registered to the 3D structural images and normalized according to the standard coordinates defined by Talairach and Tournoux atlas so as to check and correct for motion artifacts or variance in the sizes of cerebrum. The reference waveform (6 square waves)was made according to the series of the linguistic tasks, and the comparative analysis was performed between the time-intensity curves and the reference waveform at every pixel. Pixels meeting or exceeding a correlation coefficient of 0.4 (r=0.4, P<0.01)were considered as reliably associated with the linguistic tasks. The activated pixels were finally superimposed on the anatomical images to produce th e activation maps.

3 Results

3.1 The distribution mode of activated cerebral regions

In both Chinese and English tasks, all subjects demonstrated significant activation of associated cere bral regions (Picture 1, 2, 3, 4).

Hearing cortex and temporal lobe: almost all subjects demonstrated activation of both superior temporal gyrus (Brodmann41/42/22)and middle temporal gyrus(Brodmann21) and the majority demonstrated activation of inferior temporal gyrus(Brodmann20).

Traditional language zone: there were activated cerebral regions in the posterior part of the left inferior frontal gyrus (Brodmann44/45), the posterior part of superior temporal gyrus (Wernicke area), the angular gyrus of inferior parietal lobule and the supramarginal gyrus(Brodmann39/40).

Other related cerebral regions: different subjects demonstrated activation of both superior frontal gyrus(Brodmann9/10), middle frontal gyrus(Brodmann46), inferior frontal gyrus, precentral and gyruspostcentral gyrus(Brodmann4/3.1.2), superior p arietal lobule (Brodmann7), hippocampus, parahippo campal gyrus, insular lobe, cingulate gyrus (Brodma nn24/32/31), amygdaloid body, occipito-temporal ju nction(Brodmann37),

occipital lobe corpus striation periphery, parastriate area (Brodmann18/19) and so on.

A few subjects demonstrated activation of cerebellum, cerebral ganglion, caudate nucleus and so on.

3.2 Analysis of ROI(regions of interest)

We chose bilateral superior temporal gyrus and middle temporal gyrus as the regions of inter est and determined their voxels. The relative ratios of voxels of right ROI to that of bilateral ROI were calculated when the subjects took the Chinese and English tasks respectively.

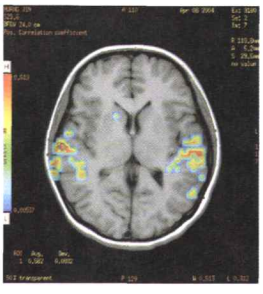


Fig.1. The cerebral activation mode distribution of one subject of non-English major, fromwhich it could be observed that superior temporalgyrus and middle temporal gyrus and right caudatenucleus were activated when the subject took the Chinese words task

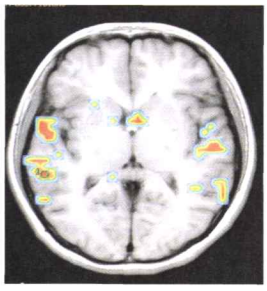


Fig.2. The cerebral activation mode distributionof one subject of non-English major, from which it could be observed that superior temporal gyrus and middle temporal gyrus and basal gangliawere activated when the subject took the English words task.

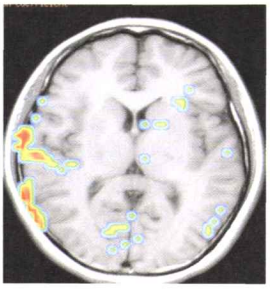


Fig.3. It was the cerebral activation mode distributionof one subject of English major when the subjecttook Chinese words task

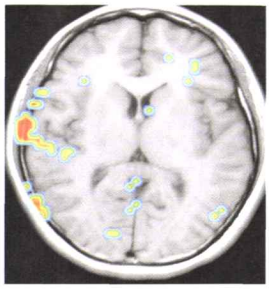


Fig.4. The cerebral activation mode distributiono f one subject of English major, from which it could be observed right majoritycerebral mode were activated, especially the temporal region and less left cerebra l modewere activated when the subject took English words task

Table 1. Voxel percentages of the right hemisphere ROI of non-English majo

Subject number	1	2	3	4	5	6
Chinese task	47.27%	41.90%	42.00%	56.91%	48.13%	45.28%
English task	41.51%	39.11%	33.79%	53.26%	60.30%	35.24%
Chinese/English	0.89	0.93	0.81	0.93	1.25	0.77

Table 2. Voxel percentages of the right hemisphere ROI of English major

Subject number	1	2	3	4	5	6
Chinese task	38.95%	50.00%	33.51%	22.45%	75.00%	18.42%
English task	34.44%	54.71%	41.85%	17.85%	81.95%	50.00%
Chinese/English	0.87	1.10	1.24	0.82	1.09	2.77

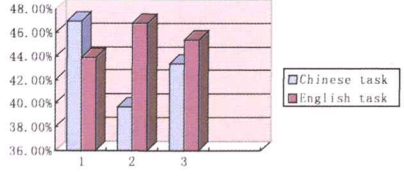


Fig.5. The average voxel percentage of right hemisphere ROI 1. non-English major 2. English major 3. overall

The tables and the chart above demon strate: 1. left hemisphere was the dominant hemisphere when the majority subjects took Chinese words and English words tasks.2.The subjects of non-English major showed greater voxel percentage of right ROI when they took Chinese words tasks than when they did English words tasks.3.The subjects of English major showed lower voxel percentage of right ROI when they took Chinese words tasks than when they did English words tasks. 4.On balance, all subjects showed lower voxel per-

centage of right ROI when they took Chinese words tasks than when they did English words tasks,but there was significant difference between the English major group and the non-English major group.

4 Discussion

The preliminary analysis of distribution modes of activated cerebral regions in the experiment showed that no exclusive cerebral region had been found either in the processing of Chinese words ta sk or in the processing of English words task, that most cerebral regions related to the phonological and semantic processing were activated,and that subjects have great individual differences in distribution modes of activated cerebral regions. Generally, there was no significant difference in the distribution modes of activated cerebral regions when subjects of either English major or non-English major took both Chinese and English words tasks. The result may be attribute to the experiment using auditory stimulation, in which auditory-related regions are activated by auditory pathway,thus avoiding the the different mechanism of activation patterns caused by the visual difference between Chinese and English writing systems. Also,the simplicity of the demanded tasks may not disclose the diff erence of the underlying processing mechanism of both Chinese and English linguistic tasks. Still pro bably,it can be ascribed to small sample size, or no difference of distribution modes of activated cere bral regions when Chinese and English linguistic ta sks were taken.

Almost all subjects demonstrated activation of bilateral superior temporal gyrus and middle temporal gyrus, which areas are of great importance in the auditory information processing,and the left of which areas are of greater importance in phonetic translation,self-regulation and information exchange between the cerebral hemispheres[6]. Phonetic analysis is done on the left superior temporal gyrus [7,8,9] (Brodmann 22), the back of which is Wernicke area. Pitch and tone are perceived and analyzed on the right superior temporal gyrus [10,11]. The activation of bilateral temporal regions corre sponds to the auditory stimulation we adopted. Meanwhile, semantic judgment is accompanied with autonomous phonetic activation. This result has something in common with "universal speech sound"[12]. Many subjects demonstrated activation of frontal lobe, especially middle frontal gyrus and inferior frontal gyrus (Brodmann 44/45/46),includ ing gyri and medial frontal gyrus. Broca area in the left inferior frontal gyrus (Brodmann44/45)is involved in the language production and middle frontal gyrus (Brodmann 46) is involved in the processing of attention and wor king memory. Some subjects demonstrated activation of inferior parietal lobules (Brodmann 39/40,including supramarginal gyrus and angular gyrus.),which area,as literature reported,was related with phonetic storage and working memory [13,14]. Subjects demonstrated activation of occipital lobe Corpus Striatum periphery (Brodmann18/19),which area was related with visual association. A phenomenon worthy of no ticing was that subjects demonstrated significant activation of cerebral cortical affiliated regions,such as medial gyrus of occipital lobe and temporal lobe,junctional zone of temporal lobe and parietal lobe(Brodmann40/39/22)and so on, which areas had relation with integration of versatile sensory information (e.g. visual sense,audition,somatic sensation). Although there was mere auditory stimulation, many other related regions played a part in the cognitive process of linguistic tasks in the experiment in varying degrees as a result of integrity and coordination of brain activation. The activation of cerebral regions mentioned above prompted that there were other activated cerebral regions in different degrees except for classical regions involved in language processing,such as Wernicke area and Broca area.

It was found that several cerebral regions were activated,which areas had little relation with linguistic cognition in classical theory. One obvious phenomenon was that many subjects demonstrated activation of basal ganglia (such as cerebral ganglion,caudate nucleus),limbic system (such as hippocampus,parahippocampal gyrus,cingulate gyrus, amygdaloid body)and insular lobe, as well as cerebellums. In the experiment,some subjects reported that they were prone to read or to read silently wh en listening to words. Cerebellum and thalamus pla yed a part in the planning and programming of vo luntary activity [15]. Limbic system had relation with human emotion (anxiety, tension and fear),motivation, attention,and so on, and all these factors participated in and affected cognition. Therefore,limbic system was supposed to be activated on the ground that some subjects showed slight fear and anxiety. It was possible that hippocampus,parahippocampal gyrus,cingulate gyrus had relation with working me mory of linguistic cognition. The activation of cerebr al regions, on the one hand,probably has relation with the intrinsic processing mechanism of individuals in linguistic cognition,and reflects the profound complexity and diversity of cognitive activities of hu man beings.

The analysis of ROI showed some common characters.To sum up,12 subjects demonstrated greater extent of participation of right cerebrum wh en they took English words task

than they did Ch inese words task. However, there was difference between subjects of English major and those of non-English major. In the non-English majors group, 5 subjects out of 6 demonstrated lower extent of participation of right cerebrum when they took English words task than they did Chinese words task and the result of the exceptional subject may be accounted for by his proficiency in English. While in the English majors group, 4 subjects out of 6 de monstrated greater extent of participation of right cerebrum when they took English words task than they did Chinese words task. So did all subjects (including one subject who had obvious right dominant hemisphere). Contingency or necessity? Sma ller sample size or criterion of measurement (ROI voxel percentage of right cerebrum)? Further research has yet to be done before conclusions are made.

One more noticeable phenomenon was that subjects with better apprehension (in either Chinese or English words task) demonstrated more aggregated activation of cerebral regions and lower voxel percentage, and vice versa. The reason may result from the transformation between declarative memory and non-declarative memory (reflective memory)[16]. Linguistically competent subjects may be adept at reflective memory in the specification and abstraction of phonetic and semantic representation of memory so that relatively fewer but more aggregated cerebral regions were activated. By contrast, some other subjects, to some extent, depended more on abstraction of representation of declarative memory, involved more active and subjective awareness, and to ok up more cerebral resources. As a result, the activation of related cerebral regions was relatively sca ttered and diffused.

The sample size was small; there was uncontrollability of certain variables; fMRI is not full-blo wn technically; and human linguistic cognition is of profound complexity. Herein, the conclusions which have so far made needed to be further verified. The gradual perfection of fMRI, and the flourishing development of cognitive psychology, integrated with such electrophysiological techniques as EEG, ERP, PETMEG and NIRSand ingenious experimental design of praxiology, will shed light on and open a broad window to human cognition.

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