Effects of Learning a Second Language on Brain Structure and Function

Konstantin Minaev

E-mail: Kostyasm26@gmail.com

Accepted for Publication: 2023
Published Date: November 2023

Abstract

This work explores how learning a foreign language affects the structure of people's brains and its functioning. It has been believed that learning a second language has benefits for people's health. Research shows that second language acquisition boosts mental health, slows the onset and progression of Alzheimer's disease, creates cognitive growth, and builds better neuronal communication. Specifically, the prefrontal cortex, which is responsible for attention and memory, is activated while learning a foreign language. In addition, the brain increases in volume, cognitive abilities improve, and memory improves. Similarly, knowing several languages allows people to switch between tasks faster and more attentively. Thus, this paper explains the most important effects of second language acquisition on the brain and discusses the underlying processes related to it.

Keywords: Language, learning, brain, structure, function, cognition, foreign second language.

1. Introduction

It has been proven that the human brain can change in response to certain external influences [1]. One such impact may be learning a second language [1]. Learning foreign languages plays a big role in the development of the brain and its structures [1]. Researchers discovered that knowing multiple languages, even superficially, is better than speaking one fluently [2]. With the knowledge of foreign languages, the brain forms additional neural connections, increases in volume, and more easily adapts to multitasking [1].

One of the benefits of learning new languages is its effect on preventing depression and stress. Experts have found that learning a language activates the pleasure center in the brain [3]. Perhaps this is determined genetically since learning new words made it possible for our ancestors to communicate with each other. Receiving some reward pushed people to study language and communication further. Thus, learning foreign languages helps people cope with stress and depression.

The brain consists of two hemispheres: right and left. When learning languages, the left hemisphere of the brain is most active. This is where information processing and foreign speech control take place. The right hemisphere is responsible for associative thinking when acquiring a second language.

The main structures responsible for understanding and reproducing speech are Broca's and Wernicke's areas, located in the left hemisphere. Broca's area is responsible for speech production, and Wernicke's area comprehends language.

One of the most interesting theories is the theory of brain plasticity. The brain undergoes enormous changes during the acquisition of a second language. When learning a foreign language, the prefrontal cortex, which is responsible for attention and memory, is activated [4].

Numerous studies have shown that our brains work differently when processing native and foreign speech [5]. Perceiving information in a foreign language requires the brain to create new neural connections, which leads to greater cognitive effort [6]. Available research shows that learning foreign languages is easier in childhood due to greater brain plasticity [7].

Many researchers are trying to understand how learning languages can change the structure of our brain through using EEG, MRI, and CT. This topic will always interest scientists since knowledge of foreign languages makes it possible for people from different countries to interact freely.

Language acquisition is a complex process that involves different areas of the brain. Numerous studies by scientists prove that under the influence of learning a second language, changes occur both in the structure of the brain and in the physiological characteristics of its work [8].

2. Increases in Brain Volume

A study by a group of scientists showed that learning a foreign language increases brain activity and forms many new neural connections [4]. Even among older respondents, the brain undergoes anatomical changes, increasing in volume. It is not the entire brain that grows, but only parts of it—the hippocampus and part of the cerebral cortex [7]. Additionally, the cerebral cortex becomes denser.

Another study also proved that learning foreign languages leads to changes in the brain. Participants with matched intelligence and language ability were randomly assigned to an experimental group who did a three-month foreign language course or a control group. The former learned between 300 to 500 new words per week. An MRI was done before and after the course. [7] These showed that the thickness of the cortex of the left middle frontal gyrus and the volume of the hippocampus were greater in those who were constantly associated with learning a foreign language. In addition, the inferior frontal and superior temporal gyri were significantly larger in translators than in the control group. Such increases in gray matter volume and changes in white matter quality have been associated with the development of linguistic neural networks and improvements in overall brain plasticity [7].

3. Impact on Cognition

It has been found that learning foreign languages significantly improves a person's cognitive abilities. Scientists conducted a large-scale study and found that children begin to memorize words as early as six months [9]. According to scientists, the most favorable age for learning a second language is before the age of 15, and they have agreed that educating children in the first five years of their lives helps shape the structure of the brain and high-quality neural networks [10]. Learning will be faster and easier at this age since the child's brain is more plastic and more easily perceives new information.

A longitudinal study measured the cognitive abilities of 853 participants at age 11 and at age 70 [11]. In particular, general intelligence, memory, reading, and information processing speed were assessed. Results implicated that people who speak two languages show higher mental abilities than people who know only one language.

Thus, bilingualism helps maintain brain health, especially in old age.

3.1 Delaying of Alzheimer's Disease

In 2013, a large-scale study was conducted to understand ways to prevent neurological disorders, such as Alzheimer's disease (AD) [12]. As a result, it was found that learning languages contributes to the growth of gray matter in the brain, especially in the

frontal and parietal lobes. Thanks to this, cognitive disorders (senile dementia, Alzheimer's disease) are delayed, as it was found that there is a large loss of gray matter for patients with Alzheimer's disease, and there is a correlation between the presence of gray matter and the general brain health [13].

In fact, people who study language develop AD symptoms approximately five years later than people who do not study languages [14]. More than 200 people who have Alzheimer's disease participated in the experiment. This is confirmed by another group of scientists [15]. Although the onset of AD can be delayed by multilingual knowledge, it does not reduce the likelihood of the disease. This may be because bilingualism increases the volume of white matter and allows it to maintain its integrity in old age [16]. White matter allows you to coordinate the work of the brain's two hemispheres and transmits information from the cerebral cortex to the underlying sections. Thus, learning languages helps preserve the integrity of the brain and ensures its normal functioning in older ages [17].

Mean value as a description for each language group (standard deviation)

Language group	Number	Age at onset[1]	Age at first appointment[2]	Duration [3]
Monolingual	109	72.6 (10)	76.5 (10.0)	3.8 (2.9)
Men	49	73.3 (9.4)	77.3 (8.9)	3.9 (2.9)
Women	60	72.1 (10.4)	75.9 (10.8)	3.7 (2.9)
Bilingual	102	77.7 (7.9)	80.8 (7.7)	3.1 (1.9)
Men	42	77.6 (7.8)	80.4 (7.8)	2.8 (1.8)
Women	60	77.8 (8.1)	81.1 (7.6)	3.3 (1.9)

1. Age when symptoms first reported by family
2. Age of first visit to clinic
3. Duration of elapsed time between [1]a[2]

Generally speaking, the age of learning languages is important. Experts from the Institute of Cognitive and Brain Sciences decided to find out which brain networks change with age. The experiment involved two groups of people. The first is young people 25-30 years old. The second group included older adults over 60 years of age. During the experiment, their brains were subjected to fMRI scans. The results of the experiment showed that young people had more active brains. In addition, in this group, the subjects had more intense exchanges in the neural networks responsible for attention and memory. In older people, less efficient communication between neural networks and greater activity in the executive areas could be observed, which suggests that the task was more difficult for them.

3.2 Knowing multiple languages allows the brain to switch between different tasks faster.

Scientists have proven that the brains of people who know several foreign languages switch more easily between tasks and more easily adapt to different tasks [18]. More than 100 six-year-old children took part in the experiment. They were divided into four groups. The first group included children who spoke only English, and the other three groups included children who knew English and a second language (Chinese, French, or Spanish).

The children were offered different tasks. Another group of scientists conducted a similar study only on adults [19]. The subjects were given tasks to quickly switch attention when changing figures, words, and colors and to correctly press buttons on the screen. All experiments confirmed that bilingualism helps one concentrate faster and switch between different tasks faster. This is especially pronounced between the ages of 30 and 50.

3.3 Learning languages significantly improves memory.

Neuroscientists conducted an experiment and proved that both hemispheres of the brain are involved to the same extent when learning a foreign language. The study involved volunteers who studied Chinese everyday for a month. To understand which part of the

brain was involved, respondents were given an fMRI of the brain before and after the start of the experiment.

The results obtained surprised the scientists in people learning a second language. It processes images entering the brain. When both hemispheres work simultaneously, the memorization process speeds up, and the likelihood of forgetting new words decreases. It has also been confirmed that memory moves from short-term to long-term in people who know several foreign languages much faster.

3.4 People who learn a second language become more attentive and better able to concentrate on a task.

Researchers have found that bilinguals are able to do several things at once and cope more easily with complex tasks at work.

Research by neuropsychologists has confirmed that people who know several languages are more attentive in performing any task [20]. They conducted an experiment. Subjects were given the Stroop task, which tests responses to stimuli. During the task, the respondents' EEG was recorded. As a result of the experiment, scientists received the following conclusions. Among subjects who knew two or more languages, errors were two times less common. In addition, EEG recordings showed that bilinguals used their brain power more efficiently and focused on the task more accurately.

4. **Conclusion**

Summarizing the results of numerous studies in Neuropsychology, learning a foreign language has a highly positive effect on the structure and function of the brain.

Learning languages can significantly improve the integrity of the brain's white matter and enlarge some parts of the brain, in addition to increasing gray matter thickness in areas associated with language processing and executive functions. This may aid in delaying the onset of Alzheimer's disease. In addition, studying foreign languages allows the brain to concentrate on different tasks quickly and improves attention and memory.

Acknowledgements

Numerous databases and internet journals are acknowledged, in addition to the numerous resources available at the National Library of Medicine, Google Scholar, and the American Psychological Association.

References

1. Li P, Legault J, Litcofsky KA. Neuroplasticity as a function of second language learning: anatomical changes in the human brain. Cortex. 2014 Sep;58:301-24. doi: 10.1016/j.cortex.2014.05.001. Epub 2014 May 17. PMID: 24996640.
2. Adesope, O. O., Lavin, T., Thompson, T., & Ungerleider, C. (2010). A Systematic Review and Meta-Analysis of the Cognitive Correlates of Bilingualism. Review of Educational Research, 80(2), 207-245.
3. Ripollés, P., Marco-Pallarés, J., Hielscher, U., Mestres-Missé, A., Tempelmann, C., Heinze, H. J., ... & Noesselt, T. (2014). The role of reward in word learning and its implications for language acquisition. *Current Biology*, *24*(21), 2606-2611.
4. Green, D. W. (2011). Language control in different contexts: the behavioral ecology of bilingual speakers. *Frontiers in psychology*, *2*, 103.
5. Thierry, G., & Wu, Y. J. (2007). Brain potentials reveal unconscious translation during foreign-language comprehension. *Proceedings of the National Academy of Sciences*, *104*(30), 12530-12535.
6. Gow, A. J., Johnson, W., Pattie, A., Brett, C. E., Roberts, B., Starr, J. M., & Deary, I. J. (2011). Stability and change in intelligence from age 11 to ages 70, 79, and 87: the Lothian Birth Cohorts of 1921 and 1936. *Psychology and aging*, *26*(1), 232.
7. Mårtensson J, Eriksson J, Bodammer NC, Lindgren M, Johansson M, Nyberg L, Lövdén

M. Growth of language-related brain areas after foreign language learning. Neuroimage. 2012 Oct 15;63(1):240-4. doi: 10.1016/j.neuroimage.2012.06.043. Epub 2012 Jun 29. PMID: 22750568.

8. Ghasemi, B., & Hashemi, M. (2011). Foreign language learning during childhood. *Procedia-Social and Behavioral Sciences*, *28*, 872-876.
9. Bergelson, E., & Swingley, D. (2012). At 6–9 months, human infants know the meanings of many common nouns. *Proceedings of the National Academy of Sciences*, *109*(9), 3253-3258.
10. Lightbown, P. M., & Spada, N. (2001). Factors affecting second language learning. *English language teaching in its social context*, 28-43.
11. Bak, T. H., Nissan, J. J., Allerhand, M. M., & Deary, I. J. (2014). Does bilingualism influence cognitive aging?. *Annals of Neurology*, *75*(6), 959-963.
12. Craik, F. I., Bialystok, E., & Freedman, M. (2010). Delaying the onset of Alzheimer's disease: Bilingualism as a form of cognitive reserve. *Neurology*, *75*(19), 1726-1729.
13. Thompson PM, Hayashi KM, de Zubicaray G, Janke AL, Rose SE, Semple J, Herman D, Hong MS, Dittmer SS, Doddrell DM, Toga AW. Dynamics of gray matter loss in Alzheimer's disease. J Neurosci. 2003 Feb 1;23(3):994-1005. doi: 10.1523/JNEUROSCI.23-03-00994.2003. PMID: 12574429; PMCID: PMC6741905.
14. Barac, R., & Bialystok, E. (2012). Bilingual effects on cognitive and linguistic development: Role of language, cultural background, and education. *Child development*, *83*(2), 413-422.
15. Bialystok, E., Craik, F. I., & Freedman, M. (2007). Bilingualism as a protection against the onset of symptoms of dementia. *Neuropsychologia*, *45*(2), 459-464.
16. Mas-Herrero, E., Adrover-Roig, D., Ruz, M., & de Diego-Balaguer, R. (2021). Do bilinguals outperform monolinguals in switching tasks? Contrary evidence for nonlinguistic and linguistic switching tasks. *Neurobiology of Language*, *2*(4), 586-604.
17. Pliatsikas, C., Moschopoulou, E., & Saddy, J. D. (2015). The effects of bilingualism on the white matter structure of the brain. *Proceedings of the National Academy of Sciences*, *112*(5), 1334-1337.
18. Prior, A., & MacWhinney, B. (2010). A bilingual advantage in task switching. *Bilingualism: Language and cognition*, *13*(2), 253-262.
19. Craik, F. I., Bialystok, E., & Freedman, M. (2010). Delaying the onset of Alzheimer's disease: Bilingualism as a form of cognitive reserve. *Neurology*, *75*(19), 1726-1729.
20. Coderre, E. L., & van Heuven, W. J. (2014). Electrophysiological explorations of the bilingual advantage: Evidence from a Stroop task. *PLoS One*, *9*(7), e103424.