Frontier and Evolution of Cognitive Neuroscience Based on Cognitive Psychology

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Keywords: Cognitive psychology; Cognitive nerve; Frontier of science; Evolutionary research

Abstract: In the 1950s and 1960s, with the joint efforts of psychologist George Miller, linguist Chomsky, Turing Award winner Newell, and artificial intelligence expert Herbert Simon, cognitive science Initial formation. In the late 1970s, George Miller and Gazaniga jointly proposed "cognitive neuroscience." The theoretical foundation of cognitive science is based on experimental psychology, neuropsychology and neuroscience, and cognitive science and neuroscience are initially integrated. The application of functional magnetic resonance imaging, electroencephalography, magneto encephalography and positron emission tomography has greatly promoted the development of cognitive neuroscience. Cognitive neuroscience has attracted great attention from all over the world. The United States took the lead in launching the "Ten Years of Brain" research program. Subsequently, the European Community, Japan and other developed countries successively launched large-scale research programs such as the "Brain Science Program" and the "International Human Frontier Science Program". Cognitive neuroscience has become an important frontier field for scientific competition in developed countries.

1. Introduction

The 21st century is "the century of the brain", and brain science is the frontier discipline of contemporary world science [1]. The past ten years have been called "the decade of the brain". In these ten years, cognitive psychology and neuroscience have been fully integrated and gradually formed a brand-new discipline-cognitive neuroscience [2]. Neuropsychology is a discipline that studies the neural mechanism of advanced cognitive function or psychological activity. It studies the relationship between brain and psychological activity or cognitive function from a neurological perspective [3]. Cognitive psychology is an experiment-based science that studies cognitive activities from the perspective of information processing. It is often established by a cognitive processing model composed of different cognitive elements [4]. It combines with neuroscience to form cognitive neuroscience, while cognitive psychology and neurology combine to form cognitive neuropsychology [5]. It has become an important development direction of neuropsychology and is also one of the most active disciplines in the "brain science era". China is facing an important opportunity to develop cognitive neuropsychological research [6].

After 20 years of rapid development, cognitive neuroscience has made great progress and achievements in both basic theories and research methods [7]. Cognitive neuroscience is a frontier discipline aiming at revealing the neural basis of brain cognitive function [8]. Patients with abnormal cognitive ability are taken as the research object, and the normal cognitive processing mode and neural basis of human beings are deduced through their specific damage and reserved cognitive structures and functions [9]. Due to the use of brain injury patients in experimental cognitive neuroscience research, it is also called cognitive neuroscience based on brain injury patients [10]. At present, relevant research has gradually entered an interdisciplinary and multi-level era of "gene-molecule-cell-loop-behavior", revealing the working principle of brain cognitive function from molecular, cell level to system and overall level [11]. Cognitive neuroscience research has strongly promoted the development of psychology and constructed psychological theories inspired by the exploration of cranial nerve mechanism of cognitive behavior, which is the real academic significance of cognitive neuroscience research to psychological research [12].

  DOI: 10.25236/cstss.2019.026

2. Contents and Significance of Cognitive Neuroscience Research

2.1. Evolution of Cognitive Neuroscience

The human brain is one of the most complex systems in nature and a great miracle of intellectual evolution. Exploring the brain and revealing the neural mechanisms of brain cognitive function is the greatest challenge for human beings to understand nature, to know themselves, and to transform the world. Humans have been studying brain-intellectual relationships for thousands of years. Most of the past studies are philosophical speculative discussions or simple empirical observations. Since the 1960s, psychology has been combined with cognitive science. The researchers obtained a large amount of data by measuring human behavioral responses and proposed many theories about human psychological activities. These theories enrich people's understanding of their own psychological activities. At the same time, these theories also have a wide range of influence in other research fields, such as computer vision, artificial intelligence, medicine, etc. In the past 30 years, the science of human cognition has undergone dramatic changes. Psychologists use the knowledge and technology of neuroscience, and neuroscientists are also using the experimental paradigm of cognitive psychology to develop a new discipline-cognitive neuroscience.

At present, cognitive neuroscience research has gradually entered the interdisciplinary and multi-level era of “gene-molecular-cell-loop-behavior”, revealing the working principle of brain cognitive function from molecular and cellular levels to systematic and overall levels. Constantly introducing new theories and methods, trying to establish a cognitive function network model in the brain interval, systematically revealing cognitive processes and their neural mechanisms from micro to macro. Cognitive neuroscience should be oriented towards the future, with the neural mechanism of brain cognition as the main body. At the same time, new methods of diagnosis and treatment of major brain diseases and new technologies of brain-like intelligence are developed in order to achieve breakthroughs in the three frontier fields of brain science, early diagnosis and intervention of brain diseases, and brain-like intelligence devices. Through the efforts of the past few decades, Chinese researchers have made many important research advances in cognitive neuroscience, but they have not yet reached the international leading level in many fields. Therefore, it is extremely necessary for our country to seize the opportunity, increase investment and plan and implement the development strategy of cognitive neuroscience in the next stage.

2.2 Significance of Cognitive Neuroscience Research

Cognitive neuroscience is a frontier subject aiming at revealing the neural basis of brain cognitive function. The breakthrough in cognitive neuroscience is of great significance to the advancement of human society. In terms of social development, the analysis of cognition and thinking principles will provide scientific basis for the development of national intelligence and educational reform and help to enhance the innovation ability of the whole people. The deep integration of cognitive neuroscience with computer technology, mathematics, information, electronics, materials and nanoscience will help solve the problem of intelligent man-machine interface. The emerging new brain-computer intelligent technology is expected to promote the development of science and technology and new industries in the future and push human society into an intelligent era. In terms of population health, cognitive impairment such as elderly neurodegenerative diseases, mental illness in middle-aged people, and mental retardation in children puts a heavy burden on society. An analysis of the neural mechanisms of these cognitive dysfunctions will help develop relevant early diagnosis and early interventions.

In terms of national defense and information security, informatization and intelligent target recognition systems can draw on the achievements of cognitive neuroscience research. Progress in brain cognitive science and brain-like intelligence is related to human health and well-being. It is expected to reshape the pattern of medical, industrial, military and service industries and enhance the country's core competitiveness. Starting from the famous “Ten Years of Brain” program in the 1990s, Europe, America, Japan and other countries have set off an upsurge in brain science research. A large brain research program has been launched. For example, in 2013, the United States and the European Union proposed a new brain science research plan almost simultaneously. Japan launched

a brain plan in 2014. In 2016, more than 60 neuroscientists from many countries in the world discussed it in the United States. Carry out global cooperation in brain science and promote the construction of the “International Brain Space Station”. The Chinese government has always attached great importance to the development of brain science. Since the early 1980s, the Shanghai Brain Research Institute of the Chinese Academy of Sciences has been established. Many studies related to brain function and brain diseases have been included in the national key basic research planning projects.

3. Neuroscience Research Based on Cognitive Psychology Theory

3.1 The Relationship between Cognitive Psychology and Cognitive Neuroscience

In the field of psychology research, cognitive psychology and experimental psychologists explore and interpret cognitive mechanisms at the overall level of behavior, and propose different theoretical models or hypotheses. However, it is often difficult to reach agreement with each other and fall into the controversy. Nowadays, cognitive neuroscience research can go beyond the limitations of traditional behavioral experiments, break the “black box” of internal psychological function that was previously unobservable, and verify or correct existing theories based on research findings in line with biological reality. Such research can provide effective solutions for theoretical debates that cannot agree, and it is also conducive to the unification and integration of various theories. Cognitive psychology covers a wide range of fields, ranging from the study of individual nerve cells to social cognition. The research scope of cognitive psychology probably includes sensory perception, memory, attention, language, thinking, etc. To some extent, cognitive neuroscience is included in cognitive psychology.

3.2 Cognitive Psychology and Neuroscience

Cognitive neuroscience is characterized by its emphasis on interdisciplinary, multi-level and multi-level intersection. The purpose of the study is to clarify the brain mechanism of cognitive activities, that is, how the human brain invokes its components at all levels. Include molecules, cell brain tissue regions and the whole brain to realize various cognitive activities. Cognitive neuroscience advocates the use of cognitive psychology and neurobiological methods to study the biological mechanisms of complex higher neural functions such as movement, consciousness, attention, language, learning and memory. It organically combines behavior, cognition and brain mechanism. The view comprehensively expounds the information processing process and neural mechanism of human and animal in perceiving objects, forming appearances, using languages, memorizing information and reasoning and decision-making from the micro-level of molecules, graph contacts, neurons and the macro-level of systems, whole brain and behavior. At present, an important development in cognitive neuroscience is that it uses neuroimaging technology to perform noninvasive functional imaging on brain activity patterns of normal people during certain cognitive operations.

Brain functional imaging techniques can be divided into two categories, one is brain function imaging based on brain metabolism or cerebral blood flow changes, and the other is brain physiological function imaging based on brain or brain magnetic signals. At present, the two types of research use a lot of block design experimental paradigm, which is suiTable for the study of advanced functions such as thinking. It should be said that the important conceptual breakthrough brought about by the rise of cognitive science in the 1950s is that it transcends the narrow view that behaviorism denies the mind. Throughout the development and evolution of cognitive paradigm to cognitive neuroscience paradigm. It is not difficult to see that in the process of its uneven exploration, it is always based on Descartes' “dualism” concept. The esteem of the spirit of the natural sciences has always been its unchanging tone, and the humanistic spirit and cultural codes of practice have become increasingly subtle. The paradigm review and the voice of cultural reflection have never stopped. This reflects and reflects the transformation of the overall paradigm of psychology research and the deepening of human mind exploration.

4. Research and Analysis of Cognitive Neuroscience in Recent Years

4.1 Cellular basis of cognitive function

The brain is made up of neurons and glial cells, which are the cellular basis of cognitive function. Neurons and glial cells are not only large but also numerous. Significant progress has been made in the study of cell classification and functional categories of neurons and glial cells. In recent years, single-cell RNA sequencing technology has developed rapidly, and this technology has also been successfully introduced into neuronal type identification. For example, the research team of the Shanghai Institutes for Biological Sciences of the Chinese Academy of Sciences has achieved the classification of somatosensory neurons by high-throughput RNA sequencing. At present and in the future, a trend is to start with the cell morphology of the neuron, record the electrophysiological properties of the neuron through patch clamp technology, and then suck out the neuron for single cell RNA sequencing. The comprehensive utilization of these technical means can realize the systematic classification of neurons from the aspects of cell morphology, RNA expression spectrum and electrophysiological properties of neurons, which is helpful for in-depth understanding of the specific role of the neurons in the cognitive function network.

4.2 Neurological mechanisms of emotional and cognitive impairment

Emotion is a psychological and physiological state that is produced by a combination of feelings, thoughts, and behaviors. The basic neural pathways of emotions, the amygdala-ventral medial prefrontal cortex and the function of the amygdala, have been extensively and deeply explored, but the neural networks of different emotions have yet to be further understood. For example, the neural loop analysis based on visual, auditory, and olfactory instinctual behavior has made important progress in recent years, which will help us understand important psychological activities such as fear and anxiety. Such abnormal emotional activities are the causes of many behavioral and mental or psychological disorders, such as depression, anxiety, and post-traumatic stress disorder. At the same time, emotional abnormalities and anxiety are accompanied by the development of most physical and mental diseases. The current research trend is to explore the neural mechanisms of emotions and interactions with other cognitive functions at the level of neural circuits, systems, whole brains, and behaviors by integrating the latest brain function imaging, gene and cognitive experiment techniques.

Alzheimer's disease is a neurodegenerative disease characterized by a general decline in cognitive function, a decline in the ability of daily living until it is eventually lost, accompanied by mental and behavioral disorders. Accounting for 60%-80% of the total number of dementia. In the past 10 years, following the development trend of the world, Chinese scholars have mainly used multi-modality MRI to find objective markers for AD diagnosis, and have also obtained some relatively consistent findings. For example, the hippocampal function and its connection in patients with MCI and AD are decreased, and the network function in the default mode of posterior cingulate gyrus is decreased, which develops and aggravates with the course of the disease. However, IWG-2 put forward the latest diagnostic standard in 2014. Regardless of typical or atypical AD, except for the core cognitive impairment, only two biomarkers related to β deposition and neuronal damage are used as diagnostic reference. Therefore, especially in China, it is necessary to solve how to further utilize the massive data of multi-modality MRI and diagnose AD at an early stage. There are also problems such as how to promote the clinical application of the above two types of diagnostic biomarkers, and how to find clinically feasible biomarkers again.

4.3 Research and Development of New Technologies in Cognitive Neuroscience

The development of cognitive neuroscience cannot be separated from the development and application of new technological means. In recent years, new technologies for studying the structure and function of the nervous system have emerged continuously at the micro, meso and macro levels, and have been applied in cognitive neuroscience research. At the microscopic and mesoscopic levels, mapping the brain is the core content or structural basis of all current international brain programs. Firstly, ultra-micro imaging technology has been applied to analyze the heterogeneity of

synapse structure and function. At present, the basic principles of molecular and cellular biology, genetics, virology, neurobiology and other disciplines have been utilized to develop and establish technical methods and tools that can be used to study the structure and function of neural circuits with neurophilic viruses as probes. Meet the initial needs of relevant research. The optogenetic technique combining optical, genetic manipulation and electrophysiological techniques has become an important means of understanding the function of specific neural circuits and thus understanding cognitive functions. In addition, high-throughput optical imaging is applied to the analysis of neural mechanisms of cognitive function.

At the macro level, a completely new atlas of human brain, namely the atlas of brain network group, is drawn based on the brain anatomical connection mode. It not only includes 210 cerebral cortex regions and 36 subcortical nuclei sub-region structures, but also quantitatively depicts the anatomical and functional connection modes of different brain region sub-regions in vivo, and gives a detailed functional description of each sub-region. For example, the brain network foundation of advanced cognitive functions such as memory, language and emotion are analyzed on a macro scale. At the same time, the fusion of brain stimulation and brain imaging technology has been successfully applied to the research of neurophysiology and brain and cognitive science, especially to the diagnostic evaluation and rehabilitation technology of cognitive impairment. The fusion of brain stimulation and brain imaging technology is not a simple technology stack, but needs to overcome many technical problems and some new scientific problems. Including the synchronization and mutual interference between brain stimulation and brain imaging technology, the neurobiological mechanism of brain imaging under brain stimulation, and how to apply brain stimulation and brain imaging fusion technology in the diagnosis and treatment of various cognitive disorders.

5. Data Analysis of Cognitive Neuroscience

5.1 Data acquisition and analysis tools for cognitive neuroscience

In the Web of Science database, the term “cognitive neuroscience” is used as the retrieval term, and the retrieval scope is “subject”. the document type is article or proceeding paper or review or meeting Abstract, with a time span of 1985-2018. the database = sci-ex-panded, cpci-s, IC, CCR-expanded, with a total of 1192 records detected. The date of data acquisition is September 26, 2018. Cognitive neuroscience research emerged in the 1990s, and the single WoS database only began to collect data in 1995. Figure 1 shows that the number of cognitive neuroscience documents is increasing obviously, and the discipline is developing vigorously. The Journal of Cognitive Neuroscience, published by the Massachusetts Institute of Technology, ranks first in terms of literature sources. It, together with four other magazines such as Neuroimage and Trends in Cognitive, covers more than 20% of the literature in this discipline and has become an important window to show the research progress in cognitive neuroscience. In addition, CitesSpaceII software is selected as a knowledge map analysis tool. When analyzing data, the value of “time slicing” is selected as 2, i.e. every two years is selected as a time interval for processing. Segmented processing is beneficial to identify the prominent inflection point of discipline evolution and the dynamic mode of discipline foreword, while improving the speed and accuracy of software operation.

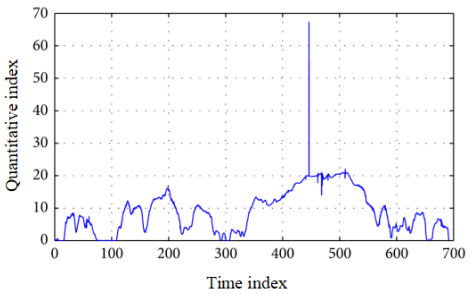

Fig.1. the Increase in the Number of Cognitive Neuroscience Documents

5.2 Cognitive Neuroscience Data Analysis Results

CiteSpaceqI software can make users easier to identify key points. It is highlighted with purple outer circles in the visual network. Identifying key points can quickly grasp a few meaningful key points for research. Keyword analysis based on salience frequency can reveal hot research topics. Figure 2 shows that cognitive neuroscience has become a hot research area from the overall level. Previously, frontal cortex, brain and activation-based neuroscience conducted material activity research from a smaller subsystem level. Cognitive science, which focuses on memory and attention, focuses on the relatively complex level of holistic behavior. They show the specific footholds of cognitive neuroscience research in two directions. As a non-invasive nuclear medicine imaging technology, PET is a node and link connecting cognitive science and neuroscience. As an important tool for cognitive neuroscience research, PET has also been shown as a pivot node in the map. In addition, through the literature co-citation network map, the cited documents can be sorted and centered.

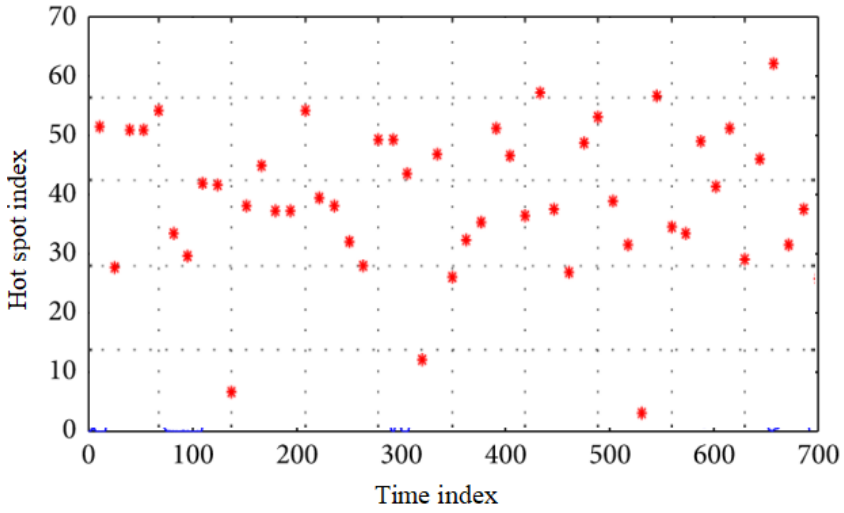

Fig.2. Hotspot Analysis of Cognitive Neuroscience Research

6. The Frontier of Cognitive Neuroscience

Cognitive psychology is an experiment-based science that studies cognitive activities (including language, memory, thinking, etc.) from the perspective of information processing. It often establishes cognitive processing models composed of different cognitive elements. It combines with neuroscience to form cognitive neuroscience, while the combination of cognitive psychology and neurology has become cognitive neuropsychology, which has become an important development direction of neuropsychology and is also one of the most active disciplines in the “brain science era”. The development of cognitive neuropsychological research in China faces an important development opportunity. The purpose of cognitive neuropsychological research is to investigate and develop the cognitive psychology theory and model of normal people, and to establish a cognitive neurobiology model, which can also provide psychological experiments for the diagnosis and rehabilitation of the disease. in accordance with. The basic research method is to find the separation between different cognitive functions, including single separation and two-way separation, while the latter is the most important basis for establishing cognitive neurobiological models.

6.1 Cognitive Neuropsychology of Memory

Cognitive psychology divides the process of memory processing into three processes: encoding, storage and extraction, and puts forward some cognitive models related to memory. Atkinson and Shiffrin's memory model, Baddeley's working memory model and Squire's theory of multiple systems of memory. On the basis of psychological models and neuropsychological research evidence, Alvarez and Squire proposed a neurobiological model of medial temporal lobe related to

memory. It is believed that MTL is a temporary storage point for information processing, which is responsible for encoding the processing information of primary and secondary cortex step by step and then projecting it to neocortex. Long-term storage of information forms long-term memory. Later, cognitive neuropsychological research found that patients with hippocampal damage not only have long-term memory damage, but also the long-term memory damage presents reverse temporal gradation. In other words, the longer the memory is preserved, the better, while the closer the memory damage is, the more obvious it is. Based on this cognitive neuropsychological evidence, a memory model of multiple traces of hippocampal complex is proposed. A large number of recent studies have shown that frontal lobe is involved in various processes of memory coding, such as monitoring of memory coding extraction and memory of background information related to memory objects.

6.2 Cognitive Neuropsychology of Emotional Processing

Emotion plays an important role in the evolution of human beings. Emotion cognition and its neural mechanism have attracted extensive attention in cognitive science. Ekman believes that only a few emotions are basic and have significant biological evolutionary significance and cross-cultural consistency. The basic emotions include joy, surprise, fear, sadness, disgust and anger. The traditional neurobiological model of emotions holds that Papez loop or limbic system is the center of various emotional processing. Recently, it has been suggested that the frontal striatal cortical circuit is also responsible for emotional processing. In the past 10 years, with the establishment of quantitative emotional face research methods and the research on information processing at the level of consciousness, the research on “emotion and brain” has been revived. At present, cognitive neuropsychological research on emotion processing mainly focuses on whether there are special brain mechanisms or bases for different emotions and which brain structures are involved in the special brain mechanisms of such emotions. This research has just begun and has become the forefront of neuroscience and cognitive science research.

The prefrontal cortex plays an important role in the regulation of emotions. The study found that patients with frontal atrophy of the frontal lobe had normal ability to discriminate on the face, and there were obvious obstacles to the discrimination of the six basic emotions. And this emotional cognitive disorder is non-selective. The evidence here suggests that the neural mechanism of emotional learning is quite complex, except for the amygdala, which is related to the cingulate gyrus, basal ganglia, insular and frontal lobe. This hypothesis, on the one hand, may lead to modifications to traditional emotional cognitive neurobiological models, but on the other hand requires more support from cognitive neuropsychological evidence. Our recently published cognitive neuropsychological studies have shown that unilateral amygdala and bilateral cingulate gyrus injury can also lead to selective fear processing disorders. Patients with Wilson's disease have a disgusting discrimination, while right iliac-parietal or frontal lobe damage leads to a general barrier to various emotional processes. These cognitive neuropsychological evidences, such as those combined with brain function imaging studies, will be of great importance for understanding the neural mechanisms of emotional cognitive processing.

6.3 Cognitive Neuropsychology of Attention

Attention is the direction and concentration of certain information and objects by psychological activities or consciousness, and it is also the process by which the brain properly allocates the resources related to sensory stimulation processing. With the rise of cognitive psychology, attention research has received extensive attention and has become an important field of cognitive psychology research. The basic characteristics of attention are concentration and selectivity, which include 4 sub-components. They are attention orientation, selective attention, scattered attention and maintenance attention. The cognitive model hypothesis of attention is perceptual selection model such as filtering model and attenuation model, response selection model and central energy theory hypothesis. In the early 1980s, Treisman proposed a feature integration model that closely integrated the internal processes of attention and perceptual processing. Paying attention to the network and its neurobiological mechanisms, Posner et al., after summarizing brain function

imaging studies and neuropsychological findings of brain damage in animals, considered attention as a network system involving a wide range of brain structures. Some neuropsychological studies such as schizophrenia will further support the attention network hypothesis and the neurobiological model of the attention network.

Recently, the research on the neural mechanism of attention and consciousness is getting hotter and hotter. The research on attention has combined psychology and neuroscience, and neuropsychology should make great achievements in this field. Descriptive neuropsychological studies on Gerstmann syndrome, attentional regression and neglect manifested by patients with parietal lobe damage have established the role of parietal lobe in visual spatial structure processing. Recent studies have shown that many viewpoints and methods in normal attention studies can be widely applied to patients with attention deficit. Comparing the information ignored on the left side of the patient with the unattended information of the normal person, the patient's neglected information is processed in the same way as the normal person does not pay attention to the information processing, and the result shows that the reaction of the right side stimulus is ignored by the left side. influences. By appropriately combining the presented stimuli, the researchers enter the consciousness of the left side of the patient, which will greatly reduce the visual neglect. Therefore, the combination of processing should be fully developed and utilized to promote the rehabilitation of patients with neglect.

7. Conclusion

The development of cognitive neuroscience will play an unprecedented and powerful role in promoting the development of psychological science in our country. Compared with the innovation of research technology, the innovation of research ideas and research paradigms is more critical to whether the interdisciplinary research of psychology and cognitive neuroscience has made significant progress. Cognitive neuroscience should adopt a “top-down” analysis approach to explore the “relationship between spirit and brain”. Instead of a “bottom-up” reductionist approach. What is observed by brain cognitive imaging technology is the neurophysiological activities of cranial nerves accompanying psychological phenomena. Cognitive neuroscience is a frontier subject in the study of brain mechanisms. The study of brain neural mechanisms of memory, emotions and attention is a hot topic in the field of cognitive neuroscience in the “century of the brain.” With the enhancement of China's comprehensive national strength and the increase of scientific research input, new technologies and advanced research conditions will be owned by more and more researchers. As neuropsychologists, we face opportunities and challenges. It has unique conditions to carry out cutting-edge research in cognitive neuroscience, and contributes to the ultimate solution to the mystery of the brain.

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