The Duality of Languages: Bilingualism and Its Effects on the Brain

Estefania Baez

Abstract

Research over the past two decades has shown the vital role of brain plasticity in language acquisition, specifically in children. When compared with older adolescents, kids in early childhood are more efficient at learning a second language. Researchers still seek to know the physiological differences in brain structure and function between bilinguals and monolinguals. Promising studies show disparities between white and grey matter structures. In addition, bilingual individuals experience a specific pattern of brain activity when switching from one language to another- dubbed 'codeswitching'. Such a pattern is found in two regions: the anterior cingulate cortex, which helps us pay attention, and the prefrontal cortex, which is the 'thinking' part of the brain (Mcrae, 2018). The culmination of elevated neurocognitive processes experienced by bilingual individuals leads to their variations in protection against neurodegenerative diseases and heightened performances in cognitive tasks.

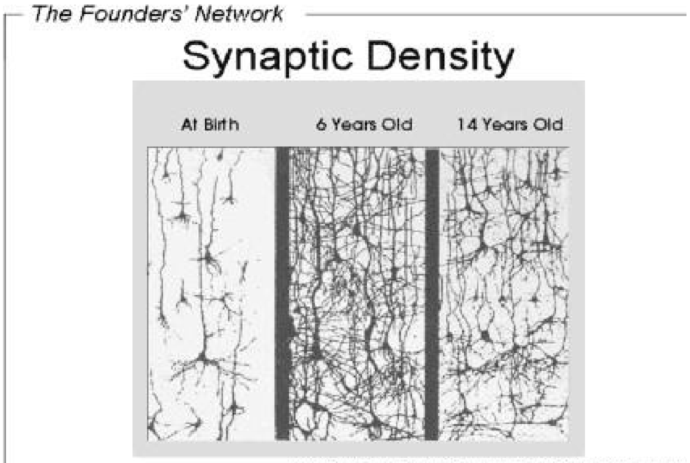
Introduction

It is estimated that over half of the worlds' population is fluent in more than one language. When you think about children in North America who speak English at school and another language at home, there was not necessarily a choice of becoming bilingual- it was a matter of housing, family, place of birth, immigration history, etc. (Bialystok, 2012) that cultivated an environment for it. It was commonly thought that learning two languages at once would be confusing and detrimental to children- but researchers argue that it actually provides cognitive and neurological benefits. Ever growing inquiries about the plasticity of the brain creates a pathway for us to discover why younger people are more likely than older adults to acquire fluency in more than one language. The physiological differences between bilingual and monolingual brains continue to intrigue researchers, and discussions about cognitive benefits of speaking more than one language should be continued and further held.

Plasticity and Brain Differences

From the ages of 0-3, an infant's brain reaches peak lifetime plasticity. Neuroplasticity can be referred to as the brain's ability to adapt, modify, or alter in response to lifelong growth, learning, or changes. For children that grow up in households where more than one language is spoken, it comes easy for them to learn both at the same time. Learning a new language uses plasticity because it includes repeated auditory exposure, semantic processing, retrieval, and speaking. The repetition of these processes over time results in gaining fluency of a language. There is a critical period that every human experiences, which is a timeframe that an individual has for optimal language acquisition. After the critical period, which is around the first 5 years of a person's life, it becomes increasingly difficult for primary language acquisition to occur.

In a study hosted by Paul Thompson, it was discovered through continuous brain scans of children aged 3-15 that peak growth rates were attenuated after puberty. The discovery arose through studying the fibers that innervate association and language cortices, for example the temporal lobe or visual cortex. These contrasted sharply with a severe, spatially localized loss of subcortical grey matter (Thompson et. al, 2000). During these critical periods, children are perceiving language for the first time, which leaves a large impression and allows for the greatest amount of growth in the brain and plasticity. While they are learning words and forming associations every day, the process of synaptic pruning contributes to the loss of subcortical grey matter. Grey matter is made up of dendrites and cell bodies of neurons, while white matter is made up of myelinated axons. Dendrites are branches in neurons that extend to synapses and receive information from other cells, and axons are the lengthy tubes of the neurons that transmit information to the synapse, where another nearby neuron can receive it.



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This pruning is a process that is important for learning and memory because it removes unused synapses so that the brain can work as coherently as it can. These processes occur faster at younger ages and allow adults with more developed brains to transmit information more efficiently.

In a general view, bilinguals of all ages demonstrate better executive control than monolinguals who are matched in age and other background factors. Bilingual children have outperformed monolingual children in non-verbal conflict tasks, and bilingual adults performed better than their monolingual counterparts in tests like the Stroop effect and Simon tasks (Bialystok et. al, 2012). These neurocognitive tasks are commonly used to test monitoring of interference, focus, and ability to focus on stimuli. Successful performance on cognitive tasks can translate into real-world problem-solving skills, like recalling details, inhibitory control, and quick decision making; these are universal abilities that aid in workplaces, education, and everyday incompetencies.

Studies show evidential parallels of bilingual individuals experiencing neural processes where increased activity is detected. Highly proficient bilinguals show increased subcortical representation of linguistic sounds, as revealed by a larger electrical brain response in the range of the sounds' fundamental frequencies. This suggests that bilinguals have more efficient and flexible auditory processing than monolinguals (Costa et. al, 2014). When neurons are consistently firing at higher rates and increasing action potentials, Long-Term Potentiation (LTP) occurs. LTP is the process of strengthening synaptic connections between neurons that has long lasting effects. The increasing processing demands that come with bilingualism can be associated with higher performances on cognitive tasks, as well as the refined synaptic connections that allow for speedy neural transmission.

In bilingual individuals, previous studies have shown our anterior cingulate and prefrontal cortices activate when we jump from one language to another (Mcrae, 2018). It was shown that it isn't starting to speak one language that is costly in brain effort, but the stopping of one language to start speaking in a second one that activates the most brain activity. Individuals who are fluent in both English and American Sign Language (ASL) have been studied for this phenomenon and have provided evidence to support the idea. While repeating prompted words in both languages, 'switching off' the ASL and continuing to produce words in English proved to be more effortful than 'switching on' the ASL (Blanco-Elorrieta et. al, 2018). Turning a language off required increased engagement of the prefrontal cortex and anterior cingulate cortex, both part of the frontal lobe, which is the area of the brain largely responsible for decision making and impulse control. These series of specific neural activations are processes that monolinguals don't especially use, and could be explanations as to why they underperform in cognitive tasks and show less neural activity compared to their bilingual counterparts.

As for long-term structural changes, a study of older, highly proficient, successive bilingual adults (70-year-olds) reported greater white matter integrity in the corpus callosum in comparison to monolinguals (Costa et. al, 2014). White matter in the brain consists of axons wrapped in myelin sheaths, which aid in the acceleration of action potentials and insulation of the axon. The more protected and the more that a neuron fires, the more the likelihood that the onset of neuro-degenerative disease would be delayed. Findings indicate that lifelong bilingualism acts as a powerful Cognitive Reserve proxy in dementia and exerts neuroprotective effects against neurodegeneration. For example, bilingual elders have displayed an average of a 4.5-year delay in the onset of Alzheimer's' Dementia compared with monolinguals of similar age (Perani et.al, 2017). Predicted causes for this delay include neural reserve and neural compensation for hypometabolism, which is the decreased metabolic rate of neurotransmitters. Hypometabolism is also often associated with neurodegenerative diseases such as Alzheimer's. Along with symptom delay, bilingual individuals with Alzheimer's Dementia also showed increased activity in frontal brain regions when the posterior regions had lower metabolic activity. The likely cause for this effect would be the consistent neural transmission over time that comes with the executive function of controlling two languages. This results in a neural reserve that eventually renders the bilingual brain more resistant against brain aging effects (Perani et. al, 2017).

Conclusion

Study after study, we find increasing evidence that the benefits of acquiring a second language at an early childhood age would translate to increased cognitive processes. In comparison with monolinguals, people who are fluent in more than one language have shown better performance on cognitive tasks, as well as physiological differences in white and grey matter density. The implications of being bilingual from an early age are consistent with having increased attention, focusing ability, and interference control. There is especially evidence of frontal lobe neural reserve that is hypothesized to be behind protection against early onset dementia. There are still many unknown neurological mechanisms that we seek to understand, such as the compartmentalization of various languages, as well as the precise neuro-preventative effects of bilingualism. Even so, educators and leaders around the world should emphasize the benefits of becoming fluent in another language and perhaps encourage further exploration into the world of multilingualism.

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