Neuroplasticity in Bilingual and Multilingual Individuals: The Role of Language Switching

Natalia Gupta

Abstract

This paper reviews how speaking, learning, managing, and switching between multiple two or more languages may promote neuroplasticity in the brain. Research suggests that bilingual and multilingual individuals' experiences promote executive function, cognitive flexibility, and neural connections. This paper also examines similarities and differences between monolingual, bilingual, and multilingual individuals through cognitive testing and brain imaging. An enhanced review is on language switching because one must regularly switch through language systems which ultimately can promote neuroplasticity. In conclusion, research suggests that regularly switching and using different languages may act as a form of cognitive training which supports neuroplasticity and long term brain health. However, factors such as language proficiency, age of acquisition, frequency of use can influence these effects.

Keywords: neuroplasticity, language switching, multilingualism, neural connectivity, executive function, cognitive reserve

Neuroplasticity in Bilingual and Multilingual Individuals: The Role of Language Switching

The brain continually modifies itself to environmental changes via a function called neuroplasticity, which enables learning new skills, recovering from injuries, and adapting to new experiences. Neuroplasticity is capable of strengthening neural connections through experience and practice (Gazerani, 2025). This phenomenon is crucial in daily activities such as memorizing, learning, problem solving and one's overall cognitive health. Many cognitively stimulating activities, including education, physical activity, and social interactions, can improve neuroplasticity.

Researchers can study neuroplasticity in a multitude of ways. They test growth through cognitive function tests which measure memory, attention, executive functioning, and cognitive flexibility. Another technique is through brain imaging which allows researchers to examine the brain over time during cognitive tasks. These measurements help researchers observe which activities relate to stronger neural connectivity, increased brain efficiency, and structural changes within the brain. Scientists rely on these cognitive indicators to determine how the brain evolves throughout life, because neuroplasticity cannot be observed in one day (Gazerni, 2025).

Language learning has recently gained attention in the world of neuroplasticity research due to its positive effects on strengthening neural connections. As we do not have one definite way to measure neuroplasticity, or its effects, researchers have begun to look for a life long process that engages multiple brain regions, continuously strengthens neural connections, and contributes to long term benefits for the brain. Learning and speaking multiple languages may be an ideal candidate, because it requires people to consistently retain and process information (Bialystok 2021). We already know that learning and managing two or more languages can strengthen and repair one's brain by engaging cognitive systems. While simultaneously adapting to new linguistic systems touches on all aspects of what we believe neuroplasticity is, studying the effects of multilingualism is difficult because language proficiency and experience varies among individuals. Frequency of language use, age of acquisition, and habits of language-switching influence how speaking multiple languages is measured. (Beatty-Martinez, 2024)

Simultaneously, several cognitive processes or neurological damages can work against neuroplasticity, for example aging. As people grow older, regular cognitive processes decline. Injuries and illnesses may further reduce cognitive function by interrupting neural pathways, which damages the speed at which typical functions are performed (Grundy et al. 2022). For example, neurodegenerative diseases, traumatic brain injuries, and age-related decline can make it difficult for the brain to maintain efficient functioning (Grundy, 2022).

Recent research shows that multilingualism serves as a protective mechanism against this. Studies show that bilingual and multilingual individuals often demonstrate a stronger cognitive reserve than monolingual individuals. Cognitive reserve is the brain's ability to function normally despite aging, injuries, or diseases (Bialystok, 2021). In addition, researchers have suggested that language learning can delay neurological conditions relating to age or underlying diseases. Learning and managing multiple languages has also been associated with changes in gray matter, which is involved in processing information and decision making, as well as white matter, which allows communication between different regions of the brain. These findings suggest that multilingual experiences may physically re-shape the brain over time (Anderson, 2024).

Previous research has hypothesized that bilingualism and multilingualism improve cognitive function through repeated usage of executive-control networks. Stocco et al. (2014) suggested that language learning serves as a form of “brain training” while Bialystok (2021) suggested being multi-lingual can serve as a protective mechanism against cognitive decline related to age, injury, or illness. Fewer studies have focused on the role of language switching. The research question this paper will examine is the role of language switching in promoting neuroplasticity and cognitive function in bilingual and multilingual individuals over a lifespan. I hypothesize that individuals who regularly switch between languages will demonstrate greater neuroplasticity because repeatedly managing multiple language systems strengthens executive-control networks, neural connectivity, and cognitive reserve over time.

Together, these findings suggest that multilingual experiences can influence neuroplasticity through cognitive, structural, and protective mechanisms. Although there is previous research on the link between multilingualism and brain health, the specific role of language switching requires further investigation.

Background

1. *Neuroplasticity*

Neuroplasticity is the brain's ability to strengthen its neural connections through learning and experiences. Instead of remaining the same after childhood, the brain continuously adapts by forming new neural pathways and reorganizing others. These changes support cognitive functions such as memory, attention, problem solving, and executive function (Gazerani, 2025).

Neuroplasticity incorporates both functional and structural changes in the brain. The functional changes help improve communication between brain regions, while structural changes may include increases in gray matter and white matter pathways (Anderson et al., 2024). Neuroplasticity is a broad process that occurs through multiple mechanisms including synaptic plasticity and neurogenesis. Neurogenesis relates to the formation of new neurons whereas synaptic plasticity refers to the existing neurons strengthening. Current studies suggest that the neuroplastic changes connected to language learning are synaptic plasticity rather than creating new neurons because it allows language learning to build and strengthen existing neural networks (Gazerni 2025).

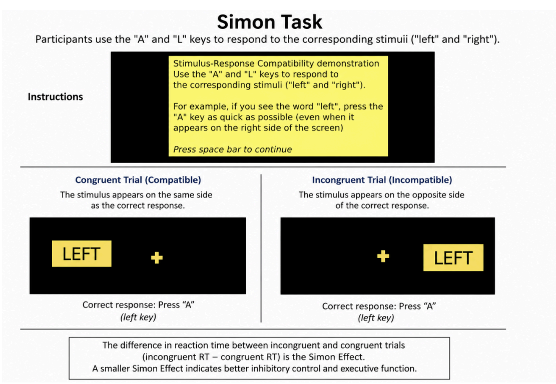
Researchers measure neuroplasticity using cognitive tests that assess memory, attention, and executive function because the changes can’t be observed directly. There are also brain imaging techniques that help evaluate executive function and structural changes such as functional, structural, diffusion, and anatomical MRI (Gazerani, 2025). Although aging and brain injuries or diseases can reduce neuroplasticity, cognitively stimulating activities can help strengthen or maintain brain functions throughout life. One of the most effective forms of cognitive stimulation is language learning (Gazerni 2025). Being able to manage multiple languages repeatedly engages executive function, making multilingualism an important aspect of brain health in an individual's everyday life (Bialystok, 2021).

2. *Methods of cognitive testing*

Researchers measure neuroplasticity using cognitive performance tasks and brain imaging techniques. These evaluate changes in executive function, brain structure, and cognitive flexibility (Gazerni, 2025). These techniques provide evidence that managing multiple languages strengthens both cognitive performance and neural connectivity. Researchers can compare average performances between groups for monolinguals, bilinguals, and multilingual participants, or they can follow the same individual over a certain period of time to determine whether cognitive performance improves with language learning or not. In other studies, the cognitive tasks are also completed while participants undergo brain imaging which allows researchers to observe the brain and which regions become active during certain tasks (Anderson et al., 2024).

A frequent task used is called the Simon Task, which measures inhibitory control by mandating participants to respond to the color of a stimulus white ignoring its location. Bilingual individuals consistently demonstrate faster reaction times than the monolinguals (Baumaart & Billick, 2018).

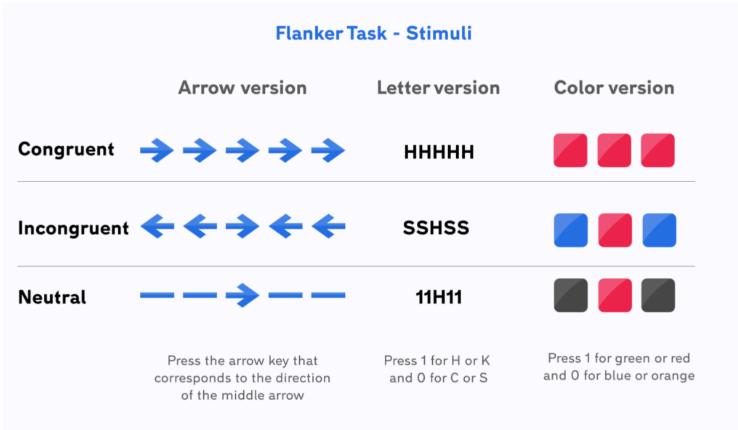
Figure 1. *Simon Task*



Simon task: the words left and right can appear on either side of the screen. A correlate with the word left. And L correlates with the word right. When you see left you must click A regardless of location on the screen, and when you see right you must click L regardless of on
the screen. *Note.* Image from PsyToolkit (n.d.).

Researchers also use the Flanker Task where participants identify a central stimulus while ignoring distracting surrounding stimuli. Bilingual individuals usually perform better on incongruent trials, demonstrating greater selective attention and cognitive flexibility ((Baumart & Billick, 2018).

Figure 2. *Flanker Task*



Note. Image from Testable (n.d.).

Flanker Test: used to measure selective attention and inhibitory control. Participants identify the directions of the center arrow while ignoring the surrounding distractor arrows. Congruent trials contain arrows pointing in the same direction as the target, whereas incongruent trials contain distracting arrows pointing in opposite directions.

Similarly, the Stroop Test, which measures inhibitory control by asking participants to identify the color of a printed word while ignoring the word itself. Multilinguals tend to outperform monolinguals on this task suggesting that bilingualism strengthens executive function. In addition to performance tasks, task-switching studies have shown that regular language switching is associated with faster reaction times and improved cognitive flexibility (Grundy et al., 2021).

Figure 3. *Stroop Effect*

Stroop Task: used to measure inhibitory and control control. Participants identify the color of the text, not the word itself. If the word “green” is printed in red ink, the correct response would be red. *Note.* Image from Science Sparks (n.d.).

Researchers combine these behavioral tests with MRI, fMRI, and diffusion tensor imaging (DTI) to examine structural changes in the brain. The MRI measures gray matter, DTI measures white matter integrity, and fMRI identifies brain regions activated during language and executive control tasks. These techniques have found increased gray matter, stronger white matter pathways, and greater executive control in bilingual and multilingual individuals suggesting that language learning produces measurable neuroplastic changes (Anderson, 2024).

3. *Protective Mechanisms*

An impressive discovery in multilingualism research is that learning multiple languages can serve as a protective mechanism against neurological declines such as: aging, disease, and injuries. Researchers indicate that regularly managing multiple languages strengthens executive control, and increases neural connectivity which ultimately creates a stronger cognitive reserve. Cognitive reserve refers to the functioning of the brain despite disease, aging, or injury (Bialystok 2021). Bilingualism has been seen to strengthen a brain by creating more efficient neural pathways that compensate for changes related to decline in the brain.

Researchers have also implied that multilingualism could support recovery following a neurological injury by strengthening cognitive systems before or after an injury occurs. Language learning does not repair damaged brain tissue, but stronger executive control systems may help individuals improve their neural pathways that have been disrupted by injury which can ultimately help individuals maintain cognitive function throughout rehabilitation (Bialystok, 2021). Also, studies have conveyed that bilingual and multilingual individuals often maintain memory and attention longer than monolinguals despite age-related changes, suggesting that life long language learning may increase the brain's ability to respond to difficult neurological conditions and changes.

Together, it is suggested that multilingualism functions as a lifelong source of cognitive stimulation. Language learning may help delay neurological decline and improve the brain's ability to recover from injury or disease by strengthening neural connections and increasing cognitive reserve.

4. *Brain Regions*

Brain imaging studies have also discovered brain regions that specifically change structurally as bilingualism increases. One study concluded that bilingualism affects five major subcorital regions who involve language management and executive function: the caudate nucleus, nucleus accumbens, putamen, thalamus, and globus pallidus (Korenar, 2023). The caudate nucleus helps bilinguals choose the correct language while suppressing other competing languages. The nucleus is associated with learning and motivation, indicating that learning languages strengthens learning strategies over time. The putamen helps speech products and vocabulary articulation while the thalamus helps in language section, memory, and communication between the regions. Because the globus pallidus did not show significant structural differences in the particular study, researches indicate it may become more relevant in bilinguals who frequently switch because it supports higher levels of cognitive control and executive function. Overall, the findings imply that language learning allows for significant neuroplastic changes in certain brain regions which are responsible for memory, learning, decision making, and executive control (Korenar et al., 2023).

While there are changes to specific brain regions, there are also structural changes associated with bilingualism in the white matter tracts that connect different parts of the brain. White matter consists of groups of nerve fibers that allow information to travel effectively between regions in the brain which is crucial for language processing and memory. (Anderson, 2024) concluded that bilingual experiences allow for changes in several connected white matter pathways such as: the corpus callosum, unicinate fasciculus, longitudinal fasciculus, and forceps minor. The corpus callosum connects the brain's right and left hemispheres which allows information to be shared quickly between each other. The uncinate fasciculus links brain regions involved in language, memory, and emotional process. The superior longitudinal fasciculus plays a crucial role in language processing and working memory. Their meta-analysis estimated that these white matter differences were equivalent to having brain tissue that was approximately 2.31 to 4.65 years younger than expected, closely matching previous findings that bilingualism may delay the onset of dementia by several years (Anderson et al., 2024). Ultimately the forceps minor connects areas of the frontal lobes which is responsible for planning, decision making, and cognitive control. Together these findings suggest that bilingualism strengthens communication networks not just brain regions which ultimately improve the brains efficiency supporting long-term neuroplasticity.

5. *Brain differences in bilingual vs monolingual vs multilingual*

There are very strong themes in language research. Monolingual, bilingual, trilingual, and multilingual individuals demonstrate vast differences in brain structure and cognitive functions. Monolinguals rely on a singular language, bilinguals rely on two languages, trilinguals rely on three languages, and multilingual individuals rely on three or more language systems. Those who speak more than one language show greater executive control in processes such as attention, inhibition, cognitive flexibility, and memory (Bialystok, 2021).

Consequently, bilinguals outperform monolingulas in tasks such as conflict resolution, attention, task switching, suggesting multilingualism is a form of lifelong cognitive training (Beatty-Martínez et al., 2024). Although bilingual and multilingual individuals show cognitive advantages, research suggests that multilingualism may provide additional benefits. Older multilingual individuals demonstrate greater cognitive reserve than bilinguals, allowing them to maintain functions despite brain age related changes which ultimately delayed dementia and cognitive impairment (Bialystok, 2021). However studies have suggested more challenges for multilingual children, as they have smaller vocabularies. However it all depends on factors such as age, proficiency, frequency, and habits (Anderson, 2018).

Overall the research suggests that the differences between monolingual, bilingual and multilingual individuals extends beyond language proficiency. Regularly using more than one language strengthens the brain's function and improves communication between brain regions which leads the brain to lasting support throughout life (Grundy et al., 2021). Instead of filing bilinguals and multilinguals into separate categories, they fall under a spectrum where frequency of language, when acquired, and level of proficiency all affect the amount of neuroplastic changes that occur.

6. *Effects and outcomes of language learning*

Research consistently shows that learning and regularly using multiple languages produces cognitive benefits that extend beyond communication. Not only strengthening language skills, bilingualism strengthens executive function, attention, memory, and problem solving by consistently activating the brain executive control networks (Bialystok, 2021). Stocco 2014 proposed that this language management functions as a form of brain training, strengthening neural connections, individual switch or practice languages.

As a result, multilingual and bilingual individuals usually outperform monolinguals on tasks involving attention, memory, and task-switching because they continually practice those tasks while speaking languages (Baumgart & Billick, 2018). Studies have also found increased gray matter and stronger white matter connectivity suggesting that language learning not only helps executive function but also brain structural health (Anderson, 2024). These structural changes contribute to a greater cognitive reserve helping bilinguals and multilinguals maintain strong cognitive function despite aging or other age-related cognitive decline. (Bialystok, 2021).

Overall, it is suggested language learning promotes lasting neuroplastic changes by improving executive function and strengthening neural connections which supports long-term brain health.

7. *Language switching/ limitations of measuring bilingualism and multilingualism*

Although research strongly supports the relationship between language learning and neuroplasticity, measuring multilingualism and bilingualism remains a challenge. Defining bilingualism simply as speaking two languages is incorrect. Instead researchers must consider multiple factors such as proficiency, age of acquisition, frequency of use, how often languages are switched which all affect cognitive outcomes (Stocco, 2014). Because all individuals differ greatly in these characteristics it remains difficult to directly compare and measure neuroplasticity relating to languages.

An important aspect of multilingualism is language switching. Language switching is the transition between two or more languages during communication. This process consists of attention control, and the ability to speak one language while activating another. Consequently, language switching engages executive control which is the function for memory, cognitive flexibility, and task switching (Beatty-Martinez, 2024). Researchers have suggested that this mental exercise serve as a form of cognitive training, strengthening neural pathways and contributing to long term neuroplastic changes in the brain. Studies also suggest that multilingual experiences can be associated with structural changes in certain regions in the brain involving language processing and cognitive control (Anderson, 2024). These regional changes provide evidence that language switching may influence not only how the brain functions but also how it is physically organized over time.

Also, language switching varies among individuals. Some individuals switch between languages multiple times throughout the day, while others use a specific language in certain environments such as work, school, or home. Researchers suggest that a balanced use of both languages correlates with stronger improvements in executive function rather than just simply knowing multiple languages (Beatty Martines, 2024). As a result researchers recognize that multilingualism exists more broadly rather than in separate categories for monolinguals, bilinguals, and multilingual individuals (Anderson, 2018). Overall these limitations help support why some studies show stronger neuroplastic changes than others.

Conclusion

In conclusion, this research supports the idea that language learning and managing multiple languages promotes neuroplasticity by strengthening executive function, neural connectivity and cognitive reserve. Bilingual and multilingual individuals consistently outperform monolinguals on tasks involving memory, attention, and cognitive flexibility. While multilingual individuals may outperform bilinguals and demonstrate greater protection against age related cognitive decline, research also suggests setbacks such as smaller vocabularies in each language. Furthermore, cognitive advantages for both bilinguals and multilinguals appear to level off after reaching a certain point of bilingual proficiency rather than increasing indefinitely.

Despite these consistent findings, researching language learning remains challenging because no one has the same experiences when learning or practicing languages. Proficiency, age of acquisition, frequency of language use, and language switching habits vary among everyone making it challenging to compare results. Most of the articles emphasized the need for more standardized methods of measuring bilingualism and multilingualism.

An ideal study would follow participants over a span of multiple years. It would carefully track their language proficiency, acquisitions, frequency, and language switching habits using cognitive tests and brain imaging. This long term study would demonstrate a clear understanding of how multilingual experiences influence neuroplasticity throughout life. Overall, the evidence that language learning is more than a communication skill: it is a lifelong form of cognitive training that helps the brain adapt and remain resilient.

The difference between monolingualism, bilingualism, and multilingualism is one topic while neuroplasticity is another in many bodies of research. While these could, and have been, easily studied independently it is a unique and important body of work to examine them together because (why are the two points stronger together rather than separately)

Even this- It is more interesting to look at these phenomena together rather than separately because

References

1. Anderson, J. A. E., Yurtsever, A., Fisher-Skau, O., Cherep, L. A., MacPhee, I., Luk, G., & Grundy, J. G. (2024). Examining the consistency in bilingualism and white matter research: A meta-analysis. Neuropsychologia, 195, 108801. https://doi.org/10.1016/j.neuropsychologia.2024.108801
2. Beatty-Martínez, A. L., Navarro-Torres, C. A., Dussias, P. E., Bajo, M. T., Guzzardo Tamargo, R. E., & Kroll, J. F. (2024). The bilingual experience shapes cognitive control across the lifespan. Annual Review of Linguistics, 10, 225–246. https://doi.org/10.1146/annurev-linguistics-031220-101426
3. Bialystok, E. (2021). Bilingualism: Pathway to cognitive reserve. *Trends in Cognitive Sciences, 25*(5), 355–364. https://doi.org/10.1016/j.tics.2021.02.003
4. Chan, C. G. H., Yow, W. Q., & Oei, A. (2020). Active bilingualism in aging: Balanced bilingualism usage and less frequent language switching relate to better conflict monitoring and goal maintenance ability. *The Journals of Gerontology: Series B, 75*(9), e231–e241. https://doi.org/10.1093/geronb/gbaa058
5. Gazerani, P. (2025). The neuroplastic brain: Current breakthroughs and emerging frontiers. *Brain Research, 1858*, 149643. https://doi.org/10.1016/j.brainres.2025.149643
6. Grundy, J. G. (2022). *Neural and cognitive effects of bilingualism across the lifespan. Neuroscience & Biobehavioral Reviews, 136*, 104617.
7. Korenar, M. (2023). Dynamic effects of bilingualism on brain structure map onto general principles of experience-dependent neuroplasticity. *Scientific Reports, 13*, Article 30326.
8. Li, P., Legault, J., & Litcofsky, K. A. (2014). Neuroplasticity as a function of second language learning: Anatomical changes in the human brain. *Cortex, 58*, 301–324. https://doi.org/10.1016/j.cortex.2014.05.001
9. PsyToolkit. (n.d.). *Simon task*. https://www.psytoolkit.org/experiment-library/touch_simon.html
10. Stocco, A., Yamasaki, B., Natalenko, R., & Prat, C. S. (2014). Bilingual brain training: A neurobiological framework of how bilingual experience improves executive function. *International Journal of Bilingualism, 18*(1), 67–92. https://doi.org/10.1177/1367006912456617
11. Testable. (n.d.). *Flanker task*. https://www.testable.org/experiment-guides/executive-function/flanker-task
12. Wei, X., Gunter, T. C., Adamson, H., Schwendemann, M., Friederici, A. D., Goucha, T., & Anwander, A. (2024). White matter plasticity during second language learning within and across hemispheres. *Proceedings of the National Academy of Sciences, 121*(2), e2306286121. https://doi.org/10.1073/pnas.2306286121