Research on the Reconstruction of Language Teaching Cognitive Process by the Advanced Achievements in Neurolinguistics

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Abstract: *Focusing on the cutting-edge achievements of neurolinguistics, this study aims to deeply explore its profound influence and reconstruction effect on the cognitive process of language teaching. By integrating the latest research in neurolinguistics on the brain's language processing mechanism, the neural basis of language acquisition, and the neural roots of individual differences in language ability, the limitations of traditional language teaching cognition are revealed. It further elaborates how neurolinguistics research provides new theoretical perspectives and practical methods for language teaching, thereby achieving a comprehensive reconstruction of the cognitive process of language teaching to improve teaching effectiveness and learners' language abilities.*

Keywords: Neurolinguistics, Language Teaching, Cognitive Process, Reconstruction.

1. Introduction

In the current era of knowledge explosion, language teaching, as an important component of the education field, constantly faces new challenges and opportunities. With the in-depth development of interdisciplinary research between neuroscience and linguistics, the frontier field of neurolinguistics is gradually emerging, providing a brand-new perspective and powerful tool for us to re-examine the internal mechanisms of language learning and understand the cognitive process of language teaching.

Traditional language teaching cognition often focuses on the accumulation of experience in teaching methods and the imparting of teaching content, while having relatively limited understanding of the brain mechanisms and neural basis behind language learning. However, the emergence of neurolinguistics has broken this limitation, enabling us to deeply explore the complex operations of the brain in language learning and utilization [3]. In recent years, the development of neurolinguistics has made a series of important progresses in exploring the processing mode of language in the brain, the critical stages of language acquisition, and the neural basis of individual differences in language ability. These research achievements not only reveal the encoding, storage, and extraction processes of language in the brain but also provide neural-level explanations for understanding individual differences in language learning.

In view of this, in-depth research on how the cutting-edge achievements of neurolinguistics reconstruct the cognitive process of language teaching has significant theoretical and practical significance. It not only helps us update teaching concepts and optimize teaching methods but also provides a scientific basis and guidance for the innovative development of language teaching.

2. Overview of the Advanced Research in Neurolinguistics

Neurolinguistics is a discipline that integrates linguistics, neuroscience, psychology, and cognitive science. It specifically studies the physiological and psychological mechanisms of language acquisition, generation, and comprehension, and investigates how the brain generates, receives, stores, and retrieves information, thereby exploring the relationship between the brain and language [6]. This fully reflects the cross-disciplinary and integrated development trend of contemporary science. The following are the frontier research directions and achievements in neurolinguistics:

2.1 Research on the Brain Language Processing Mechanism

The research in this direction mainly focuses on the regions and neural networks related to language generation, comprehension, and perception in the brain. By using neuroimaging techniques such as functional magnetic resonance imaging (fMRI) and electroencephalogram (EEG), the activities of the brain during language processing are observed in real time to further reveal the specific location and time course of language processing in the brain. For example, fMRI can locate specific areas related to language generation, comprehension, and storage by detecting changes in blood flow in the brain when performing language tasks; EEG can record the electrophysiological activities of the brain in real time, revealing the synchrony and timing of different brain regions when processing language [2].

Moreover, language processing involves multiple brain regions, and these regions do not work in isolation but collaborate through complex neural networks, including classic language regions such as Broca's area and Wernicke's area, as well as extensive neural networks in the frontal lobe, parietal lobe, and temporal lobe. Different brain regions have different roles in speech, vocabulary, syntax, and semantic processing [9]. They integrate, transfer, and process information through neural networks to achieve language comprehension, generation, and expression.

Specifically, Broca's area is mainly responsible for language generation and expression, including the organization of vocabulary and the construction of grammatical structures; when learners perform oral expression or writing, this area

shows a significant increase in activity. Wernicke's area focuses on language comprehension, analyzing the meaning of speech, vocabulary, and sentences; when listening to others' speech or reading text and understanding its meaning, Wernicke's area is activated. In the neural network, the parietal lobe is responsible for integrating sensory input and constructing a spatial coordinate system to represent the surrounding world, so it is important for processing and interpreting somatosensory input and processing language; the frontal lobe is closely related to advanced language functions such as language expression, semantic understanding, and mastery of grammatical rules [12]. It is also involved in the generation, planning, and execution of language, as well as the working memory and attention control of language; the neural network of the temporal lobe is related to auditory perception, speech recognition, and language understanding. The auditory center in the temporal lobe can receive and process sound information to help recognize speech, understand the meaning of language, and match it with stored language knowledge [1]. The neural networks of these brain regions collaborate with each other to jointly support all aspects of language learning and language processing.

2.2 Research on the Neural Basis of Language Acquisition

This direction delves deeply into the neural mechanisms of children's acquisition of their mother tongue and adults' learning of a second language. Studies [10] and [11] have found that there is a sensitive period for language acquisition, and early language environment and experience play a crucial role in the formation and development of the brain's language neural network. At the same time, neural synapses in the brain will be adjusted and optimized according to the richness and quality of language input. Rich language environment stimulation can prompt the formation of more neural connections, thereby establishing a stronger language processing network.

Therefore, the language processing areas of the brain in adulthood still have a certain degree of plasticity [2], and the connections between neurons can be adjusted and reshaped based on new experiences and learning. When adults learn a new language, the brain mobilizes multiple regions to work collaboratively to process the new language information. For example, the temporal lobe region responsible for auditory processing, the frontal lobe region responsible for language generation, and the parietal lobe region responsible for semantic understanding will adapt to the needs of language learning by establishing new neural connections or strengthening existing connections. In this process, appropriate training is the key to stimulating brain plasticity. This includes systematic language course learning, immersive language environments, communication with native speakers, etc. Through repeated language input and output exercises, the brain can gradually form new neural pathways, thereby improving language comprehension, expression, and production abilities.

Furthermore, the interaction between genetic and environmental factors on language acquisition has also received attention. Genes to a certain extent determine the initial structure and function of the brain, thereby affecting an individual's innate propensity and potential for language learning. Certain genes may be related to language-related cognitive abilities, such as speech perception, grammar understanding, and vocabulary memory. However, genes are not the only determining factor. Environmental factors such as the quality of language input, the frequency and diversity of language communication, and the level of education can also affect the effect of language acquisition. A rich language environment can provide a large number of language stimuli and learning opportunities, promoting the development and functional optimization of the brain's language processing areas. Therefore, individuals with specific genetic variations may exhibit better or worse language learning abilities in a specific language environment. Similarly, good environmental stimulation can compensate for certain genetic deficiencies, while a poor environment may limit the language development potential of individuals with favorable genes.

Last but not the least, research is currently exploring the impact of multilingual acquisition on the brain's structure and function. In terms of brain structure, multilingual acquisition may lead to an increase in the gray matter volume in certain areas of the cerebral cortex. For instance, in language processing-related areas such as Broca's area and Wernicke's area, due to the long-term demand for processing multiple languages, the growth and connection of neurons in these areas become denser, and structural adjustments may occur. In the white matter structure of the brain, nerve fiber bundles that connect different brain regions, such as the corpus callosum, may also change. Functionally, the brains of multilingual learners demonstrate higher flexibility and adaptability when processing languages. When they hear or read a language, the brain can quickly switch to the corresponding language mode and activate the vocabulary, grammar, and semantic knowledge related to that language. Research techniques such as fMRI also show that when multilingual learners process different languages, the brain's activation patterns may differ, and in some cases, the activation areas for different languages may overlap, indicating that the brain can effectively integrate and distinguish information from multiple languages.

Besides, multilingual acquisition may also influence the brain's cognitive control ability. To select and switch between multiple languages and avoid interference between them, regions such as the prefrontal cortex of the brain need to exert a stronger inhibitory and regulatory role, thereby enhancing cognitive flexibility and attention control ability. Current research is further exploring the details of the impact of multilingual acquisition on the brain's structure and function. For example, it examines whether there are differences in the impact of starting to learn multiple languages at different ages on the brain, how language features of different languages (such as grammar structure and phonetic system) affect the brain's processing methods, and the relationship between multilingual acquisition and cognitive aging.

2.3 Research on the Neural Roots of Individual Differences in Language Ability

There are obvious differences in language ability among individuals, which can largely be traced back to differences in

genes and neural structures. These genetic-level differences affect the secretion of neurotransmitters related to language processing in the brain, the function of receptors, and the development and connection patterns of neurons.

On one hand, differences in neural structures, such as the thickness of the cerebral cortex, the volume of brain regions, and the connection strength and pattern of white matter fiber bundles, can influence language ability. For example, the structural features of areas responsible for language processing in the brain may be related to an individual's language expression fluency, comprehension ability, and the difficulty level of language learning. And there are differences in the gray matter volume and white matter structure of certain areas of the cerebral cortex in people with strong language ability compared to those with weak language ability. On the other hand, in terms of the brain's function, the activation patterns of the brain and the connection patterns of neural networks are also directly related to individual differences in language ability. When people with strong language ability process language tasks, the brain's activation pattern may be more efficient and coordinated, and the connection of neural networks may also be tighter and more complex. Certain gene variations may cause individuals to exhibit different characteristics in language learning speed, language memory ability, or language perception.

These cutting-edge research achievements in neurolinguistics provide new perspectives and inspirations for language teaching. They help teachers better understand the neural mechanisms of language teaching and learning, the brain's language processing mechanisms, the process of language acquisition, and individual differences in language ability, thereby providing valuable scientific basis for optimizing teaching methods and strategies.

3. Challenges to Traditional Views on the Cognitive Process of Language Teaching

3.1 The Stimulus-Response Model Based on Behaviorism

Behaviorist psychology holds that learning occurs through the formation of connections between stimuli and responses. In language teaching, this model emphasizes triggering learners' language responses through external environmental stimuli and consolidating and forming language habits through repeated practice and reinforcement. Specifically, teachers provide language stimuli, such as demonstrating correct pronunciation, grammatical structures, or vocabulary usage. Students then make corresponding language responses, such as imitating pronunciation and constructing sentences. When students' responses are correct, teachers give positive reinforcement, such as praise and rewards, to increase the possibility of that correct response occurring again; when the responses are incorrect, teachers provide corrections and negative reinforcement to prompt students to adjust their language behaviors. This model mainly focuses on external behavioral manifestations and practice reinforcement, and its advantage lies in its clear operability and measurability. Through a large amount of repetitive practice and timely reinforcement, students can master some basic language skills in a short period of time.

However, research in neurolinguistics has revealed the role of specific regions and neural networks within the brain in language processing, indicating that language learning is not merely a simple mechanical connection of external stimuli and responses but involves complex neural activities in the brain. Specifically, the collaborative work of regions related to language generation, comprehension, and storage in the brain challenges the view that language habits can be formed merely through repeated stimuli and reinforcement, suggesting that language learning needs to comprehensively consider various internal mechanisms of the brain; otherwise, it may overlook students' internal thinking processes and active construction abilities, making it difficult to cultivate students' language creativity and ability to flexibly use the language.

3.2 The Information Processing Model Based on Cognitive Psychology

Cognitive psychology considers learning as an information processing process, including stages such as perception, encoding, storage, and retrieval. In language teaching, this model focuses on how learners cognitively process language knowledge. In the perception stage, learners receive language input through senses such as vision and hearing, and conduct initial recognition and attention to the language materials. In the encoding stage, learners transform the received language information into meaningful mental representations and establish connections with existing knowledge and experience. The storage stage involves storing the encoded language knowledge in memory, including short-term memory and long-term memory. Finally, when it is necessary to use the language, learners retrieve the corresponding language knowledge from memory and conduct language output. This information processing model emphasizes the active participation of learners and internal cognitive processes. It believes that learners do not passively accept language input but actively analyze, integrate, and construct language information. This is helpful for cultivating students' language comprehension and application abilities, as well as problem-solving skills.

Research in neurolinguistics has discovered significant genetic and neural structural differences in language ability among individuals, meaning that language learning cannot be understood merely from the process of information processing but also requires consideration of individual innate factors at the neural level. Coupled with the relatively abstract nature of this model, further research and practical exploration are needed regarding how to specifically promote the effective progress of each stage and how to deal with individual differences.

4. Reconstruction Directions of the Cognitive Process of Language Teaching

4.1 Emphasizing Multisensory Integration

When the human brain processes language information, it does not rely solely on a single sensory channel but integrates and collaboratively processes information from multiple sensory systems such as auditory, visual, and tactile. For example, when we hear a word and simultaneously see its

written form or touch related symbols, the brain can understand and remember this language element more comprehensively and deeply.

In language teaching practice, it is of great significance to make full use of multimodal teaching resources. Teachers can use various forms such as pictures, videos, audios, and physical objects to provide students with rich and diverse language input. For instance, when teaching new words, not only explain the pronunciation and meaning orally but also show relevant pictures or physical objects, and even play audio or video clips containing the word. In this way, students can receive information about the word at multiple sensory levels, thereby forming a more complete and profound impression in the brain. This multisensory integration teaching method can enhance students' attention and participation, stimulate their learning interest and enthusiasm. Because different sensory stimuli can complement and reinforce each other, it helps students better understand the meaning, usage, and context of the language, thereby improving the effectiveness and efficiency of language learning.

4.2 Focusing on Individual Differences

There are significant differences in brain structure and function among individuals, and these differences are closely related to language learning ability. Everyone has a unique learning style. Some students are better at learning through auditory methods, while others tend to learn through visual or kinesthetic means; cognitive characteristics also vary, for example, some students have strong logical thinking ability, while others are more creative and imaginative; in terms of neural advantages, some students may exhibit stronger abilities in certain aspects of language processing, such as speech perception or grammar understanding.

Therefore, language teaching should pay more attention to personalization. Teachers can understand each student's learning style, cognitive characteristics, and neural advantages through observation, testing, and communication with students, and then tailor differentiated teaching plans for them. For example, for auditory learners, more listening training and oral communication can be conducted; for visual learners, more charts, pictures, and text materials can be provided. In addition, with the help of advanced technologies such as real-time electroencephalogram monitoring, it is possible to obtain more directly the brain activity status and neural feedback information of learners during the learning process. Teachers can adjust the difficulty, progress, and teaching methods of the teaching content in a timely manner based on these data to meet the real-time learning needs of students and achieve personalized adaptive learning in the true sense. This approach can maximize the potential of each student and improve their learning effectiveness and satisfaction.

4.3 Utilizing the Plasticity of the Brain

The brain demonstrates remarkable plasticity during the language learning process, which implies that the neural connections and structures of the brain can continuously change and optimize through learning and experience. When

learners have the courage to attempt new language expressions, actively participate in language communication, make mistakes, and accept corrections during this process, the brain will constantly adjust and reconfigure neural connections to process and store language information more effectively.

In teaching, teachers should create a positive, supportive, and encouraging learning environment to make students feel that making mistakes is part of learning rather than a sign of failure. Teachers can provide diverse language practice opportunities, such as group discussions, role-playing, writing workshops, etc., and encourage students to boldly express their thoughts and viewpoints. When students make mistakes, teachers should provide feedback and guidance in a constructive way to help them learn and grow from the mistakes. Through such methods, students' learning motivation and initiative can be stimulated, promoting the continuous formation of new neural connections and pathways in the brain, thereby enhancing the ability and level of language learning.

4.4 Valuing Emotional Factors

There is a close connection and interaction between the emotional center in the brain and the language areas. Emotional states largely influence the brain's learning mechanism and cognitive processing [8]. When students are in a positive emotional state, such as excitement, pleasure, and confidence, the neurons in the brain will be more active, and cognitive resources can be allocated more effectively, thereby facilitating the absorption, understanding, and memory of language knowledge. Conversely, negative emotions, such as anxiety, tension, and fear, may inhibit the brain's learning function, leading to distraction, rigid thinking, and memory decline. Therefore, in language teaching, teachers should pay attention to students' emotional experiences and strive to create a relaxed, pleasant, and supportive learning atmosphere.

Teachers can focus on students' emotions in various ways, such as establishing a good teacher-student relationship and giving students full respect and trust; adopting an incentive evaluation method to affirm students' efforts and progress; designing interesting, challenging, and moderately stressful teaching activities to enable students to feel a sense of achievement while enjoying the learning process. Such a teaching environment can make students more emotionally willing to engage in learning, improve their learning enthusiasm and initiative, and thereby enhance the effect of language learning.

5. Language Teaching Strategies Based on Neurolinguistics

5.1 Multimodal Teaching and Context Construction of the Brain

The brain demonstrates stronger learning ability and memory effect when processing information related to contexts. Therefore, in teaching, different language contexts can be created to maximally activate the areas that process and understand language input and generate language output.

Multimodal teaching utilizes multiple sensory channels, such as visual, auditory, and tactile, to convey and receive language information; context construction of the brain is to create language-related scenes that are realistic, vivid, and dynamic to assist learners in better understanding and applying the language.

Multimodal teaching provides rich materials and stimuli for the context construction of the brain, making the constructed context more real, three-dimensional, and vivid. Different modal information works together to help learners construct clear and specific context images in their brains. The context construction of the brain provides a meaningful framework and purpose for multimodal teaching, enabling multimodal information to be organized, integrated, and understood in specific contexts, allowing learners to understand and remember language knowledge more effectively.

In the language perception stage, multimodal materials are utilized, such as showing a video about dining in a restaurant (visual) while playing the relevant background sounds (auditory), to arouse students' interest and attention and lay the foundation for context construction. In the comprehension stage, describe the context details in the video and explain the relevant language expressions (such as ordering food and communication), helping students construct a complete dining context in their brains and understand the application rules and meaning of the language in this context. In the application stage, create a similar restaurant context and have students engage in role-playing (kinesthetic) to actually communicate using the learned language and strengthen their language application ability in specific contexts. In the consolidation stage, present the multimodal materials again to have students recall the context and language application, and consolidate the learned knowledge through exercises and assignments.

The strategy of combining multimodal teaching based on neurolinguistics with the context construction of the brain can fully utilize the cognitive characteristics of the brain, enhance the effect of language teaching, and promote students to learn the language more efficiently.

5.2 Gamification Teaching and the Reward Mechanism of the Brain

Gamification teaching is an effective teaching method based on the brain's reward mechanism, integrating teaching content and goals into game forms that are interesting and challenging. In a gamified language learning environment, when learners complete tasks, make progress, or achieve victory, it triggers the brain's intrinsic reward mechanism, releasing neurotransmitters such as dopamine, thereby generating a sense of pleasure and satisfaction and further strengthening related behaviors and cognitive processes.

In the learning motivation stimulation stage, teachers can design an interesting language game opening, such as vocabulary puzzles or language riddles, to attract learners' attention and stimulate their intrinsic motivation to participate in language learning. In the knowledge input stage, new language knowledge points are presented gradually through game levels. For example, in an adventure game, learners can obtain new grammar rules or vocabulary after passing each

level. In the practice and consolidation stage, arrange competitive games for learners to practice the learned content in competition. When they answer questions correctly or complete tasks, provide timely rewards, such as virtual badges, points, or upgrades. In the knowledge application stage, create role-playing games that simulate real scenarios, and learners use the learned language to solve problems in the games. Successfully completing tasks brings a sense of achievement, further strengthening the application ability of knowledge. In the learning assessment stage, use the performance data in the games as the assessment basis and provide additional rewards for outstanding learners, such as praise, small gifts, or special privileges. This immediate feedback can stimulate the brain's reward mechanism, enhance students' enthusiasm and confidence in participating in language learning, and cultivate their sense of competition and cooperation.

5.3 Rhythm Teaching and the Phonetic Perception of the Brain

The prosodic features of language, including aspects such as pitch, duration, intensity, intonation, stress, and rhythm, are crucial for the brain's phonetic perception and processing. While the brain perceives and processes these prosodic features, it can link them to the meaning and emotion of the language. For instance, the undulating changes in intonation can convey different emotions and tones, the position of stress can affect the meaning of words and sentences, and rhythm helps improve the fluency and comprehensibility of the language.

In teaching, teachers focus on rhythm teaching and allow students to feel and master these prosodic elements through demonstration, imitation, and practice. For example, through methods such as poetry recitation, song singing, and imitation of oral conversations, students' brains can become more敏锐 in perceiving the changes and patterns of speech. This helps students form more accurate and natural pronunciations and improve the fluency and accuracy of oral expression. Simultaneously, rhythm teaching can also enhance students' appreciation of the musicality and rhythm of the language, thereby enhancing their overall perception and aesthetic ability of the language.

5.4 Segmented Teaching and the Fatigue Recovery of the Brain

Prolonged brain activity may lead to an imbalance in the secretion and regulation of neurotransmitters (such as dopamine, serotonin, etc.), affecting the signal transmission between neurons and thereby causing fatigue. In a fatigued state, the energy metabolism of the brain changes, and insufficient glucose supply affects the normal functions and activities of neurons. Repetitive and high-intensity language tasks may cause fatigue in the neural networks involved in language processing, manifested as weakened connections and sluggish responses between neurons.

In language teaching, understanding and following the fatigue recovery cycle of the brain is of utmost importance. Teachers can adopt segmented task arrangements based on the duration and difficulty of the course, and reasonably arrange appropriate rest times to avoid prolonged consecutive

high-intensity language activities. During the rest period, the brain can effectively relax and recover, remove metabolic wastes, and re-adjust the balance of neurotransmitters. Thus, when students return to learning, the brain can engage in new learning tasks with more energy and higher attention, thereby improving the effectiveness and quality of learning. Additionally, reasonable rest arrangements can also reduce students' learning pressure and anxiety, creating a more relaxed and positive learning atmosphere.

In conclusion, these language teaching strategies based on neurolinguistics, by fully considering the cognitive mechanisms and learning patterns of the brain, can create a more optimized and effective learning environment for students and enhance the effect and quality of language teaching.

6. Conclusion

The cutting-edge research in neurolinguistics has brought a brand-new understanding and reconstruction to the cognitive process of language teaching. Applying these research results to language teaching practice not only prompts instructional design to be more in line with the brain's operation mode but also better meets the individualized needs of learners and promotes the innovation and development of language education. Future research needs to further strengthen interdisciplinary cooperation, deepen the understanding of neurolinguistic mechanisms, and continuously explore their effective application in language teaching. Only in this way can the comprehensive optimization of the cognitive process of language teaching be achieved and complex neuroscience research be transformed into practical teaching strategies.

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