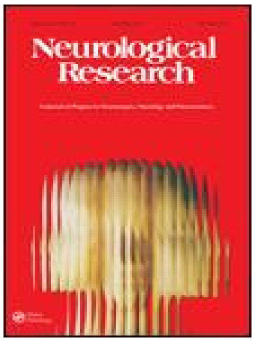

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Magnetoencephalography of language: new approaches to understanding the cortical organization of Chinese processing

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Objective: Chinese is a logographic language. Many of its psycholinguistic characteristics differ from those of alphabetic languages. These differences might be expected to entail a different pattern of neural activity underpinning Chinese language processing compared to the processing of alphabetic languages. The aim of the current study was to investigate neural language centers for processing Chinese language information in healthy Chinese speakers using magnetoencephalography (MEG). Overall, we aimed to elucidate language-specific and language-general characteristics of processing across different language scripts.

Methods: Ten healthy Chinese-speaking subjects were asked to silently read genuine Chinese characters and view pseudo-characters in a MEG scanner. The functional language areas were located by overlapping the MEG results over magnetic resonance imaging (MRI) images.

Results: Distinctive late magnetic response waves were observed in both hemispheres while the subjects were reading genuine Chinese characters. The polarization of the response waveforms was found to be greater in the left than the right hemisphere. Broca's area was found to be located at the back of gyrus frontalis inferior or gyrus frontalis medius. Wernicke's area was located at gyrus temporalis medius, gyrus temporalis superior and gyrus supramariginalis. In addition, Wernicke's area was activated earlier than Broca's area.

Conclusion: Native Chinese speakers reading Chinese characters showed neural responses that were lateralized to the left hemisphere. Overall, the functional brain areas activated by reading Chinese in this study corresponded to classical language centers found for alphabetic languages in previous studies, but some differences were also found in the specific patterns of activation.

Keywords: Chinese, language processing brain areas, MEG

Introduction

The use of structural and functional brain imaging in conjunction has provided a new avenue for examining the neural basis of cognitive functions. There are presently at least five methods that can be used to localize the functional areas related with language processing. These include magnetoencephalography (MEG), functional magnetic resonance imaging (fMRI), positron emission tomography, single photon emission computed tomography and transcutaneous magnetic stimulation. MEG has high temporal resolution (to the millisecond) as well as high spatial resolution. These features make it an appropriate technique for accurately localizing functional language areas in the brain. As a result, MEG has become one of the most efficient brain-imaging and neuronavigating approaches in the localization of the neural substrates of language[1,2].

Chinese, a typical logographic, non-alphabetic language, has many characteristics that distinguish it from alphabetic languages (e.g. English, Italian). For example, Chinese is a 'tonal' language, in which a syllable (e.g. /*ba2*/) consists of onset (/*b*/), rime (/*a*/) and tone (/*2*/). In the Mandarin language, there are 21 separate onsets, 35 rimes and four tones. Tones allow the disambiguation of syllables that share identical onsets and rimes. The basic reading unit in Chinese is the character (e.g. 拔). A character usually corresponds to a syllable in sound (/*ba2*/) and a morpheme in meaning (pull out). There is, however, no direct segmental correspondence between character and syllable; some morphemes (e.g. 蚂蚁, /*ma3yi3*/, ant) are composed of multiple characters (蚂 and 蚁). Furthermore, most Chinese characters (~80%; e.g. 打, /*da3*/, to beat) have a semantic radical (e.g. 扌, to

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Table 1 Demographic data of the volunteers

Case	Gender	Age (years)	Degree
1	Male	28	Bachelor
2	Female	31	Bachelor
3	Male	37	Bachelor
4	Female	33	Bachelor
5	Female	35	Master
6	Male	30	Doctor
7	Female	29	Master
8	Male	28	Bachelor
9	Male	30	Master
10	Male	36	Bachelor

From *Table 1*, we can saw that there are six males and four females, aged between 28 and 37 years.

do some thing using hands). This can provide certain cues of meaning for the whole character. In a word, the visual forms of characters provide some semantic information. Together, these distinctive characteristics of the Chinese language might be expected to lead to the activation of different neural substrates when Chinese text is processed compared with the neural substrates of alphabetic language processing.

Previous studies using MEG to localize language processing areas have generally been based on calculations of sequential single equivalent current dipole sources accounting for late auditory evoked field components that are elicited in both hemispheres. These studies have typically used either a recognition memory task for spoken words[3], or a task that involves listening to synthesized vowel sounds[4]. The present study aims to use MEG to explore the neural centers of language processing during the reading of Chinese characters. Our results will be compared with neural activation patterns that have previously been observed in the processing of alphabetic languages. These results will help to reveal both the language-specific and language-general components of the neuroanatomical mechanisms of processing language information.

Subjects

Ten healthy native Chinese speakers (six males and four females; age range: 28–37 years) participated in this study (*Table 1*). Participants were a mixture of postgraduates and people training in the Department of Neurology, Beijing Tiantan Hospital, Beijing, China. Participants had no history of language disorders or cognitive impairments.

Materials and methods

Materials

Our stimuli contained 90 real Chinese characters, and 90 Chinese pseudo-characters (180 characters in total). The real characters were common in the Chinese corpus (e.g. 纸, /*zhi3*/, paper; 伞, /*san3*/, umbrella). The pseudo-characters were constructed by changing the strokes or logographemes of real characters (e.g. [illegible], [illegible]). The two types of characters were matched for stroke number.

Procedure

The 180 characters were presented in pseudo-random order. Each character was visually presented for 1 second on the screen, following a 1 second interval. The subjects were required to read the real characters silently, and to passively view the pseudo-characters.

Data collection and analysis

We used a 151-channel MEG system to record the pattern of brain activation while the subjects completed the above task. For each subject, we set three marks in both ear lobes, and at the middle point between the eyebrows. The marks defined the relative positions of the brain and magnetometer. The line between the two marks of the ear lobes defined the Y-axis and the vertical line between the middle point of the eyebrows and the middle point of the Y-axis defined the X-axis. The Z-axis was defined as a line along the X–Y plane, going through the point of intersection of the X- and Y-axes. These axes made it possible for us to match the coordinates of the MEG signals with those of the MRI images. The MEG signals of subjects were collected by a sensor located within a helmet. Data were excluded if the movement of subjects' heads in the scan stage exceeded 5·0 mm. Finally, we fixed gelatin pearls to three origins and carried out an MRI scan.

The MEG signals were filtered with the waves of overlapped figure (band width: 0·5–20 Hz, sample velocity: 300 Hz). We considered the magnetic signal response within a latency of 100 ms to be an early component produced by vision, which was excluded from analysis. For analysis, we selected the signal between 150 and 700 ms. We considered this part of the signal to include the metaphase and late components representing the language processing induced stimulation. The components of the response to visual stimulation were calculated through the SAM model. From this analysis, we obtained the position parameters of the response component.

We then filtered the calculated component (condition of component selection: amount of error$<$50), and combined the MEG component figure with the MRI image. This procedure enabled the localization of neural areas involved in Chinese language processing.

Results

The MEG results showed that after the presentation of the character stimuli, subjects' elicited two late magnetic neural responses. The left hemisphere elicited a waveform showing a greater degree of polarization. The late elements of the response waves (200–600 ms after stimuli presentation) exhibited similarly shaped waveforms. Moreover, the results also indicated that Broca's area was located at the back of left gyrus frontalis inferior or gyrus frontalis medius. Wernicke's area was located at the left gyrus temporalis medius, gyrus temporalis superior or gyrus supramariginalis (*Table 2*). Wernicke's area was found to become activated earlier than Broca's area (*Figure 1*).

Conclusion

The localization of language functional areas is an important issue for pre-surgical planning. Over one

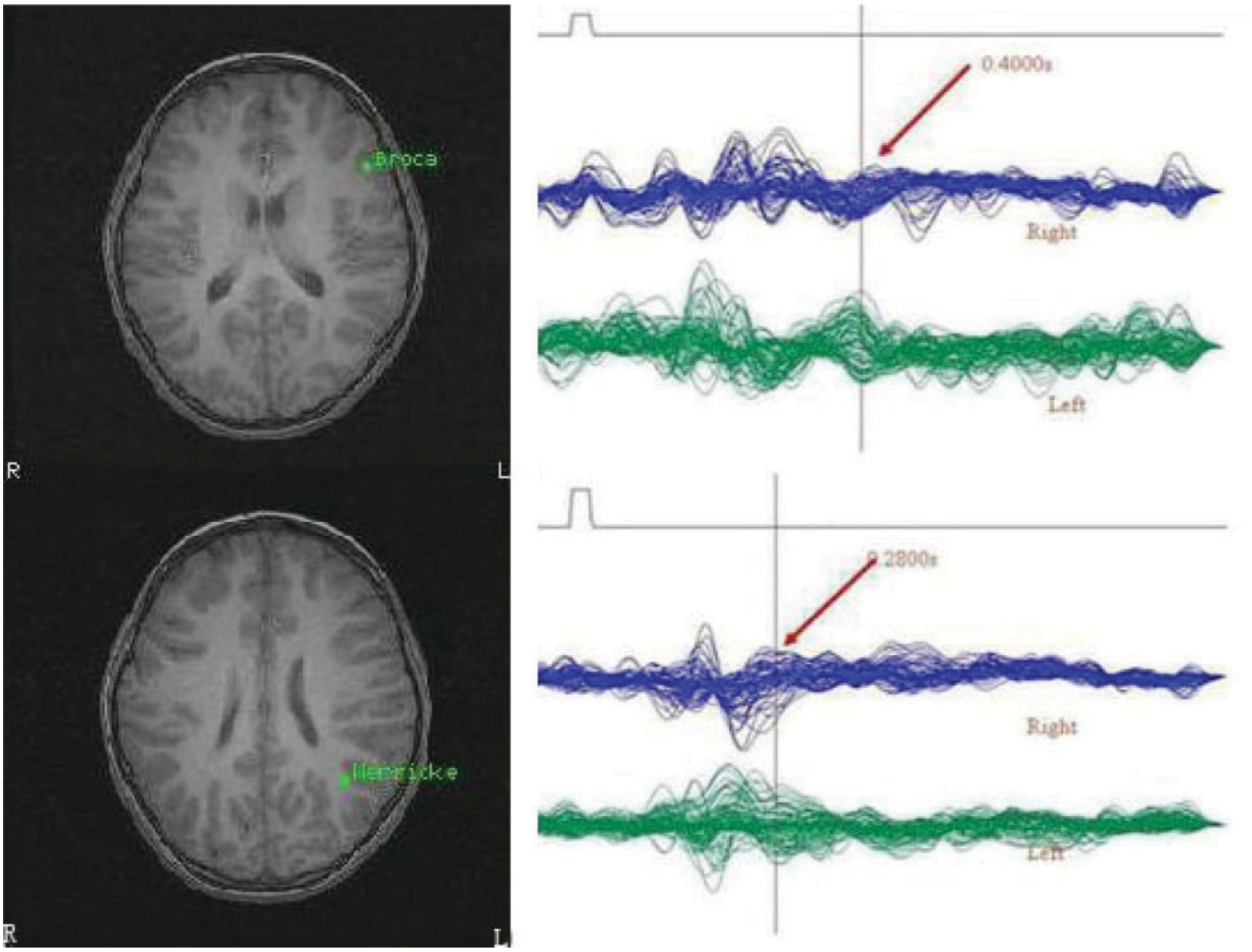

Figure 1 Language functional areas of a native Chinese speaker male From the figure, we can see that both cerebral hemispheres induced two late magnetic reaction waves and the left wave shape showed greater polarization; Broca's area appeared in 400 ms after stimulation, located at the left gyrus frontalis inferior, while Wernicke's area appeared in 280 ms after stimulation, located at the left gyrus temporalis medius, and Wernicke's area appeared before Broca's area

century ago, the correspondence of behavioral and anatomical data in aphasic patient populations led to the proposal of four language centers: (1) an auditory language center (Wernicke's area); (2) a reading language processing center (angular gyrus of inferior parietal lobule); (3) a writing language center (left superior parietal lobule and left middle frontal gyrus); (4) a motor language center (Broca's area).

Chinese, a typical logographical language, differs from the alphabetical languages in certain processes, such as word recognition and reading. The study of Chinese language processing, therefore, has been

Table 2 Language functional area of the volunteers with spatio-temporal data

Case	Time (ms)	Lateralization	Wernicke's area	Time (ms)	Broca's area
1	270	Left	Gyrus temporalis medius Gyrus temporalis superior	370	Gyrus frontalis inferior Gyrus frontalis medius
2	280	Left	Gyrus temporalis superior	400	Gyrus frontalis inferior
3	290	Left	Gyrus supramariginalis	420	Gyrus frontalis inferior
4	260	Left	Gyrus temporalis superior Gyrus supramariginalis	380	Gyrus frontalis inferior
5	270	Left	Gyrus temporalis medius Gyrus temporalis inferior	380	Gyrus frontalis inferior Gyrus frontalis medius
6	290	Left	Gyrus temporalis medius	410	Gyrus frontalis inferior
7	300	Left	Gyrus temporalis superior	430	Gyrus frontalis inferior
8	310	Left	Gyrus supramariginalis Gyrus temporalis superior	420	Gyrus frontalis inferior
9	260	Left	Gyrus temporalis superior	400	Gyrus frontalis inferior
10	280	Left	Gyrus supramariginalis Gyrus temporalis medius	460	Gyrus frontalis inferior Gyrus frontalis medius

Table 2 showed that Broca's area is located at the back of left gyrus frontalis inferior or gyrus frontalis medius and Wernicke's area is located at the left gyrus temporalis medius, gyrus temporalis superior or gyrus supramariginalis.

highlighted in neuroimaging studies as a potential way to reveal the language-specific and language-general mechanisms of neural language processing.

In our study, we observed that Broca's and Wernicke's areas were involved in the processing of written Chinese characters. The areas in which we found activation showed a general correspondence to the classically defined language brain areas. In the other words, our findings support the notion that these classic language centers are involved in language processing across language types. Other brain-imaging studies on Chinese obtained similar findings[5–8].

It has previously been clearly demonstrated that the neural areas involved in language processing are lateralized to the left hemisphere[9]. Some studies[10,11] have reported that the left-dominant pattern of neural activation is similar between Chinese and English. One study[12] suggested that in the Chinese language task, language processing was lateralized to the left hemisphere, but that a small number of functional areas in the right hemisphere were also activated. Another study[13] using MEG, observed an additional activation in the right temporal region in Chinese language processing. Further, the area of the brain activated by Chinese processing was larger than that activated by English processing. Other studies[14,15] also observed that the right hemisphere was activated in the processing of Chinese characters. Our results showed that both hemispheres were activated during Chinese language processing, but that polarization was greater in the left than in the right hemisphere. Chinese characters may activate both hemispheres because they have a language component as well as a graphic component, and the visual symbols are more complicated than phonetic characters in alphabetic languages. In addition, they contain geometrical information to a larger extent. Processing physical orientation, the recognition of spatial structure and the processing of geometrical images are functions dominated by the right hemisphere. As a result, the right hemisphere is thought to be primarily involved in the processing of visual information while the left hemisphere is predominantly involved in the processing of language information.

To conclude, the present study found, using MEG, that the processing of written Chinese in native Chinese speakers is lateralized to the left hemisphere. The Broca's and Wernicke's areas found to be activated in Chinese language processing correspond to the classical language centers previously reported in alphabetic language processing. Our results, however, also showed some activation patterns that differed from those reported for alphabetic languages. This suggests that the neural processing of language does show some language-specific features across different language scripts. These findings may aid pre-surgical planning in Chinese speakers undergoing brain surgery.

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Yumei Zhang and Ning Zhang contributed equally to this paper.

References

1 Kober H, Moller M, Nimsky C, *et al.* New approach to localize speech relevant brain areas and hemispheric dominance using spatially filtered magnetoencephalography. *Hum Brain Map* 2001; **14**: 236–250

2 Mäkelä JP, Forss N, Jääskeläinen J, *et al.* Magnetoencephalography in neurosurgery. *Neurosurgy* 2006; **59**: 493–511

3 Papanicolaou AC, Simos PG, Castillo EM, *et al.* Magnetoencephalography: A noninvasive alternative to the Wada procedure. *J Neurosurg* 2004; **100**: 867–876

4 Szymanski MD, Perry DW, Cage NM, *et al.* Magnetic source imaging of late evoked field responses to vowels: Toward an assessment of hemispheric dominance for language. *J Neurosurg* 2001; **94**: 445–453

5 Bowyer SM, Moran JE, Mason KM, *et al.* MEG localization of language-specific cortex utilizing MR-FOCUSS. *Neurology* 2004; **62**: 2247–2255

6 Ju S-H, Chen F, Zheng K-E, *et al.* Acoustic language test: A functional MRI study. *J Clin Radiol* 2003; **22**: 461–465

7 Liu H-L, Wu C-T, Chen J-C, *et al.* Implementations of clinical functional magnetic resonance imaging using character-based paradigms for the prediction of Chinese language dominance. *J Comput Assist Tomogr* 2003; **27**: 207–212

8 Pataraia E, Simos PG, Castillo EM, *et al.* Reorganization of language-specific cortex in patients with lesions or mesial temporal epilepsy. *Neurology* 2004; **63**: 1825–1832

9 Zhao X-H, Zhao J-M, Yang Z-Y, *et al.* A study of Chinese cerebral representation in Chinese with fMRI. *J Pract Radiol* 2004; **20**: 298–301

10 Sun J-L, Wu J, Li S-M, *et al.* Magnet source imaging studied on language cortex areas whose native language is Chinese. *J China Radiol* 2003; **37**: 363–376

11 Zhao X-H, Zhao J-M, Yang Z-Y, *et al.* A study of Chinese cerebral representation in Chinese with fMRI. *J Pract Radiol* 2004; **20**: 298–301

12 Li E-Z, Xu C-W, Han Y, *et al.* Brain fMRI study of language and music. *J China Radiol* 1999; **33**: 311–315

13 Lin Y-Y, Liao K-K, Chen J-T, *et al.* Neural correlates of Chinese word: An MEG study. *Int J Psychophysiol* 2006; **62**: 122–133

14 Li H-T, Ching M-F, Peter F, *et al.* An fMRI study with written Chinese. *Neuroreport* 2000; **12**: 83–88

15 Lin C-Y, Xiao Z-W, Shen L, *et al.* Similar brain activation patterns for writing logographic and phonetic symbols in Chinese. *Neuroreport* 2007; **18**: 1621–1625