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The Impact of Foreign Language Learning on Cognitive Abilities in Older Adults: A Review under the Framework of Brain Plasticity Theory

Yuwen Gong

School of Foreign Languages, East China Normal University, Shanghai, China
10220710401@stu.ecnu.edu.cn

Abstract: With the global aging population, the issue of aging-related cognitive decline has become a major concern for elderly health. Given the significance of maintaining cognitive function in the elderly, this study focuses on the impact of foreign language learning on their cognitive abilities. Through an in-depth review of a wide range of academic reviews and empirical studies, several key findings have been revealed. Brain plasticity theory indicates that the elderly's brains can adapt through learning, and foreign language learning, as a form of cognitive training, has a positive impact on neural structure and function. It improves various cognitive functions such as executive function, working memory, and attention. Moreover, effective learning strategies have been proposed, including optimizing course design with a progressive difficulty gradient and multimodal inputs, and considering individual differences.

Keywords: cognitive abilities, older people, the elderly, foreign language learning, brain plasticity

1. Introduction

Given the global aging population, aging and cognitive decline has received considerable critical attention as it has become a major challenge to elderly health. The traditional view holds that brain plasticity weakens with age. However, with the development of neuroimaging technology, numerous studies demonstrate that cognitive training can have a positive impact on the brain structure and function of the elderly [1, 2]. Among various forms of cognitive training, foreign language learning has become a heated research target considering the proven advantages of bilingualism [3]. Bubbico et al found that after four months of foreign language learning, the overall cognition and functional connectivity of the elderly had significantly improved [4].

The present study address the following questions:

1) How did brain plasticity theory support foreign language learning in older adults?

2) What specific cognitive abilities are influenced by foreign language learning?

3) How can foreign language learning be optimized to enhance cognitive skills in older individuals?

The main contribution of this study is to review the existing theories between foreign language learning and cognitive abilities in older adults, provide a scientific basis for targeted cognitive interference methods, and promote interdisciplinary studies.

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2. The core concepts of the brain plasticity theory and its applicability among the elderly

2.1. The essence of brain plasticity and its persistence across the lifespan

Brain plasticity, also known as neuroplasticity or neural plasticity, refers to the nervous system's ability to adapt to environmental changes through structural reorganization and functional optimization. This process includes the remodeling of neuronal connections, synaptic formation and reinforcement, and the reconfiguration of neural networks [1]. Research has shown that this ability is not exclusive to the developmental stage but rather persists throughout the entire lifespan [2]. This theory emphasizes that even in adulthood and old age, the brain retains a capacity for adaptation through learning, training, and environmental changes.

2.2. The application of brain plasticity in different trainings for older people

For the elderly, the theory of brain plasticity has important applicability. Studies indicate that cognitive training, exercise, and lifestyle changes can significantly improve the cognitive function and quality of life of the elderly [5]. For example, cognitive training can delay cognitive decline by enhancing the brain's executive control functions, working memory, and attention [6]. Targeted interventions such as numerical training, auditory training, and cognitive training have been found to improve auditory comprehension and cognitive performance in older adults [7]. Moreover, high-intensity interval training (HIIT) has also been demonstrated to effectively improve the memory, information processing speed, and cognitive flexibility of the elderly [8].

The theory of brain plasticity provides the elderly with the possibility of improving their cognitive function through training and lifestyle changes. This theory not only supports the importance of the elderly continuing to learn and participate in cognitive activities but also provides a scientific basis for the development of effective intervention measures. However, the effects of brain plasticity vary among people of different age groups. Younger groups usually show better training effects and long-term maintenance abilities, while the effects for the elderly may be more limited [6]. Consequently, future research is needed to further explore the impact of individual differences on brain plasticity and develop personalized training programs suitable for the elderly [9].

2.3. The uniqueness of foreign language learning as a neural stimulus

Language learning involves the integration of cross-modal information (such as the coordination of the auditory, visual, and motor cortices) and requires the activation of a wide neural network. Neuroplasticity provides the biological foundation for foreign language learning among the elderly [1]. Studies have demonstrated that through repeated practice and stimulation, cognitive trainings promote an increase in the volume of gray matter in the cerebral cortex and an enhancement of the connections of white matter nerve fibers. An fMRI study by Bubbico et al. showed that four months of English learning significantly enhanced the functional connectivity between the right inferior frontal gyrus (rIFG) and the left superior parietal lobule (lSPL) in the elderly [4]. These brain regions are closely associated with executive control and working memory, which are critical for language processing and cognitive flexibility.

3. The influence mechanism of foreign language learning on the cognitive abilities of the elderly

Empirical research on the correlation between foreign language learning by the elderly and cognitive abilities mainly focuses on the following aspects:

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3.1. Changes at the neural structure level

Changes at the neural structural level mainly have two aspects--the Enhancement of White Matter Integrity and the Reorganization of Gray Matter Volume. Diffusion Tensor Imaging (DTI) data show that in foreign language learners, the axial diffusivity (AD) in regions such as the prefrontal - occipital fasciculus and the corpus callosum increases. This indicates an improvement in the integrity of the axonal membrane, which may be related to enhanced myelination. Additionally, an increase in gray matter density has been observed in the left angular gyrus, a region associated with semantic processing, as well as in the bilateral anterior cingulate gyrus, which is involved in conflict monitoring. These structural changes are believed to support vocabulary retention and inhibitory control abilities [10].

3.2. Improvement of cognitive functions

Cognitive ability encompasses various domains, including information processing, problem-solving, learning, and memory. These abilities can be manifested in various ways, including attention, memory, thinking ability, and language ability. Within the framework of brain plasticity, cognitive ability is regarded as an ability that can be changed and developed through training and environmental stimuli. This perspective underscores the importance of education and training in enhancing cognitive ability.

Numerous studies have shown that foreign language learning has a positive impact on the cognitive functions of the elderly. For example, a randomized controlled trial conducted by Bubbico et al. in Italy found that second - language learning programs can induce changes in the brain functions of healthy elderly people [4]. In an experimental research in the UK, Gruneberg and Pascoe improved the productive and receptive abilities of English vocabulary among elderly women through the keyword method. Research by Klisch et al. in Austria also indicated that bilingual training has a significant impact on the cognitive abilities of the elderly [11]. A randomized controlled trial of German native speakers aged 65 to 80 showed that the group learning Spanish demonstrated better cognitive abilities when performing tasks [12]. Moreover, short-term intensive foreign language learning has been shown to improve executive function, a high-level cognitive ability closely linked to age-related cognitive decline [13].

In fact, plenty of studies have shown improvements in specific dimensions of cognitive abilities and its hidden neural mechanism, as shown in Table 1 below.

Table 1: Improvements in the dimensions of cognitive function

Cognitive Dimension	Specific Performance	Correlation with Neural Mechanisms
Executive Function	Shorter reaction time in the Stroop task and lower error rate in task - switching	Functional reorganization of the prefrontal - basal ganglia loop [6,10]
Working Memory	Improved scores in the digit span test and expanded information - holding capacity	Enhanced activation of the dorsolateral prefrontal cortex (DLPFC) [4,10]
Attention	Improved performance in sustained attention tasks (such as CPT) and enhanced resistance to interference	Optimized functional connectivity of the parietal - thalamic network [12]
Global Cognition	Increased total scores on the MMSE/MoCA scales, especially in sub - items of language fluency and abstract thinking	Enhanced synergy between the default mode network (DMN) and the central executive network [4,14]

In addition, language learning enhances cognitive reserve, enabling the elderly to maintain functional compensation even in the case of neuronal loss [10, 13].

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4. Social participation and mental health

Foreign language learning not only enhances cognitive functions but also promotes social integration and mental health. By participating in foreign language learning programs, the elderly can broaden their horizons, engage in more social activities, and reduce depressive symptoms [15].
Studies indicate that foreign language learning can broaden the horizons of the elderly, promote their social activities, reduce depressive symptoms, and increase their sense of well-being. Foreign language learning can also enhance the self-esteem and self-cognition of the elderly.

In summary, existing researches suggest that foreign language learning has significant positive impacts on the cognitive functions of the elderly, including improving cognitive abilities, promoting neural plasticity, enhancing social participation, and improving mental health. However, variations in research design and methodology, as well as the lack of long-term follow-up studies and the exclusion of participants with preexisting cognitive impairments, limit the generalizability of these findings [16]. Therefore, future research is needed to further validate these findings and explore the impact of different learning environments and individual differences on the results. A more refined approach is needed to better understand its mechanisms and long-term effects. Moreover, despite its considerable benefits for both physical and mental well-being, the elderly may encounter psychological barriers such as anxiety during the learning process, thus requiring targeted teaching strategies and support [17].

5. An exploration of strategies for effectively enhancing the cognition of the elderly through foreign language learning

5.1. Key factors affecting the cognitive benefits of foreign language learning

5.1.1. Learning methods and intensity

Different learning strategies and methods may have distinct effects. Computer-Assisted Language Learning (CALL) has been proven to be an effective learning tool, which can increase learners' interest and motivation, and provide target language input, interactive feedback, and opportunities [18, 19]. The keyword method and English teaching under the concept of lifelong learning have been proven to be beneficial for the elderly [15]. As a teaching strategy, the flipped classroom can improve the learning participation and teaching quality of the elderly [20].

In terms of Task Types, combining explicit instruction (such as grammar rule explanations) with implicit learning (such as situational communication) is more effective. For example, integrating the keyword memorization method (as in the research by Gruneberg & Pascoe) can simultaneously enhance both receptive and productive vocabulary abilities [11]. Similarly, training Intensity also matters. A high - intensity short - term course, 5 times a week and 90 minutes each time (such as the Spanish learning experiment), significantly improves executive function [13]. However, it is necessary to avoid anxiety caused by cognitive overload.

5.1.2. Individual differences

Individual conditions vary a lot in foreign language learning. For instance, as for Baseline Cognitive State: Elderly people with greater thickness of the prefrontal cortex are more likely to benefit from language training ($r = 0.42$, $p < 0.05$) [10]. In addition, the motivation and attitude of the elderly towards foreign language learning have a significant impact on their learning outcomes. Their motivations include improving cognitive functions, enhancing social participation, and increasing the quality of life. Moreover, Learners' motivations—such as improving cognitive function, fostering social engagement, and enhancing quality of life—affect their learning outcomes. Additionally, older

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learners often prefer participatory learning environments, peer-supported study groups, and the integration of CALL technology to facilitate engagement [19].

Research shows that the elderly generally have relatively high interest and motivation in learning foreign languages, yet anxiety may affect learning effectiveness. A study at Wenzhou Senior University found that foreign language classroom anxiety was prevalent among the elderly English-learning group, with significant differences observed based on educational background, learning duration, and proficiency levels [17]. Given that the elderly may encounter psychological barriers such as anxiety during the learning process, targeted teaching strategies and support are essential. One promising intervention is mindfulness-based psychological training, which has been shown to alleviate classroom anxiety. The study at Wenzhou Senior University reported a 23% reduction in anxiety levels following mindfulness-based interventions, which, in turn, improved learning persistence [17].

5.2. Recommended strategies and expansion of research directions

Future practice can optimize educational strategies in the following ways. In course design, a progressive difficulty gradient should be implemented—starting with vocabulary memorization and gradually advancing to complex syntactic generation. Additionally, multimodal input, such as VR-based situational simulations, can enhance engagement and learning outcomes. The cross-modal synergistic effect should also be explored; for instance, integrating language learning with physical movement (e.g., gesture-assisted memory techniques) can activate the mirror neuron system, thereby improving memory encoding efficiency. Moreover, evaluation systems need further refinement. Integrating neuropsychological assessments, such as the Attention Network Test (ANT), with functional near-infrared spectroscopy (fNIRS) can facilitate real-time monitoring of brain activation patterns, providing valuable insights into the neural mechanisms underlying foreign language learning [12].

Future research should consider the following aspects. One is longitudinal tracking. It is necessary to determine the duration of cognitive benefits. Though existing study shows that the effects of 4-month training can last for 6 - 12 months [10], more Specific research designs with different time spans are required to determine the long-term effects of FFL in older adults. Most of the current studies are based on small-sample cross-sectional designs. In the future, it is necessary to conduct multi-center longitudinal studies to verify the causal relationships. In addition, the moderating effect of cultural background on learning outcomes should be explored, and low-cost and highly accessible language intervention programs should be developed

The significance for public health should not be omitted. Each additional year of foreign language learning can reduce the risk of conversion to mild cognitive impairment (MCI) by 7% [3]. It is recommended to incorporate language courses into community - based health promotion programs for the elderly and provide learning subsidies in combination with medical insurance policies.

6. Conclusion

In conclusion, this research delves deep into the profound connection between foreign language learning and cognitive enhancement among the elderly. Grounded in the concept of brain plasticity, research confirms that the aging brain retains its capacity for adaptation and growth. Foreign language learning, involving cross - modal information integration, serves as a potent neural stimulus. Studies have revealed that it induces changes at the neural structure level, like enhancing white matter integrity and reorganizing gray matter volume. Functionally, it significantly boosts cognitive functions such as executive function, working memory, and attention. Moreover, it contributes to social participation and mental well - being.

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However, despite these promising findings, current research has notable limitations. Many studies rely on small-sample, cross-sectional designs, lacking the longitudinal data necessary to establish long-term effects. To address these gaps, future research should prioritize multi-center longitudinal studies, investigate the moderating role of cultural background, and develop cost-effective, scalable language intervention programs.

Given the potential of foreign language learning to promote cognitive health, its integration into public health policies and educational frameworks could have far-reaching benefits. However, this study acknowledges certain limitations in scope. It primarily focuses on the cognitive benefits of foreign language learning among older adults, with limited discussion on methodological approaches and practical implementation. Moving forward, researchers and educators should consider leveraging artificial intelligence and emerging technologies to enhance language learning experiences for older adults, thereby exploring more innovative and effective pedagogical strategies.

By refining research methodologies and expanding practical applications, foreign language learning can be fully harnessed as a cognitive intervention, contributing to healthier aging and improved quality of life for older adults.

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