INTERNATIONAL JOURNAL OF PSYCHOLOGY, 2003, *38* (5), 299–310

Cognitive neuroscience in China

Xiaolin Zhou

Centre for Brain and Cognitive Sciences, Peking University, Beijing, China

Yue-jia Luo

Key Laboratory of Mentel Health, Chinese Academy of Sciences, Beijing, China

In the last decade, cognitive neuroscience in China has advanced in at least four aspects: first, specialized research institutes and bodies have been set up throughout the nation; second, more and more high-tech research facilities and approaches have been adopted by domestic researchers; third, international conferences on cognitive neuroscience have been held in Mainland China; and finally, publications relating cognitive processes to neural activation and functioning have increased. This paper selectively reviews research on perception and face recognition, attention, language, memory, and disorders in cognitive brain functions carried out by scientists in Mainland China. For visual perception, some excellent work has been carried out to investigate the neural mechanisms of perceptual priming, perceptual grouping, and perception of global/local properties in compound stimuli. For attention, much work is on issues such as the time course of brain activation in selective attention, the patterns of event-related potentials in visual and auditory selective attention, and the effect of pre-cueing on spatial attention. Because the Chinese language has many unique characteristics in phonological and syntactic systems and in the writing system, much research carried out in China takes advantage of these characteristics, trying to separate the universal and language-specific aspects of language processing and their neural correlates. Memory research is mainly at neuropsychological and neurobiological levels. Disorders of cognitive functioning and their underlying impairments in the brain are attracting more and more attention. The paper concludes that as the Chinese economy is growing fast, more resources will be poured into basic research. Thus, systematic research in various fields of cognitive neuroscience by Chinese scientists is no longer a dream. It is reasonable to expect that research in this field will be accelerated in China and become an important force in the world in the near future.

Au cours de la dernière décennie, la neuroscience cognitive en Chine a connu un essort relativement à au moins quatre aspects : premièrement, des instituts et des organismes spécialisés de recherche furent mis sur pied à travers la nation; deuxièmement, de plus en plus d'appareils de recherche de haute technologie et d'approches furent utilisés par les chercheurs; troisièmement, des conférences internationnales sur la neuroscience cognitive furent tenues en Chine; et finalement, les publications reliant les processus cognitifs à l'activation et au fonctionnement neuraux ont connu une croissance rapide. Cet article constitue une revue sélective des recherches effectuées par les scientifiques chinois sur la perception et la reconnaissance du visage, l'attention, le langage, la mémoire et les désordres des fonctions cérébrales cognitives. Pour la perception visuelle, d'excellents travaux furent menés pour examiner les mécanismes neuraux de l'amorçage perceptuel, du regroupement perceptuel et de la perception des propriétés globales/locales dans les stimuli composés. En ce qui concerne l'attention, plusieurs recherches ont porté sur des thèmes tels que le décours temporel de l'activation cérébrale dans l'attention sélective, les patrons des potentiels évoqués dans l'attention sélective visuelle et auditive et l'effet de pré-indices sur l'attention spatiale. En raison du fait que la langue chinoise possède des caractéristiques uniques sur le plan des systèmes phonologique, syntaxique et écrit, plusieurs recherches menées en Chine ont pris avantage de ces caractéristiques afin de faire ressortir les aspects universels et spécifiques du processus du langage et les aspects neuraux qui leur sont associés. Pour sa part, la recherche sur la mémoire fut principalement reliée à la neuropsychologie et à la neurobiologie. Par ailleurs, les désordres du fonctionnement cognitif et les détériorations cérébrales leur étant associées constituent des thèmes de recherche de plus en plus populaires. Cet article conclut qu'étant donné que l'économie chinoise se développe rapidement, davantage de ressources pourront être versées dans la recherche de base. Ainsi, la possibilité pour les scientifiques chinois de faire de la recherche systématique dans les champs variés de la neuroscience cognitive n'est plus

Correspondence should be addressed to Dr Xiaolin Zhou, Department of Psychology, Peking University, Beijing, 100871, China (E-mail: xz104@pku.edu.cn).

http://www.tandf.co.uk/journals/pp/00207594.html DOI: 10.1080/00207590344000088

un rêve. Il est raisonnable de s'attendre à ce que la recherche dans le domaine de la neuroscience cognitive en Chine s'accroisse et devienne une force mondiale importante dans un proche futur.

En la última década, la neurociencia cognitiva en China ha mostrado adelantos en por lo menos cuatro aspectos: primero, se instalaron institutos de investigación y otros organismos especializados en todo el país; segundo, los investigadores han adoptado cada vez más instalaciones y enfoques de investigación de alta tecnología; tercero, se han realizado congresos internacionales sobre neurociencia cognitiva en China continental; y finalmente, han aumentado rápidamente las publicaciones que relacionan los procesos cognitivos con la activación y el funcionamiento neuronal. Este trabajo reseña selectivamente la investigación que sobre percepción y reconocimiento de la cara, atención, lenguaje, memoria y trastornos de las funciones cerebrales cognitivas han realizado los científicos de China continental. Respecto a la percepción visual se han llevado al cabo excelentes trabajos para investigar los mecanismos neurales de la primacía perceptual, agrupamiento perceptual, y percepción de propiedades globales/locales de estímulos compuestos. En lo que respecta a la atención, gran parte del trabajo versa sobre el curso temporal de la activación cerebral en la atencion selectiva, las pautas de potenciales relacionados al evento en la atención selectiva visual y auditiva, y el efecto de la señal previa sobre la atención espacial. Dado que los sistemas fonológico y sintáctico, y el sistema de escritura del lenguaje chino poseen características únicas, mucha de la investigación conducida en China saca provecho de estas características, e intenta aislar los aspectos universales y específicos del lenguaje relativos al procesamiento del lenguaje y sus correlatos neurales. La investigación en memoria se desarrolla principalmente en los niveles neuropsicológico y neurobiológico. Cada vez atraen más atención los trastornos del funcionamiento cognitivo y el daño al cerebro subyacente. El documento concluye que a mayor crecimiento de la economía china, más recursos se destinarán a la investigación básica. Por lo tanto, la investigación sistemática de los científicos chinos en varios campos de la neurociencia cognitiva ya no es un sueño. Resulta razonable esperar que la investigación en el campo de la neurociencia cognitiva en China se acelere y convierta en una fuerza importante en el mundo en un futuro cercano.

INTRODUCTION

It has been widely accepted by scientists around the world that the 21st century is a new era for the development of science, i.e., a time for biological and brain sciences. After "the decade of the brain" in Europe, the United States, and Japan at the end of the last century, the interdisciplinary research of cognitive functions and their underlying neural mechanisms has become one of the mainstreams of science. It seems that it is no longer just a dream to solve the long-standing philosophical and scientific question of the relationship between brain and mind.

The development of cognitive neuroscience in other countries provides both challenge and opportunities to the scientific investigation of brain functions and mechanisms in China. Although the study of cognitive processes and their underlying brain mechanisms can be traced back to the 1920s in China, only in the last 10 years has cognitive neuroscience gained its momentum. The development of cognitive neuroscience in China is evidenced in at least four aspects: the setting up of specialized research institutes and bodies; the adoption of high-tech research facilities and approaches; the holding of international conferences on cognitive neuroscience; and the increase of publications, both nationally and internationally, relating cognitive processing and neural functioning.

The Chinese government has designated cognitive science as one of the 18 disciplines that get special support in the 10th "5-year plan." Encouraged by the government's drive, scientists from different areas of the country are unifying to form new research centres. For example, in 2001, after several years of discussion and consultation, Peking University (the top university in China) finally set up an interdisciplinary Center for Brain and Cognitive Sciences, with participating scientists from the Department of Psychology, the School of Life Sciences, the Center for Information Science, the Institute of Neuroscience, the Institute of Mental Health, and several affiliated hospitals. The Chinese Academy of Science has several key laboratories in the Institute of Psychology, the Institute of Biophysics, and other institutes devoted to cognitive neuroscience research. A brand-new Institute of Neuroscience has also been set up in the Chinese Academy of Science. Several principal researchers there have a strong bias for relating neural activities to higher cognitive functions. A recent development is that a national organization, the Chinese Association of Cognitive Neuroscience, will soon show its face on the map. This body, with the blessing of the Chinese government, will promote cognitive and brain sciences in China.

New research facilities and approaches have been introduced into China along with the setting up of new research centres and institutes. For example, there are now at least 20 laboratories in China that have EEG setups, so the ERP (event-related potential) technique can be actively used to investigate various aspects of cognitive processing. There are also several groups of researchers using functional magnetic resonance imaging (fMRI) to examine the neural correlates underlying perception, attention, memory, language, and other cognitive processes. These studies, mostly in the process of being published, have been carried out in collaboration with clinical doctors in hospitals. However, the Chinese Academy of Science has purchased a 3 Tesla fMRI scanner that will be devoted exclusively to basic research. Peking University is also actively pursuing the idea of setting up a fMRI brain imaging centre.

Cognitive neuroscientists in China are now not only actively participating in international events such as the Human Brain Mapping conference, but also holding conferences and symposia themselves. For example, in August 2002 an International Conference on Cognitive Neuroscience was held in the seaside city Qingdao. About 300 scientists from all over the world participated in the meeting. In October 2002, an International Symposium on Cognitive Neuroscience of Learning and Memory was sponsored by the Center for Brain and Cognitive Sciences at Peking University. Several internationally well-known scientists, including one Nobel laureate, gave key speeches. In August 2004, the “Olympic Games” of psychological science, the International Congress of Psychology, will take place in Beijing. Such events push Chinese neuroscientists into the front line and facilitate their exchange and collaboration with colleagues all over the world. Right now, the Chinese Association for Cognitive Neuroscience is being sponsored and supported by over 100 scientists in China.

Although cognitive neuroscience research in China is still at its dawn, scientists have made progress in many aspects of cognitive processing. In the next sections, we will selectively review the results and findings of recent studies conducted by researchers from Mainland China. We do not claim that the literature is evenly treated or that this review is comprehensive, but we do hope that this glimpse of research will give our international colleagues a good picture of what is going on in cognitive neuroscience in China and will also encourage them to exchange ideas and collaborate with our Chinese scientists. Our review is divided into five sections, covering perception and face recognition, attention, language, memory, and disorders in cognitive brain functions.

PERCEPTION AND FACE RECOGNITION

Perception and attention has long received attention from psychologists and neurobiologists in China. Some excellent work has been done by cognitive neuroscience researchers. Here we introduce a few studies that have been noticed by the wider scientific community.

Neural mechanism of perceptual priming by visual motion

Perceptual priming is an important form of automatic learning that gives us efficient perception and action in a motion environment. Luo, Jiang, and colleagues studied the temporal dynamics of neural activity by using ERP and fMRI and asking subjects to make judgments on the apparent motion of two-dimensional sine-wave grating (Jiang, Luo, & Parasuraman, 2002a; Luo, Jiang, & Parasuraman, 1999b; Luo, Jiang, Tang, & Parasuraman, 2002). Both the early and late ERP components were enhanced in the priming condition, only the late component was larger in the weak priming condition, but there was no ERP effect in the nonpriming condition. Significant activation from the fMRI image was found in ventral occipital area, inferior temporal cortex, and intraparietal cortices. The results using ERPs and fMRI, suggested that the visual motion priming consisted of both early and late stages of visual processing, which begin as early as 100 ms in the early visual occipital areas and the later processing areas of the inferior temporal (MT), superior temporal and intraparietal cortices. They also compared young and old people using the same paradigm, showing a significant reduction in the extent of motion priming in both behaviour (Jiang, Luo, & Parasuraman, 2002b) and electrophysiological data (Luo, Jiang, Lawsin, & Parasuraman, 2000) for the older group. These findings might reflect age-related changes in temporal processing in human visual cortex and these delayed neural responses to subsequent motion signals.

Neural correlates of visual perceptual grouping in humans

To study the difference between grouping processes defined by different Gestalt laws, Han and colleagues (Han & Humphreys, 1999; Han, Humphreys, & Chen, 1999b, 1999c) first measured reaction times to the discrimination of perceptual groups defined by proximity and similarity of shape. They found that responses were faster to proximity than similarity stimuli, suggesting that proximity grouping may occur prior to grouping by similarity. Han et al. (Han, Ding, & Song, 2002; Han, Song, Ding, Yund, & Woods, 2001) further recorded high-density ERPs to the discrimination of perceptual groups formed by proximity and similarity. They found that proximity grouping induced a positive activity between 100 and 120 ms after stimulus onset over the medial occipital cortex. This early positivity was followed by an occipito-parietal negativity with an onset of 180 ms and larger amplitudes over the right than the left hemisphere. However, grouping by shape similarity was reflected only in a long-latency occipito-temporal negativity with an onset of 260 ms and larger amplitudes over the left than right hemispheres. The results suggest that the grouping processes defined by different Gestalt groupings may have distinct neural substrates.

Neural mechanisms of perception of global/local properties of compound stimuli

To examine the neural mechanisms underlying the perception of global and local features of hierarchically organized patterns, Han et al. (Han, Fan, Chen, & Zhuo, 1997, 1999a; Han, He, Yund, & Woods, 2001; Han, He, & Woods, 2000) recorded ERPs for the identification of shapes at the global or local levels of compound stimuli. They first observed an enlarged occipital P1 to local relative to global targets regardless of whether attention was focused on one level or divided on both levels of compound shapes. In addition, they found an enhanced occipito-temporal N2 in the local relative to global conditions. Similar modulations of the posterior N2 were observed during selective attention to global or local features of compound stimuli displayed in the periphery of the visual field. The ERP components over the anterior areas are also modulated by global/local processing: Local targets elicited anterior N2 and P3 waves with longer peak latencies relative to global targets. The findings provide ERP evidence for neural activities at different time courses and levels of the brain structure underlying global and local perception. In a recent fMRI study, Han et al. (2002) found that attention to the global level of compound letters produced stronger activation over the medial occipital cortex relative to the local attention. Furthermore, compound stimuli induced stronger activation in the right middle occipital cortex in global relative to local attention conditions but stronger activation in the left inferior occipital cortex in local relative to global attention conditions. The asymmetry over the occipital cortex was weakened by unilateral presentation and by contrast balancing. The results identified distinct neural substrates for global and local attention and indicated that the lateralization of global and local processing is modulated by the position and SF spectrum of the compound stimuli.

Face recognition

Recently a series of experiments including subsequent memory (DM effect) comparing oriental and Caucasian faces, old/new effect, face inversion effect, internal and external features of face, and the meaning of N170 were conducted by Luo and his colleagues (Peng, Wei & Luo, 2002a; Peng, Wei, Luo, Zhao, & Wang, 2002b; Wu, Ye, & Luo, 2003). The experimental results showed that Western faces produced a smaller N100 and a larger P170 and a larger LPC than Eastern faces. This suggested the following. (1) More attention is paid to faces of other races at the early stage of perceptual processing, and then an encoding stage begins earlier for same-race than for other-race faces (Peng et al., 2002a). (2) The P170/N170 represents face structure encoding, which is probably located over the parietal-occipital areas. The P600 is related to retrieving memories of faces, which might be generated at the frontal-central area. The face recognition units and the name code are separated. More mental attention is paid to other-race faces at the early stage of perceptual processing and at the late stage of retrieving memories (Wu, et al., 2003). (3) These results illustrate that more resources were given to Western than Eastern faces, thus providing electrophysiological evidence for the other-race effect. (4) The N170 reflected the face structure encoding unit and direct visual processing unit (Peng et al., 2002b). (5) The N260 reflected the different encoding manner for Eastern and Western faces in the brain: It can probably be called the "specific race component." These views are different from the classical model of face recognition by Bruce and Young (1986). The authors made some modifications on Bruce and Young's face recognition model. ERP studies on face cognition were also carried by other researchers, e.g., Liao and Shen's work on ambiguous faces (1993) and Yang, Chen, Huang, and Liu's work on face familiarity (1993).

Shen and colleagues (Chen, Zhang, & Shen, 2002; Shen, Zhang, & Chen, 2002) recently published a series of interesting papers in *Vision Research*. In the experiments, rhesus monkeys were trained to discriminate faces and geometrical figures. The hole feature speeded up learning of face discrimination, but obstructed learning of figure discrimination. The most important feature appears to be the hole face component, but this changes to the shape feature of figures under reduced stimulus presentation duration. The results suggest that the neural correlates exist not only in IT neurons, but also in combination with an executive mechanism. The consequence is different for human subjects, for whom the hole was predominant in figure recognition. The precedence of features in perception thereby depended on subject species, stimulus set, and ecological significance of the perceiving process.

ATTENTION

Early stages of research (1980s)

The work on attention by Wei and Tang (1982), using the event-related potentials (ERPs) technique, was probably one of the earliest studies of cognitive neuroscience in China. The P300 amplitude was enhanced in the attended condition in auditory selective attention. Similar results were also reported by Luo and Wu (1990).

Lin and Tang (1985) conducted a behavioural study on children aged 8–13 years with attention deficit hyperactivity disorder (ADHD). They suggested that family environment is an important factor in the aetiology of the ADHD group. Attention tests and analysis of urinary epinephrine dynamics might be useful in the diagnosis of ADHD.

A set of animal experiments was conducted by Li, Tanaka, and Creutzfeldt (1990). The results showed that neurons in the dorsal segment of the prelunate gyrus (area DP) of two monkeys trained to fixate a small spot of light responded poorly or not at all to stationary or moving light stimuli. Circumscribed receptive fields could not be determined in the majority of these cells. About 25% of the units became active at certain gaze position and about 70% of the neurons were activated when monkeys looked attentively at an object and explored it visually. The authors suggested that area DP might represent activities related to behavioural aspects of vision rather than to features of the visual image itself.

Selective attention in the visual and auditory modality

Since the middle 1990s, Wei, Luo, and their colleagues have used a new paradigm—cross-modal and delayed response—to study selective attention in the visual and auditory modality (Fu & Wei, 1996; Luo & Wei, 1997a, 1997b, 1997c, 1999a, 1999b; Wei, 1995; Wei, Chan, & Luo, 2002). A modified oddball paradigm with nonverbal (Luo & Wei, 1997a, 1997c, 1999a) and verbal stimulus materials (Luo & Wei, 1997b, 1999b) was developed to facilitate attentional focus and to minimize target effects on deviance-related components of auditory and visual ERPs elicited with long inter-stimulus intervals (ISIs). The more pure unattended mismatch negativity (MMN) and attended MMN related to nontargets in the paradigm provided convincing data for the unresolved questions of whether the effect of attention is on the MMN, and if there is an analogous automatic deviant-related negativity in the visual modality. Separate multimodal stimulus blocks focusing attention on either the visual or auditory modality were also used (Luo & Wei, 1997a, 1997b, 1997c, 1999a, 1999b; Wei, 1995). Deviant-related components (DRC) were obtained by subtracting ERPs of the standard stimulus from that of the deviant stimulus in the visual and auditory modality and in the attended and unattended condition. Auditory MMN and a visual MMN-like negativity were elicited both when stimuli were attended and when unattended. In contrast, N2b and P3 were produced only under the attention condition. These results showed that the effect of attention on auditory MMN amplitude had a distribution change following different time windows of the MMN zone. This result supported the suggestion that the attended auditory MMN is a mixed wave composed of genuine MMN, N2b, and possible P165. The effect of attention on MMN may stem from the contamination of these overlapping components. At least three simultaneous internal templates capable of supporting automatic processing could be maintained in multiple sensory modalities. Regarding the question of whether or not visual MMN and verbal MMN exists, it can be suggested that the MMN exists in the visual modality (Luo & Wei, 1997c; Wei et al., 2002) and in the language processing process (Luo & Wei, 1997b, 1999b).

The attentive components were obtained by subtracting ERPs in the unattended condition from those in the attended condition. The results suggested that the attended N1 enhancement is primarily caused by a component with endogenous origins and that the early attention effect occurs before the exogenous components. Cross-modal attention to deviant stimuli modulates modality-specific processing in the brain, whereas attention to standard stimuli affects modality-nonspecific or supramodal processing (Luo & Wei, 1999b).

The N270 effects on selective attention and on conflict processing were investigated by Wang and colleagues (Wang, Kong, Tang, Zhuang, & Li, 2000; Wang, Wang, Kong, Cui, & Tian, 2001). The ERPs were recorded to determine if the magnitude or the colour of the two numbers was identical. The N270 occurring after the onset of the second number (S2) was elicited when S2 conflicted with the first number (S1) in task-relevant and/or irrelevant attribute conflicts. The N270 amplitude tended to be more negative in task-relevant conflict than in irrelevant conflict. Therefore, the conflict processing activity can be initiated independently of the task, but is enhanced in task-relevant conflict.

Spatial attention effects precued by different scales

When a spatial cue directs a person's attention to a region of the visual field, a stimulus presented there is detected and discriminated faster and more accurately than when the same stimulus is presented elsewhere (Posner, 1980). Processing of a target stimulus is also facilitated by the precision of cues to target location. Compared to a large, imprecise cue, a small, precise cue speeds reaction time (RT) to a target in both detection

(Castiello & Umiltà, 1990) and visual search tasks (Greenwood, Parasuraman, & Alexander, 1997). The temporal dynamics of the spatial scaling of attention during visual search were examined by recording ERPs (Luo, Greenwood, & Parasuaraman, 2001). The young participants performed a search task in which the search array was preceded by valid cues that varied in size and hence in precision of target localization. The effects of cue size on short-latency (P1 and N1) ERP components, and the time course of these effects with variation in cue-target stimulus onset asynchrony (SOA), were examined. RT to discriminate a target was prolonged as cue size increased. The amplitudes of the posterior P1 and N1 components of the ERP evoked by the search array were affected in opposite ways by the size of the precue: P1 amplitude increased whereas N1 amplitude decreased as cue size increased, particularly following the shortest SOA. The results show that when top-down information about the region to be searched is less precise (larger cues), RT is slowed and the neural generators of P1 became more active, reflecting the additional computations required in changing the spatial scale of attention to the appropriate element size to facilitate target discrimination. In contrast, the decrease in N1 amplitude with cue size may reflect the broadening of the spatial gradient of attention. The results provided electrophysiological evidence showing that the spatial scale of attention modulated neural activity in early visual cortical areas and activated at least two temporally overlapping component processes during visual search. The experiment paradigm was further upgraded by Luo and his colleagues (Gao, Luo, Wei, Peng, & Wei, 2002a, 2002b; Gao, Wei, Peng, & Luo, 2002c). The results showed that the P1 and N1 components under visual attention were mainly related to the spatial location processes; the P2 and N2 components elicited by cue were probably related to the size of attention range; and the processing of spatial location information was earlier than that of other information in visual attention, which supports the theory that spatial selection is a prerequisite for correct processing of visual object information.

The visual spatial attention elicited by peripheral cueing was investigated by Fu, Fan, Chen, and Zhuo (2001). ERPs were recorded while the subjects were performing a spatial frequency discrimination task and a location discrimination task with stimuli randomly flashed in the left or right visual field. Prior to each stimulus a peripheral cue was presented with a validity of 75%. The results showed that the subjects responded faster in the valid condition than in the invalid condition. The earliest C1 ERP component was not affected by cue validity, and this suggested that visual spatial attention elicited by peripheral cueing does not involve striate cortex. Valid stimuli elicited larger contralateral P1 but a smaller contralateral N1 than invalid stimuli. The early onsets of these attentional effects show that spatial attention affects stimulus processing at early sensory/perceptual stages. The latencies of contralateral P1 and contralateral N1 were shorter for invalid trials, however. The ipsilateral N1 was enhanced by valid trials in the spatial frequency discrimination task but not in the location discrimination task, whereas the contralateral N1 was larger for invalid trials than for valid trials in both tasks. The results suggest that attention effects yielded by peripheral cueing occurred at the early stage rather than at the late stage. The dissociation between the contralateral P1 and N1 was illustrated by the effects of peripheral cueing, which were significantly different from those of central cueing or sustained attention tasks, and again suggests that different mechanisms are involved in involuntary and voluntary attention systems.

LANGUAGE PROCESSING

The Chinese language is perhaps best known for its logographic writing system, for its extensive use of compounding to form new words, and for the use of lexical tone to differentiate lexical items (Zhou, 2002). Previous cognitive research into Chinese language processing hence concentrates mostly on the lexical processing of normal people (e.g., Zhou, 2000; Zhou & Marslen-Wilson, 1999a, 1999b, 2000a, 2000b) and brain-damaged patients (Weekes, Chen, & Gang, 1997; Zhou, Bai, Shu, & Qu, 1998). Cognitive neuroscience research follows the same trend, although studies in other directions are also being carried out.

Neural correlates of Chinese character reading

The basic orthographic units—the characters—in the logographic Chinese writing system can be differentiated broadly into two categories: simple and complex. Simple characters are holistic visual patterns that cannot be divided meaningfully into sublexical units. Complex characters constitute about 95% of all modern Chinese characters and most of them (80%) are composed of a semantic radical on the left and a phonetic radical on the right. Phonetic radicals have the function of indicating the pronunciations of whole characters, i.e., encoding phonological information at the subcharacter level. However, due to the evolution of the writing system, this function is not complete. Only about one third of complex characters are regular, with the same pronunciations as their phonetic radicals, while about another third are irregular, with their pronunciations having no relation to their phonetic radicals. Behaviour studies (e.g., Fang, Horng, & Tzeng, 1986; Hue, 1992; Peng, Yang, & Chen, 1994; Seidenberg, 1985; Zhou & Marslen-Wilson, 1999b) have found an interaction between regularity and frequency, with low-frequency regular characters named faster than low-frequency irregular characters, but with no significant difference between high-frequency regular and irregular characters. In a fMRI study, such an interaction between frequency and regularity was also observed (X. Zhou, Tang, Weng, Ma, & Li, 2001). The authors asked subjects to name implicitly 40 regular words and 40 irregular words presented in blocks while a series of MR images were acquired. The data showed higher activation for low-frequency irregular characters than for low-frequency regular characters in several brain regions, including inferior frontal cortex (BA 44), middle frontal cortex (BA 9), fusiform and inferior posterior temporal cortex (BA 37). (Different brain activations for regular and irregular characters were also obtained by Tan, Feng, Fox, & Gao, 2001a, although the later study did not manipulate frequency.) In contrast, high-frequency regular and irregular characters had very similar brain activation patterns, with the only difference being that regular characters had higher activation in extrastriate cortex (BA 18) and in the fusiform. These findings were interpreted as an indication of competition between lexical and sublexical processing for low-frequency irregular characters in brain activation.

fMRI studies also showed that processing Chinese characters is mostly left-hemisphere dominated, in contrast with claims made in previous studies using other methods. Both Tan et al. (2000) and Tang et al. (2002) discussed this issue explicitly (see also Kuo et al., 2001). Other studies compared character naming directly with picture naming (Tang, Zhou, Weng, Ma, & Li, 2001) and with *pinyin* (the Chinese alphabet) naming (Y. P. Chen, Fu, Iversen, Smith, & Matthews, 2002). Tang et al. found that after subtracting baselines, picture and character naming have common activation areas in bilateral extrastriate cortex (BA18/19), left superior parietal cortex (BA7) and right middle temporal cortex. The different activation areas for pictures and characters involve higher activation for pictures in left fusiform and right parietal cortex (BA7). The authors did not observe different activation between pictures and words in the left supra-marginal gyrus, which has been identified as a special place for the translation from orthography to phonology in reading alphabetic words. It was reasoned that picture naming and character naming use largely the same neural substrates and access to phonology, and that reading Chinese characters is mainly mediated by semantic activation. Using a block design involving a phonological and lexical task in which subjects were asked to decide whether visually presented, paired Chinese characters or *pinyin* "sounded" like a word, Y. P. Chen et al. (2002) demonstrated that reading Chinese characters and *pinyin* activate a common brain network including the inferior frontal, middle, and inferior temporal gyri, the inferior and superior parietal lobules, and the extrastriate areas. However, some regions show relatively greater activation for either *pinyin* or Chinese character reading. Reading *pinyin* led to a greater activation in the inferior parietal cortex bilaterally, the precuneus, and the anterior middle temporal gyrus. In contrast, activation in the left fusiform gyrus, the bilateral cuneus, the posterior middle temporal, the right inferior frontal gyrus, and the bilateral superior frontal gyrus were greater for nonalphabetic Chinese reading. Thus, overall there are no differences in terms of hemispheric specialization between alphabetic and nonalphabetic scripts. However, differences in language surface form appear to determine relative activation in other regions. Some of these regions (e.g., the inferior parietal cortex for *pinyin*, and fusiform and gyrus for Chinese characters) are candidates for specialized processes associated with reading via predominantly assembled (*pinyin*) or addressed (Chinese character) procedures.

Brain activation in lexical semantic processing

Several fMRI studies have also been conducted to examine brain activation in processing the semantic properties of Chinese characters and words. In one study, Tan et al. (2001b) required subjects to make semantic and homophone decisions to presented pairs of characters. Compared to the fixation baseline, peak activations resulting from semantic as well as homophone decisions were localized in the left middle frontal gyrus (BA 9). In addition, more right-hemisphere cortical regions (i.e., BAs 47/45, 7, 40/39, and the right visual system) were involved in reading Chinese relative to reading English. The authors suggested that the left middle frontal area (BA 9) coordinates and integrates the intensive visuospatial analysis demanded by the square configuration of the logographs and the semantic (or phonological) analysis required by the experimental tasks. Processing logographic Chinese characters has brain regions common to processing alphabetic words as well as regions specialized in logographs only. In another study, Xiang et al. (in press) asked subjects to perform three semantic tasks with different loads of discrimination. All three semantic tasks activated distributed brain areas, including the right posterior inferior cerebellum. Much stronger activation was found in the cerebellum in more difficult tasks, in terms of the activation volume and signal intensity. These results suggest that cerebellum activation is involved in semantic discrimination and is modulated by discrimination difficulty.

Lexical semantic processing was also investigated using the ERP technique. Luo, Hu, Weng, and Wei (1999a) measured 20 subjects' ERPs during a lexical decision task in which Chinese characters were used in conditions of both related (antonym) and unrelated words. The results indicated that the reaction times yielded by unrelated words were 130 ms longer than those elicited by unrelated words. The condition of unrelated words elicited significantly higher amplitude and longer latency of N350/450 than those of related words at each of the 17 ERP recording sites. Furthermore, the amplitude of N210 and N350/450 were larger in the right hemisphere than in the left hemisphere.

Sentence processing

In comparison to lexical processing, neurolinguistic research on Chinese sentence processing is rarely seen. Law and Leung (2000) reported the performances of two Cantonese aphasics on tasks examining their sentence processing deficits. The data on sentence comprehension show that thematically noncanonical sentences, full passives, and subject-gap sentences present greater difficulty to these patients than canonical sentences, truncated passives, and object-gap sentences. The data on a Cantonese grammaticality judgment test elicited clear judgments from normal subjects and aphasics, contrary to the claim that grammaticality judgments in Chinese are probabilistic and fragile. Most interestingly, the patients' overall performance patterns reveal a double dissociation between sentence comprehension and judgment of sentence well-formedness, suggesting that the two tasks are supported by independent processing mechanisms.

The brain-imaging technique is now being used to map syntactic and semantic processes onto the brain. In a fMRI study (Luke, Liu, Wai, Wan, & Tan, 2002), Chinese-English bilingual subjects performed two experimental tasks: a syntactic plausibility judgment task, in which they decided whether a viewed verb phrase was syntactically legal, and a semantic plausibility judgment task, in which they decided whether a viewed phrase was semantically acceptable. It was found that a large-scale distributed neural network covering the left mid-inferior frontal and mid-superior temporal cortices was responsible for the processing of Chinese phrases. The right homologue areas of these left cortical sites were also active, although the brain activity was obviously left-lateralized. Unlike previous research with monolingual English speakers, which showed that distinct brain regions mediate syntactic and semantic processing of English, the cortical sites contributing to the syntactic analysis of Chinese phrases coincided with the cortical sites relevant to semantic analysis. Stronger brain activity, however, was seen in the left middle frontal cortex for syntactic processing, whereas for semantic processing stronger cortical activations were shown in the left inferior prefrontal cortex and the left mid-superior temporal gyri. The authors concluded that syntactic processing is less independent in reading Chinese. This is attributable to the linguistic nature of the Chinese language: Semantics and syntax are not always clearly demarcated.

MEMORY

Neuroscientific research into memory processes in China has been covered partly by Lin and Sui in this issue. Here we concentrate on two lines of research and on papers published in international journals.

Memory deficits in brain-damaged patients

Q. S. Wang and Zhou (2002) investigated retrieval and encoding of episodic memory in normal ageing and in patients with mild cognitive impairment (MCI). They found a significant decline in the function of orientation, language, and praxis as well as memory impairment in the MCI group. Impairment of encoding and retrieval of episodic memory was observed in the MCI group, suggesting that encoding of episodic memory is vulnerable to interruption. Zhang, Wang, Li, Huang, and Cui (2002) recorded ERPs on patients with obstructive sleep apnoea syndrome (OSAS). Patients were presented with visual stimuli in a task requiring them to match the shape and serial position of the probes against previously memorized items. It was found that N2b-late positive-going (LPC) components were elicited by probes that identically matched the memorized items (no-conflict condition). In contrast, N270-LPC and N270-N430-LPC components were elicited by probes having low conflict and high conflict with the memory set respectively. Conflict ERPs associated with processing of conflicting information are more vulnerable than no-conflict ERPs to hypoxic cerebral damage.

In a more theoretically oriented study, J. Yang and her colleagues (2003) addressed the question of whether the medial temporal lobe (MTL) plays a critical role in implicit memory for new associations. Priming for new associations was examined in two different tasks, in 18 patients with focal lesions all involving the MTL. In Experiment 1, following a study phase for pairs of unrelated words, subjects performed a perceptual identification task on old, recombined, and new pairs of words presented at brief exposure durations. In contrast to control subjects, and despite a normal level of item priming, the patients failed to show superior identification of the old pairs relative to the recombined pairs, the measure of associative priming. In Experiment 2, subjects engaged in speeded naming of the print colour for previously studied words presented in the original colour or in a different old colour, and for unstudied words. Again, in contrast to control subjects and despite a normal level of item facilitation on colour-naming reaction time, the patients failed to show priming for recently experienced new associations between words and colours. Explicit recognition memory by the patients was abnormal in both experiments. The present results suggest that MTL is critical for forming new associations of the types assessed here.

Neurobiological study of memory

Another line of research examined the effects of pharmacological manipulations on memory. Ou, Tang, and Cai (2001) investigated the effect of huperzine A, a reversible and selective acetylcholinesterase inhibitor, on reserpine- or yohimbine-induced spatial working memory deficits in monkeys. They used a delayed response task that depends on the integrity of prefrontal cortex. Reserpine (0.1 mg/kg, i.m.) or yohimbine (0.01 mg/kg, i.m.) led to significant impairments in the monkeys' ability to perform the delayed response task. Huperzine A (0.01 mg/kg, i.m. in reserpine-treated monkeys; 0.01–0.1 mg/kg, i.m, in yohimbine-treated monkeys) significantly improved the reserpine- or yohimbine-induced memory impairments. The effect of huperzine A on memory impairments exhibited an inverted U-shaped dose–response pattern, suggesting that it may improve working memory via an adrenergic mechanism (see also Ye, Cai, Wang, & Tang, 1999). Another study by J. Zhou, Zhang, and Tang (2001) found that huperzine A can attenuate cognitive deficits and hippocampal neuronal damage after transient global ischaemia in gerbils. Five minutes of global ischaemia in gerbils results in working memory impairments shown by increased escape latency in a water maze and reduced time spent in the target quadrant. These signs of dysfunction are accompanied by delayed degeneration of pyramidal hippocampal CA1 neurons and by decrease in acetylcholinesterase activity in the hippocampus. Subchronic oral administration of huperzine A (0.1 mg/kg, twice per day for 14 days) after ischaemia significantly reduced the memory impairment, reduced neuronal degeneration in the CA1 region, and partially restored hippocampal choline acetyltransferase activity.

On the other hand, it was found that local infusion of an alpha-1 adrenergic agonist into the prefrontal cortex impairs spatial working memory performance in monkeys (Mao, Arnsten, & Li, 1999). Stimulation of alpha-2 adrenoceptors in the monkey or rat prefrontal cortex (PFC) has been known to improve spatial working memory (SWM) and stimulation of alpha-1 adrenoceptors in the rat PFC has been reported to impair SWM. This study replicated the effect of alpha-1 adrenoceptors in the monkey PFC (see also Li, Mao, Wang, & Mei, 1999). Li and Kubota (1998) also found that alpha-2 adrenergic modulation of prefrontal cortical neuronal activity related to a visual discrimination task with GO and NO-GO performances in monkeys.

DISORDERS IN COGNITIVE BRAIN FUNCTIONS

Cognitive neuroscience research in China focuses not only on the basic brain mechanisms of normal cognitive functioning, but also on the impairment of such functioning in populations that need special attention. Above we have touched some studies on brain-damaged patients. Here we present another two aspects of neuropsychological studies.

Research on ADHD

As mentioned above, researchers in China recognize the importance of studying attention deficit hyperactivity disorder (ADHD), which occurs in 5 out of 100 children. Consistent with Western data, there are more boys than girls suffering from ADHD (Hong, Huang, Wang, Huang, & Chen, 2002), and their family circumstance is one of the pathogeny factors. A group of ADHD patients were tested using the Wechsler Intelligence Scale for Children-RC, Wechsler Memory Scale (WMS), Number Cancellation Test, Raven's Standard Progressive Matrices, and Stroop test (Liu & Wang, 2002). Almost all scores of the ADHD children were less than those of the controls and this suggested that levels of intelligence, memory, and attention in ADHD children are lower that those in normal children. Memory, language, motor ability, and executive functions were significantly impaired in ADHD children. Jiang et al. (1999) investigated the relationship between ADHD children in Shanghai and their dopamine transporter 1 gene. However, the result did not find any relation between them.

Wang, Zhou, Wang, and Zhang (in press) used a Stop Signal task to investigate two kinds of response inhibition, response conflict and response stopping.

Subjects were two subtypes of children with ADHD (predominantly inattentive and combined) and normal controls. The results showed that ADHD children were deficient in both kinds of response inhibition compared with normal controls. In response stopping, it was more difficult for ADHD children to withhold response when responding with their left hands, which means that they have a significant deficit in the right hemisphere. No significant differences were observed between the combined and inattentive ADHD group. In response conflict, normal children did not show significant conflict effect, suggesting that their strong conflict control ability can overcome the mild conflict manipulation. The inattentive ADHD group showed a significant conflict effect when responding with their left hands, suggesting impairment in control functions of the right hemisphere and the anterior cingulate. The combined ADHD group was more impaired than the inattentive ADHD children, showing a larger conflict effect when responding with either left or right hands. This suggested that the two types of ADHD children were impaired to a different extent in neurocognitive functions.

Cognitive impairment in dementia

Luo and Wu (1991) examined 102 patients, cognitively impaired due to cerebropathies. The mean latency of P300 for dementia patients was longer and the amplitude was lower than those for the age-matched controls. There was a negative correlation between the P300 amplitude and scores on the Mini-Mental State Exam (MMSE). Thirty-one patients were dynamically tested by ERPs and the MMSE. The result showed that decrease in the P300 latency was always associated with clinical improvement in cognitive function and increase in MMSE score, while prolongation in the P300 latency was associated with clinical deterioration and decrease in MMSE score. The P300 is therefore a reasonable index to provide an objective and quantitative measurement for cognitive function.

In another experiment, the auditory mismatch negativity (MMN) and the P300 of ERPs were compared in normal children with or without musical meditation training (Luo, Wei, & Brendan, 1999c). The experimental group consisted of 11 subjects who had been trained with musical meditation for 6 months and the control group consisted of 12 subjects (matched for age, sex, and grade) who had not received musical meditation. MMN amplitudes in the trained children were larger than those in the control group. In addition, the MMN amplitudes were identical in both "attend" and "ignore" conditions for both groups. This evidence suggests that auditory brain function has been affected by musical meditation training. It thus suggests that the MMN is capable of assessing changes to the brain function in normal subjects. There were no significant differences in the P300 latencies and amplitudes between the two groups. This result suggested that MMN and P300 might reflect different aspects of brain function.

CONCLUDING REMARKS

As we said at the beginning of this paper, cognitive neuroscience research in China is still new, but it has registered its presence on the map of science. Research in the last few years demonstrates that Chinese cognitive neuroscientists are capable of doing original and interesting research. We believe that as the Chinese economy is growing, more resources will be poured into basic research and that the advance of cognitive neuroscience in China will accelerate in the next few years. Systematic research in various fields of cognitive neuroscience by Chinese scientists is no longer a dream and cognitive neuroscience research in China will become an important force in the world.

REFERENCES

Bruce, V., & Young, A. W. (1986). Understanding face recognition. *British Journal of Psychology, 77*, 305–327.

Castiello, U., & Umilta, C. (1990). Size of the attentional focus and efficiency of processing. *Acta Psychologia, 73*, 195–209.

Chen, Y. C., Zhang, W. W., & Shen, Z. (2002). Shape predominant effect in pattern recognition of geometric figures of rhesus monkey. *Vision Research, 42,* 865–871.

Chen, Y. P., Fu, S. M., Iversen, S. D., Smith, S. M., & Matthews, P. M. (2002). Testing for dual brain processing routes in reading: A direct contrast of Chinese character and pinyin reading using fMRI. *Journal of Cognitive Neuroscience*, *14*, 1088–1098.

Fang, S.-P., Horng, R.-Y., & Tzeng, O. (1986). Consistency effects in the Chinese character and pseudo-character naming tasks. In H. S. R. Kao & R. Hoosain (Eds.), *Linguistics, psychology, and the Chinese language* (pp. 11–21). Hong Kong: Center of Asian Studies, University of Hong Kong.

Fu, S. M., Fan, S. L., Chen, L., & Zhuo, Y. (2001). The attentional effects of peripheral cueing as revealed by two event-related potential studies. *Clinical Neurophysiology*, *112*, 172–185.

Fu, S. M. & Wei, J. H. (1996). Auditory mismatch negativity reflects automatic process: Evidence from intermodal selective attention paradigm. *Acta Psychologica Sinica*, *28*, 89–96.

Gao, W. B., Luo, Y. J., Wei, J. H., Peng, X. H., & Wei, X. (2002a). ERP study on scale of visual spatial attention with fixed cues. *Acta Psychologica Sinica, 34*, 443–448.

Gao, W. B., Luo, Y. J., Wei, J. H., Peng, X. H., & Wei, X. (2002b). Brain dynamic mechanisms on the visual

attention scale with Chinese characters cues. *Chinese Science Bulletin*, *47*, 1644–1649.
Gao, W. B., Wei, J. H., Peng, X. H., & Luo, Y. J. (2002c). The mechanism of gain in scale of visual attention. *Space Medicine and Medical Engineering*, *15*, 210–211.
Greenwood, P. M., Parasuraman, R., & Alexander, G. E. (1997). Controlling the focus of spatial attention during visual search: Effects of advanced aging and Alzheimer disease. *Neuropsychologia*, 113–120.
Han, S., Ding, Y., & Song, Y. (2002). Neural mechanisms of perceptual grouping in humans as revealed by high density event related potentials. *Neuroscience Letters*, *319*, 29–32.
Han, S., Fan, S., Chen, L., & Zhuo, Y. (1997). On the different processing of wholes and parts: A psychophysiological study. *Journal of Cognitive Neuroscience*, *9*, 686–697.
Han, S., Fan, S., Chen, L., & Zhuo, Y. (1999a). Modulation of brain activities by hierarchical processing: A high-density ERP study. *Brain Topography*, *11*, 171–183.
Han, S., He, X., & Woods, D. L. (2000). Hierarchical processing and level-repetition effect as indexed by early brain potentials. *Psychophysiology*, *37*, 817–830.
Han, S., He, X., Yund, E. W., & Woods, D. L. (2001). Attentional selection in the processing of hierarchical patterns: An ERP study. *Biological Psychology*, *56*, 113–130.
Han, S., & Humphreys, G. W. (1999). Interactions between perceptual organization based on Gestalt laws and those based on hierarchical processing. *Perception and Psychophysics*, *6*, 1287–1298.
Han, S., Humphreys, G. W., & Chen, L. (1999b). Uniform connectedness and classical Gestalt principles of perceptual grouping. *Perception and Psychophysics*, *61*, 661–674.
Han, S., Humphreys, G. W., & Chen, L. (1999c). Parallel and competitive processes in hierarchical analysis, perceptual grouping and encoding of closure. *Journal of Experimental Psychology: Human Perception and Performance*, *25*, 1411–1432.
Han, S., Song, Y., Ding, Y., Yund, E. W., & Woods, D. L. (2001). Neural substrates for visual perceptual grouping in humans. *Psychophysiology*, *38*, 926–935.
Hong, J. F., Huang, B. Q., Wang, L. Z., Huang, X. F., & Chen, F. Q. (2002). The psychological-social risk factors of ADHD. *Chinese Journal of Child Health Care*, *10*, 73–75.
Hue, C.-W. (1992). Recognition processes in character naming. In H.-C. Chen & O. J. L. Tzeng (Eds.), *Language processing in Chinese* (pp. 93–107). Amsterdam: North-Holland.
Jiang, S. D., Xin, R., Qian, Y. P., Lin, S. C., Tang, G. M., & Wang, D. Y. (1999). The relationship between ADHD and dopamine transporter 1 gene. *Chinese Journal of Mental and Nervous Disease*, *25*, 355–357.
Jiang, Y., Luo, Y. J., & Parasuraman, R. (2002a). Neural correlates for perceptual priming of visual motion. *Brain Research Bulletin*, *57*, 211–219.
Jiang, Y., Luo, Y. J., & Parasuraman, R. (2002b). Priming of two-dimensional visual motion is reduced in older adults. *Neuropsychology*, *16*, 140–145.
Kuo, W. J., Yeh, T. C., Duann, J. R., Wu, Y. T., Ho, L. T., Hung, D., Tzeng, O. J. L., & Hsieh, J. C. (2001). A left-lateralized network for reading Chinese words: A 3 fMRI study. *NeuroReport*, *12*, 3997–4001.
Law, S. P., & Leung, M. T. (2000). Sentence processing deficits in two Cantonese aphasic patients. *Brain and Cognition*, *72*, 310–342.
Li, B. M., & Kubota, K. (1998). Alpha-2 adrenergic modulation of prefrontal cortical neuronal activity related to a visual discrimination task with GO and NO-GO performances in monkeys. *Neuroscience Research*, *31*, 83–95.
Li, B. M., Mao, Z. M., Wang, M., & Mei, Z. T. (1999). Alpha-2 adrenergic modulation of prefrontal cortical neuronal activity related to spatial working memory in monkeys. *Neuropsychopharmacology*, *21*, 601–610.
Li, C. Y., Tanaka, M., & Creutzfeldt, O. D. (1990). Attention and eye movement related activation of neurons in the dorsal prelunate. *Brain Research, 496*, 307–313.
Liao, G. F., & Shen, Z. (1993). Effects of ambiguous figure recognized as either face or non-face stimulus on ERPs in human subjects. *Acta Psychologica Sinica*, *25*, 271–276.
Lin, W. J., & Tang C. M. (1985). Family environment, attention tests, and peripheral adrenaline secretion in hyperactive children. *Acta Psychologica Sinica*, *17*, 410–417.
Liu, Y. X., & Wang, Y. F. (2002). Cognitive functions of children with attention deficit hyperactivity disorder. *Chinese Medical Journal*, *82*, 389–392.
Luke, K. K., Liu, H. L., Wai ,Y. Y., Wan, Y. L., & Tan, L. H. (2002). Functional anatomy of syntactic and semantic processing in language comprehension. *Human Brain Mapping*, *16*, 133–145.
Luo, Y. J., Greenwood, P., & Parasuraman, R. (2001). Dynamics of the spatial scale of visual attention revealed by brain event-related potentials. *Cognitive Brain Research*, *12*, 371–381.
Luo, Y. J., Hu, S., Weng, X. C., & Wei, J. H. (1999a). Effects of semantic discrimination of Chinese words on N400 component of event-related potentials. *Perceptual and Motor Skill, 89*, 185–193.
Luo, Y. J., Jiang, Y., Lawsin, C., & Parasuraman, R. (2000). Electrophysiological effects of visual motion priming comparison with young and old subjects. *NeuroImage*, *11*, 791.
Luo, Y. J., Jiang, Y., & Parasuraman, R. (1999b). Neural mechanisms of visual motion priming revealed by event-related brain potentials. *NeuroImage*, *9*, 983.
Luo, Y. J., Jiang, Y., Tang, Y. Y., & Parasuraman, R. (2002). Neural mechanism of unconscious visual motion priming. *Chinese Science Bulletin,47*, 193–197.
Luo, Y. J., & Wei, J. H. (1997a). The cross-modal research on attention components of event-related potentials. *Acta Psychologica Sinica*, *29*, 92–100.
Luo, Y. J., & Wei, J. H. (1997b). The cross-modal study on ERP deviance-related components of Chinese language. *Acta Psychologica Sinica, 29*, 400–408.
Luo, Y. J., & Wei, J. H. (1997c). Mismatch negativity of ERP in cross-modal attention. *Science in China (Series C)*, *40*, 604–612.
Luo, Y. J., & Wei, J. H. (1999a). Cross-modal selective attention to visual and auditory stimuli modulates endogenous ERP components. *Brain Research*, *842*, 30–38.
Luo, Y. J., & Wei, J. H. (1999b). Event-related potential on the cross-modal identification of Chinese language. *Science in China (Series C)*, *42*, 113–121.
Luo, Y. J., Wei, J. H., & Brendan, W. (1999c). Effects of musical meditation training on auditory mismatch negativity and P300 in normal children. *Chinese Medical Sciences Journal*, *14*, 75–79.
Luo, Y. J., & Wu, Z. Y. (1990). Research on P300 component of auditory ERP in 175 normal persons. *Chinese Journal of Nervous and Mental Disease*, *16*, 272–275.
Luo, Y. J., & Wu, Z. Y. (1991). The assessment and dynamic

observation in rehabilitation course on the auditory P300 on patients with cognitive impairment. *Chinese Journal of Rehabilitation*, *6*, 58–62.
Mao, Z. M., Arnsten, A. F. T., & Li, B. M. (1999). Local infusion of an alpha-1 adrenergic agonist into the prefrontal cortex impairs spatial working memory performance in monkeys. *Biological Psychiatry*, *46*, 1259–1265.
Ou, L. Y., Tang, X. C., & Cai, J. X. (2001). Effect of huperzine A on working memory in reserpine- or yohimbine-treated monkeys. *European Journal of Pharmacology*, *433*, 151–156.
Peng, D., Yang, H., & Chen, Y. (1994). Consistency and phonetic-independency effects in naming tasks of Chinese phonograms. In Q. Jing, H. Zhang, & D. Peng (Eds.), *Information processing of the Chinese language* (pp. 26–41). Beijing: Beijing Normal University Press.
Peng, X. H., Wei, X., & Luo, Y. J. (2002a). Encoding mechanism of Eastern and Western face recognition revealed by ERPs. *Journal of Cognitive Neuroscience*, *(Suppl)*, 35–36.
Peng, X. H., Wei, J. H., Luo, Y. J., Zhao, L., & Wang, G. F. (2002b). Brain processing component during face cognition—N170 revealed by ERPs. *Space Medicine and Medical Engineering*, *15*, 303–304.
Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*, 3–25.
Seidenberg, M. S. (1985). The time course of phonological code activation in two writing systems. *Cognition*, *19*, 1–30.
Shen, Z., Zhang, W. W., & Chen, Y. C. (2002). The hole precedence in face but not figure discrimination and its neuronal correlates. *Vision Research*, *42,* 873–882.
Tan, L. H., Feng, C. M., Fox, P. T., & Gao, J. H. (2001a). An fMRI study with written Chinese. *NeuroReport*, *12*, 83–88.
Tan, L. H, Liu, H. L., Perfetti, C. A., Spinks, J. A., Fox, P. T., & Gao, J. H. (2001b). The neural system underlying Chinese logograph reading. *NeuroImage*, *13*, 836–846.
Tan, L. H., Spinks, J. A., Gao, J. H., Liu, H. L., Perfetti, C. A., Xiong, J. H., Stofer, K. A., Pu, Y. L., Liu, Y. J., & Fox, P. T. (2000). Brain activation in the processing of Chinese characters and words: A functional MRI study. *Human Brain Mapping*, *10*, 16–27.
Tang, Y., Zhang, W. T., Ma, L., Weng, X., Li, D., He, H., & Jia, F. (2002). The laterality of brain function in silent reading of Chinese words revealed by fMRI. *Acta Psychologica Sinica*, *34,* 333–337.
Tang, Y., Zhou, X., Weng, X., Ma, L., & Li, D. (2001). The similarity and differences of brain activation in naming pictures and reading Chinese characters. *NeuroImage*, *Suppl. 13,* S614.
Wang, H. J., Wang, Y. P., Kong, J., Cui, L. L., & Tian, S. J. (2001). Enhancement of conflict processing activity in human brain under task relevant condition. *Neuroscience Letters*, *298,* 155–158.
Wang, Q. S., & Zhou, J. N. (2002). Retrieval and encoding of episodic memory in normal aging and patients with mild cognitive impairment. *Brain Research*, *924*, 113–115.
Wang, Y., Zhou, X., Wang, Y., & Zhang, Y. (in press). Response inhibition in two subtypes of children with ADHD in a stop signal task. *Acta Psychologica Sinica.*
Wang, Y. P., Kong, J., Tang, X. F., Zhuang, D., & Li, S. W. (2000) Event-related potential N270 is elicited by mental conflict processing in human brain. *Neuroscience Letters*, *293*, 17–20.
Weekes, B. S., Chen, M. J., & Gang, Y. W. (1997). Anomia without dyslexia in Chinese. *Neurocase*, *3*, 51–60.
Wei, J. H. (1995). The paradigm of stimultaneous-like stimuli and delayed response. *Journal of Development in Psychology, 42*, 28–30 (in Chinese).
Wei, J. H., Chan, T. C., & Luo, Y. J. (2002). A modified oddball paradigm "cross-modal delayed response" and the research on mismatch negativity. *Brain Research Bulletin*, *57*, 221–230.
Wei, J. H., & Luo, Y. J. (1997). A hypothesis on plasticity of attention filter. *Acta Psychologica Sinica, Suppl*, 1–5.
Wei, J. H., & Tang, C. M. (1982). Effects of attention on the late components of human brain auditory evoked potentials. *Acta Psychologica Sinica*, *14*, 246–252.
Wu, W., Ye, X. J., & Luo, Y. J. (2003). Retrieving from recent and remote memories with Eastern and Western faces. *Journal of Cognitive Neuroscience*. (Suppl. 108).
Xiang, H., Lin, C., Ma, X., Zhang, Q., Bower, J., Weng, X., & Gao, J. (in press). Involvement of the cerebellum in semantic discrimination, A fMRI study. *Human Brain Mapping*.
Yang, J., Weng, X., Guan, L., Kuang, K., Zhang, M., Sun, W., Yu, S., & Patterson, K. (2003). Involvement of the medial temporal lobe in priming for new associations. *Neuropsychologia*, *41*, 818–829.
Yang, W. J., Chen, W. M., Huang, H. J., & Liu, M. T. (1993). A preliminary study of visual ERP in understanding of familiar photographs. *Acta Psychologica Sinica*, *25*, 415–418.
Ye, J. W., Cai, J. X., Wang, L. M., & Tang, X. C. (1999). Improving effects of huperzine A on spatial working memory in aged monkeys and young adult monkeys with experimental cognitive impairment. *Journal of Pharmacology and Experimental Therapeutics*, *288*, 814–819.
Zhang, X., Wang, Y. P., Li, S. W., Huang, X. Z., & Cui, L. L. (2002). Early detection of cognitive impairment in patients with obstructive sleep apnoea syndrome, an event-related potential study. *Neuroscience Letters*, *325*, 99–102.
Zhou, J., Zhang, H. Y., & Tang, X. C. (2001). Huperzine A attenuates cognitive deficits and hippocampal neuronal damage after transient global ischaemia in gerbils. *Neuroscience Letters*, *313*, 137–140.
Zhou, X. (2000). Phonology in lexical processing of Chinese: Priming tone neighbours. *Psychological Science*, *23*, 133–140.
Zhou, X. (2002). Processing Chinese words and characters. In S. Lesen (Ed.), *Gutenbergs Folgen* (pp. 215–237). Baden-Baden, Germany: Nomos Verlagsgeellschaft.
Zhou, X., Bai, X., Shu, H., & Qu, Y. (1998). Non-semantic anomia: A case study of a Chinese brain-damaged patient. *Psychological Science*, *21*, 193–196.
Zhou, X., & Marslen-Wilson, W. (1999a). The nature of sublexical processing in reading Chinese characters. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *25*, 819–837.
Zhou, X., & Marslen-Wilson, W. (1999b). Phonology, orthography, and semantic activation in reading Chinese. *Journal of Memory and Language*, *41*, 579–606.
Zhou, X., & Marslen-Wilson, W. (2000a). The relative time course of semantic and phonological activation in reading Chinese. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 1245–1265.
Zhou, X., & Marslen-Wilson, W. (2000b). Lexical representation of compound words, Cross-linguistic evidence. *Psychologia*, *43*, 47–66.
Zhou, X., Tang, Y., Weng, X., Ma. L., & Li, D. (2001). Brain activation in reading regular and irregular Chinese characters. *NeuroImage (Suppl), 13*, S634.