Language Research in The Third Generation of Cognitive Science

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Abstract

The third-generation cognitive science adopts the method of imaging and simulating the human brain, whereby it uses high-tech brain imaging technology and computer neural simulation technology to explain the complex relationship between human cognitive activity, language ability and brain nerves, and reveal the secrets of the advanced functions of the human brain. Based on the third-generation cognitive science, this paper introduces the neural mechanisms of language production and language processing and reveals the interrelationship between language research and neural simulation under the third-generation cognitive science.

Keywords

Third-generation cognitive science, neural mechanisms of language, three research directions

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1. Introduction

In the 1950s, a "cognitive revolution" broke out in Europe and the United States, and an emerging discipline-cognitive science-was born. Cognitive science is the science that studies the information processing process of human beings from sensory thinking, including from sensory input to solving complex problems, intelligent activities from human individuals to human society, and the nature of human intelligence and machine intelligence (Shi Zhongzhi *et al*., 1990). In 1995, Daniel Osherson pointed out in his opening remarks for An Invitation to Cognitive Science (Volume 1) that cognitive science is a discipline that studies various forms of human intelligence, from perception and behavior to language and reasoning (Wang Yin, 2002). Lakoff & Johnson (1999) in their co-authored book "Philosophy of Experience", Lakoff & Johnson further clarified that cognitive science is the science of studying conceptual systems, the science of studying intelligence based on experience, and divides cognitive science into first-generation cognitive science and second-generation cognitive science. The first generation of cognitive science began in the 1950s and accepted the traditional British-American analytical philosophy (analytical philosophy) viewpoints, advocating dualism, symbolism, symbolic arbitrariness, meaning representation theory, and non-metaphorical meaning. Dualism believes in the separation of body and mind and advocates the study of the mind under the condition of separation of body and mind, and only describes the functional relationship represented by symbols. Symbolism believes that the basic unit of human intelligence is symbols, and the cognitive process is based on symbols. Various forms of thinking are based on the formal operation of symbols, regardless of the meaning of symbols; the arbitrary view of symbols advocates the separation of symbols and meanings, and the two are an arbitrary relationship; meaning representation theory believes that the representation of the mind is symbolic, and meaning can be obtained based on the relationship between symbols or the correspondence between symbols and the outside world; non-metaphorical meaning means that all meanings are not produced based on metaphors and imagination.

The second generation of cognitive science appeared in the 1970s. It was based on the phenomenology of Husserl and Merleau—Ponty and believed that the essence of the mind originated from the experience of the body. Therefore, the experiential nature of the mind, the unconscious nature of cognition, and the metaphorical nature of thinking have become its philosophical views. The experiential nature of the mind believes that human categories, concepts, reasoning, and minds are not objective and true reflections of the external world but are obtained and formed by one's own physical experience and are formed by the human sensorimotor system (sensorimotor system) (Piaget, 1972). The most basic form of most human reasoning relies on the concept of topology in space. The interaction of the body, brain, and environment provides a cognitive basis for daily reasoning. Leccoff and Johnson (1999: 497) pointed out: "Concepts are formed through the body, brain, and experience of the world, and can only be understood through them. Concepts are obtained through experience, especially through perception and muscle motor ability". Therefore, the concept of space and body parts are the basis for us to form abstract concepts. The unconscious nature of cognition believes that people have no direct perception of what they think and think in their minds. Even understanding a simple discourse requires many cognitive processes and neural processing processes. Sensory neural processing processes such as vision, hearing, and smell cannot be realized, and most reasoning cannot be realized. The human category is conceptualized according to an archetype. An archetype is a neural structure that allows us to reason and imagine related to this category. The metaphorical nature of thinking points out that metaphors are based on physical experience, and the relevance of people's daily experience will guide people to obtain basic metaphors. It is the product of the body, experience, brain, and mind, and gains meaning through experience. Metaphor makes most abstract thinking possible. Its basic role is to map reasoning from the origin domain to the target domain. Most reasoning is metaphorical. Metaphor is a characteristic of human thinking and exists in human culture and language (Wang Yin, 2002). Both the first-generation cognitive science and the second-generation cognitive science believe that language and cognition exist in the human brain, but there are fundamental differences between the two on the source of intelligence, the method of characterization, the content of research, and the conclusions drawn. So, how to understand and define cognitive science? Why is there such a big difference in language research between the two generations of cognitive science?

2. Definition of Cognitive Science

In order to better understand the third-generation cognitive science and reveal the mystery of the interrelationship between neural simulation and language research, it is necessary for us to introduce the definition of cognition, the hierarchical nature of cognition, and the main contents of cognitive science research.

2.1 Definition of Cognition

The word cognition comes from Latin and refers to the process by which a person acquires knowledge or learns. Gui Shichun (1991) believes that the simplest definition of cognition is the acquisition and use of knowledge, which is an internal psychological process. Yuan Yulin (1996) believes that cognition is the most advanced information processing process of the human brain, which runs through complex human behaviors such as problem solving, concept formation, and language understanding. The most essential feature of cognitive activities is the use of knowledge to guide people's current attention and behavior. It involves (1) the acquisition, characterization and transformation of information into knowledge, (2) the memory (storage and extraction) of knowledge, (3) The use of knowledge for reasoning and other psychological processes. "Cihai" (1999 edition) is interpreted as: "Cognition is acknowledgement, which refers to the activity of recognizing objective things and acquiring knowledge." Peng Qingling *et al.* (2004) pointed out that people's acquisition and application of knowledge depend on a series of human psychological activities, such as perception, attention, memory, learning, thinking, decision-making, problem-solving, understanding, and language generation. The general term for these psychological activities is cognition. Lekov and Johnson (1999) pointed out that cognition not only covers a wealth of content, such as mental arithmetic, mental structure, meaning, conceptual system, reasoning, etc., but also should include sensorimotor systems that can contribute to human conceptualization and reasoning ability.

2.2 Hierarchical Nature of Cognition

Zhao Nanyuan (2002) divides various concepts related to cognition into 7 levels and 4 stages, namely physical stage, physiological stage, psychological stage, and cultural stage:

The first level is the biophysical and biochemical levels at the physical level. This level is separated from the psychological level, so it is extremely difficult to directly use physical or chemical principles to explain cognition; the second level involves the physiological level and the physical level, and the central content is to study the characteristics of individual neurons, the information transmission between neurons and other neurons, and the information processing inside neurons; the third level is the physiological level of the neuron network level. At this level, there are two aspects of neurophysiology and artificial neuronal networks. They are closely related, refer to each other, complement each other, and verify each other; the fourth level is the neural network group level. The concept of this level is relatively broad, involving psychological and physiological levels. In terms of functions, this level discusses the basic functions of the psychological level, such as classification and pattern recognition, action pattern generation, local prediction, intelligent models, etc.; The fifth level is the consciousness level, which is at the center of the psychological level, and the research issues are basically the same as the psychological research level. The main problems of consciousness-level research are high-level neural activities such as consciousness, emotion, perception, behavior, and thinking, and try to explain these activities on a lower-level principle, so that clues to the mechanisms required to construct these functions can be obtained through analysis; the sixth level is the language level, which involves the psychological level and the cultural level, and is related to the mechanism of the cognitive system. This level mainly studies language, symbolic representations, skills, etc. Symbolic representation is the promotion of language concepts, including various expressions such as poses, graphics, and expressions, as well as the ability to understand these representations. Language is only a special case of symbolic representation. Skill is a proficient behavior produced by complex organized actions. The ability to represent symbols or use language is also a skill. The ability to master language depends on the language center of the human cerebral cortex and the motor center that operates the vocal organs, but which language is spoken depends on cultural and environmental factors. Therefore, language ability is biologically inherited, while specific language structures arise from cultural evolution. The same is true for other skills, including symbolic representation, which depend on the cognitive system or brain structure on the one hand, and on the cultural environment on the other; the seventh level is called the logical level, which belongs entirely to the cultural level. This level includes all cultural phenomena such as logic, science, religion, and art. It emphasizes that logic is the product of cultural evolution and the superstructure of cognition.

2.3 Content of Cognitive Scientific Research

Gui Shichun (1991) pointed out in the article "Cognition and Language" that cognitive scientific research focuses on all aspects of cognition, and the most basic is the human intelligent system and other properties. The Strategic Development Research Group of the Institute of Psychology, Chinese Academy of Sciences (2001) defines cognitive science as "a science that studies the nature and laws of intelligence of humans, animals, and machines. The research content includes advanced psychological phenomena such as perception, learning, memory, reasoning, language understanding, knowledge acquisition, attention, emotion, and general consciousness."

Cognitive science is the interdisciplinary research and discussion on mind or intelligence. Mind refers to people's mental abilities such as perception, attention, memory, learning, thinking, understanding, and thinking innovation; intelligence refers to the mental ability to use knowledge to solve problems such as judgment, reasoning, and imagination.

Shen Jiaxuan (2004) and Wang Yin (2005) believe that people's understanding of cognition can be divided into narrow, broad and high-level understanding. In a narrow sense, cognition is equivalent to the process of information processing. It is the psychological processing of symbols. Cognition is broken down into a series of stages such as perception, memory, imagination, speech, and problem solving or thinking. Each stage can be assumed to be a unit. These units perform specific operations on the input information. The broad understanding is that cognition is the same as cognition, which refers to the human brain reflecting the essential attributes and internal connections of objective things and is a psychological activity that explains the meaning and effect of things on people. High-level understanding believes that cognition is a system that accepts new knowledge based on the old knowledge structure. It is the process by which the old knowledge structure changes and develops accordingly after the new knowledge is accepted and absorbed by the old knowledge structure. It is a kind of psychological ability to learn from the past and use existing knowledge to solve problems. This kind of mental ability is equivalent to the four processes of "pattern— similarization— adaptation— balance" in Piaget's book "Principles of Epistemology of Occurrence".

3. Third-generation Cognitive Science

In 2004, Howard proposed two new concepts of third-generation Scientific Cognition and imaged and simulated brain in his book "Neuromimetic Semantics". The third-generation cognitive science uses high-tech brain imaging technology and computer neural simulation technology to explain the complex relationship between human cognitive activity, language ability and brain nerves, and reveal the secrets of the advanced functions of the human brain. As the human nervous system is a basic unit composed of neurons or nerve cells, the nervous system is divided into the central nervous system and the peripheral nervous system. The brain is the supreme command of the central nervous system, divided into two hemispheres, left and right, including the surface nerve cell layer and the deep nerve cell nucleus. A complex psychological process requires three basic functional areas to work together. These three areas are divided into: a joint area to ensure the regulation of tension and awakening, a joint area to accept, process, and preserve information about the external environment, and a joint area to formulate procedures, regulate, and control psychological activities. Human neural activity is a biochemical process, and language-related neural activity provides relevant content and research scope for language neural research.

The three major paths of language research under the third-generation cognitive science: neurocognitive linguistics research, cognitive neural simulation research, and brain imaging technology research.

3.1 Research on Neurocognitive Linguistics

The research scope of neurocognitive linguistics involves the neuropsychology of speech formation, speech understanding, and speech communication. There are changes in speech processes when the brain is partially damaged. Its main goal is to understand and explain the neural basis of language and speech and explore the mechanisms and processes of language use.

In the process of the creation and development of neurocognitive linguistics, Lamb (Lamb, 1998) made great contributions. His theoretical development has gone through four important periods: the hierarchical period, the relational network period, the cognitive period, and the neural period. In the neurocognitive linguistics camp, the more influential scholars include Peter Reich, Lockwood and Makkai. Although their research have their own points and their theoretical perspectives are different, their research and discoveries have enriched and developed the theory of neurocognitive linguistics. In China, Professor Cheng Qilong (2001) has been devoted to studying the theory of neurocognitive linguistics. He critically inherited Lamb's theoretical model, advocated the unified research ideas of theory-driven and corpus-driven opposition in the theoretical framework of the three basic attributes of language, and established a conceptual framework (Cheng Qilong, 2006) to approach the language system.

The theoretical goal of neurocognitive linguistics is mainly to express the cognitive ability and processing process of the brain's language system. Language cognitive ability and its processing process are the ability and brain process of language generation and understanding in a certain environment.

Starting from the facts of brain functional areas and language phenomena, the relationship network of the language system includes a network of three hierarchical subsystems. These three hierarchical subsystems are the conceptual hierarchical system, the grammatical hierarchical system, and the phonological hierarchical system. In a network of relationships, a unit is just a connection and communication relationship between the unit and other units. From the point of view of processing, the information processing of the relational network is two-way, and at the same time it is parallel. The construction of a network of relationships is synthesis. Synthesis is carried out based on analysis of linguistic phenomena. Analysis is decomposition and classification. Such analysis is inductive. In order not to contradict the facts of the brain, the analysis of language phenomena must be based on the three-level relationship network of language as the framework, and the decomposition and classification must be guided by the theoretical framework. This kind of analysis is deductive. Based on analysis, the various relationship types obtained from decomposition are comprehensively connected into a network of relationships, and the cognitive ability of the network is tested by activation processing (Cheng Qilong, 2001:132).

Since the development of neurocognitive linguistics, remarkable results have been achieved. It builds a bridge between linguistics and neuroscience. Neurocognitive linguistics explains the methods by which the brain characterizes, learns, obtains, and processes information, and provides an explanatory framework for some topics in neurocognitive science; neurocognitive linguistics also explains many difficult problems in linguistics, psychology, etc.

3.2 Cognitive Neural Simulation Research

The essence of all cognitive systems is a symbolic processing system (Yuan Yulin, 1998). This view of symbolic processing regards the human brain as an information processing system like a computer.

The computers developed in the 1950s gradually simulated human intelligent activities, and the discipline of artificial intelligence emerged. In the study of simulating human intelligent activities, the computer science community has two opposing views: symbolism and associationism. The symbolist view believes that the basic unit of human intelligence is symbols, and the cognitive process is symbolic operations under symbolic representation. Human thinking is analogous to symbolic calculations. Due to the many flaws in the research method of symbolism in simulating cognitive processes, since the 1980s, integrationism has emerged. The associationist view holds that the mechanism of cognitive activity is based on the constant change in the strength of connections between neurons, and it performs parallel distributed processing of information. The biggest difference between symbolism and associationism is that human cognition is like a computer's symbolic system, and information is stored in the human brain in the form of a series of symbols. The cognitive process is like the processing process of numbers, which outputs a sequence of signals according to certain program instructions. On the other hand, associationism believes that information is stored in the weights of neural network unit channels, and the cognitive process is a dynamic hierarchical development process, and the activation of the unit depends on the weights and the activities of other units.

In 1987, Harnad proposed a three-level theory of cognitive representation. The theory is: the lowest level is mimetic characterization, which is the sensory input; the middle level is categorical characterization, that is removing most of the structure of the original input and retaining the unchanging components that form categorization; the highest level is symbolic characterization or description system (description system), which is symbolic marking of categorical characterization. This theory is a method of analyzing problems, such as categorical perception.

Gädemfors (1996, 2000) was deeply influenced by Harnad's hierarchical theory of cognitive representations and proposed three forms: symbolic representation, subconceptual statement, and conceptual statement (2000 Gädemfors: 33-58). These three representations are equivalent to the analog representation of Harnard: icon representation, explicit representation, and symbolic representation. The basic hypothesis of symbol representations: the processing of the cognitive system is like a computer, and cognition processes abstract symbols according to a specific set of rules. In the entire processing process, the meaning of symbols does not play any role. As the material basis of symbol processing, the human brain is considered to have nothing to do with the representations process in symbol representations, because the thinking state that the human brain can achieve can also be realized by computers. In short, the human brain is regarded as a computing machine that can receive information input from the perceptual system, generate symbolic sentences, perform logical processing based on sentences, and then convert logical processing into verbal or non-verbal behavioral output. The basic hypothesis of sub-conceptual representations: Cognitive activities are mainly carried by the connection between various information. The same events that occur in space or time will establish a connection in the human brain. Events that have a common meaning or similar physical attributes are also connected to each other in the human brain. The sub-conceptual representation uses artificial neuron networks (ANNs) to simulate the connectionism of the connections between various thinking units. A complex association system consists of many simple but closely related neurons that process the received information in parallel. There is no central control neuron in the entire neuron network. Each neuron is an independent information processor. After being activated, it transmits the information it receives to other neurons associated with it. The behavior of the entire neuron network is determined by the initial activation state and the connection between the neurons. The representations system of correlation theory can be regarded as a multi-dimensional space (high- dimensional space) composed of many neurons and connections between neurons. Conceptual representations are an intermediate link connecting symbolic representation and sub-conceptual representation, and it is an indispensable level for the formation of categorization and concepts (Lan Chun, 2005). Due to space constraints, this article will not repeat the categorization and concept formation.

In 2000, Kerdemfors published his monograph "Conceptul Space: Thoughts of Geometric Shapes", which delves into the macroscopic symbol representations, micro-conceptual representations, and intermediate conceptual representations that play a connecting role.

This paper believes that Zhao Nanyuan's cognitive hierarchy has high reference value for understanding the three representations of Gädemfors.

3.3 Research on Brain Imaging Technology

The human brain is divided into left and right hemispheres. The surface of the hemisphere is covered by many nerve cells and non-myelinated nerve fibers. It is gray in color and called gray matter, which is the cerebral cortex. The inner surface of the hemisphere is composed of the medullary of many nerve fibers, called white matter. The cerebral cortex is divided into several functional areas: (1) Primary sensory areas. This area includes the visual area, the auditory area, and the sensory area of the body. It accepts light stimuli from the eyes, sound stimuli from the ears, and various stimuli from the skin surface and internal organs. It is an area that accepts and processes external information; (2) Primary motor area. The main function of this area is to issue instructions to dominate and regulate the body's position, posture, and movement of various parts of the body in space; (3) Speech area. It is mainly located in the left hemisphere of the brain and consists of the Broka area and the Wilnik area; (4) The joint area. In addition to the above-mentioned areas, the human cerebral cortex also has a wide range of brain areas with integrated or joint functions. The joint area is divided into sensory joint area, motor joint area and forehead joint area.

The two hemispheres of the brain seem to be the same, but in fact, there are obvious differences in structure and function between the two hemispheres. The left hemisphere of the brain is mainly responsible for speech, reading, writing, mathematical operations, and logical reasoning; the right hemisphere of the brain is mainly responsible for perceiving the spatial relationship between objects, emotions, and appreciating music and art.

Cognitive neuropsychologists try to obtain important information about brain structure and function through multiple channels. This information enables people to determine the sequence of activity and the relationship between the sequence of activity and time of different regions of the brain when the subject completes a certain cognitive task. Various techniques for studying brain function are mainly manifested in the difference between time and space resolution. In terms of time indicators, some technologies provide activity information at the millisecond level, while others consider brain activity from a longer time frame. In terms of spatial indicators, some technologies provide activity information at the single-cell level, while others provide activity information for multiple groups of cells.

Electroencephalogram (EEG) is obtained by recording the biological electrical activity inside the brain on the surface of the scalp. Minimal electrical changes in the brain can be recorded by electrodes on the surface of the scalp. These changes can be displayed through the cathode ray tube in the oscilloscope. The key problem with EEG is that the spontaneity of EEG activity or many background activities hinder the recording of information processing activities caused by stimulation. The solution to this problem is to present the same stimulus multiple times. Subsequently, the EEG fragments after each stimulus is presented are extracted and arranged according to the trigger time of the stimulus. After superimposing these EEG fragments, a single waveform is obtained on average. Through this technique, we can obtain event-related potentials (ERPs) from EEG records, which allows us to separate the effects of stimulation from the background. Event-related potentials are very effective in evaluating the time characteristics of certain cognitive activities.

The principle of magnetic resonance imaging (MRI) is to use electromagnetic fields to excite atoms in the brain. The magnetic field changes caused by this process are detected by a magnet surrounding the subject. These changes are transformed by a computer into a very accurate three-dimensional image. Magnetic resonance imaging technology has been used to measure brain activity to provide functional magnetic resonance imaging (fMRI). Local neuronal excitement will cause an increase in blood flow in this area, which contains oxygen and glucose. As the content of oxygen carried by hemoglobin affects the magnetic field characteristics of hemoglobin, magnetic resonance imaging technology can measure changes in functional oxygen in the brain. Functional magnetic resonance imaging has higher spatial and spatial resolution than positron emission tomography and is therefore more effective.

Magnetoencephalography (MEG) technology uses a superconducting quantum interference device (SQUID) to measure magnetic field changes in EEG activity. Brain magnetic maps can be considered as a direct measurement of neural activity in the brain, and the measurement accuracy is very high. This is partly because the brain does not actually have any obstacles to the magnetic field. It is characterized by magnetic field signals that reflect changes in neural activity relatively directly, and provide specific time information about cognitive processes, with a time resolution of milliseconds, to distinguish the order of cerebral cortex excitement (Peng Qingling 2003).

4. Conclusion

Neurocognitive linguistics research, cognitive neural simulation research, and brain imaging technology research are the three paths of language research under the third-generation cognitive science, which belong to different disciplines. Neurocognitive linguistics is a branch of linguistic research and belongs to the category of linguistics; cognitive neural simulation research belongs to the field of computer science; brain imaging technology belongs to the content of cognitive psychology research. Although they belong to different disciplines, they are interconnected and interact with each other within the framework of language research, and they are an important part of the third-generation cognitive science. Neurocognitive linguistics not only links linguistics with brain neuroscience, but also combines linguistics with computational science and artificial intelligence research; cognitive neural simulation research uses a combination of language cognitive simulation and computer simulation technology to combine language cognition and computational science; brain imaging technology makes full use of high-tech technology, combined with brain neuroscience, has stepped out of a path of empirical research. Therefore, the combination of the three disciplines to discuss the relationship between language and thinking, and to try to reveal the mystery of language and brain nerves, has a wide range of development prospects and application value.